TURKEY ENERGY OUTLOOK | 2020

Sabancı Üniversitesi

IICEC | SABANCI UNIVERSITY ISTANBUL INTERNATIONAL CENTER FOR ENERGY AND CLIMATE

TURKEY ENERGY OUTLOOK | 2020

Turkey Energy Outlook 2020

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About IICEC

The Sabancı University Istanbul International Center for Energy & Climate (IICEC) is an independent Center at Sabancı University that produces energy policy research and uses its convening power at the energy crossroad of the world. Utilizing this strategic position, IICEC provides national, regional and global energy analyses as a research and an international networking center. Since it was established in 2010, IICEC has leveraged Istanbul's strategic position to host high-level Forums featuring sector leaders from government, international organizations, industry and academia fostering substantive discussion among key stakeholders with the aim of charting a sustainable energy future. IICEC also hosts seminars and webinars on important energy policy, market and technology areas.

As a research center in one of the most reputable universities in its region, IICEC has built a comprehensive technological and economic overview of the Turkish energy economy, published research reports on a wide variety of energy and climate topics and supports energy education at Sabancı University. IICEC also provides concise analyses of key energy market developments for policy makers and energy professionals with busy agendas. IICEC emphasizes a holistic and quality analytic approach integrating energy policy objectives with technological assessments, economic analyses, market drivers, regulatory factors and reflecting business acumen.

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Foreword

In 2010, inspired by the discussions with Dr. Fatih Birol, I established the Sabancı University Istanbul International Center for Energy and Climate (IICEC). Its purpose was to inform policymakers, industry, academics and opinion leaders on key energy challenges and opportunities and provide them with objective analysis. The first task for IICEC was to establish a distinguished platform for the exchange of ideas with key energy and climate stakeholders taking advantage of Istanbul's convening power at the crossroads of the energy-producing and energy-using world. After several International Forums with world-wide leaders in government and industry, IICEC undertook a second task to undertake original analysis as a University research center. During the time that IICEC was producing energy market and policy assessments, research reports, and publications, I learned of a major undertaking by the IICEC team: a comprehensive and quantitative analysis of the Turkish energy economy beginning with an extensive data collection and modeling project. I then learned of Dr. Birol's challenge to the IICEC staff to develop a *Turkey Energy Outlook* with the expectation that this title would be merited with in-depth, comprehensive and objective policy modeling and analyses.

I am proud to say that the *Turkey Energy Outlook* has exceeded expectations. You will find, in clear language, a complete and independent assessment of Turkey's energy economy. It shows how interdependent all of Turkey's economic sectors are to each other with an analytic structure that reflects them. An in-depth assessment is provided within each energy and fuel sector chapter. Each chapter reflects a detailed assessment of Turkey's in-place energy infrastructure and the markets in which they operate. Looking forward, they show how Turkey can best benefit from emerging energy technologies and advance progress towards more competitive energy markets. Two Scenarios are provided to show the integrated outcomes of a variety of energy policies with the aim of strengthening Turkey's energy economy, technological advancement, energy security and environmental sustainability. Numerous and specific policy recommendations are made to advance these objectives including policies that will grow the role of the private sector and explain the benefits of greater private sector involvement and wider stakeholder benefits. At the same time, a strong role is proposed for government leadership since a progressive partnership among the government, industry and academia, *the success triangle*, is essential for Turkey's social, economic and environmental progress.

The *Turkey Energy Outlook* is particularly welcome now as we come to the close of a tumultuous year. The tragic Covid-19 pandemic has, at the time of this publication, already caused over a million deaths worldwide and pushed the world economies into recession. On the other side of the ledger, Turkey's recent exploration and production investments have, just two months ago, paid dividends far in excess and far more quickly than most experts' expectations. The *Turkey Energy Outlook* has been able to reflect both of these factors, along with numerous others in its projections and policy assessments. I hope you will appreciate the *Turkey Energy Outlook* as much as I did. I expect that it will become and remain a Turkish energy handbook and also serve as an eye-opening experience for our international audience including the investor and technology community.

Ms. Güler Sabancı
Founding Chair of the Board of Trustees
Sabancı University

Authors

The Turkey Energy Outlook was led by IICEC Director **Prof. Carmine Difiglio** and IICEC Research Director **Bora Şekip Güray** including the scenario development, modeling and supporting analyses. The TEO was also authored by Carmine Difiglio, Bora Şekip Güray and IICEC Energy Analyst **Ersin Merdan**. The TEO modeling work also benefitted from the modeling framework established by IICEC Senior Researcher **Dr. Danial Esmaeili**.

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This Turkey Energy Outlook (TEO) would not have been possible without an extensive collaboration with government officials, experts in industry and faculty members from academia. It was built in stages first by assembling an extensive database of the Turkish energy economy and a modeling framework to understand how technology developments, Turkish economic growth, different energy policies, and energy market developments would change the trajectory of future fuel use, energy demand, energy trade balances and a wide variety of other variables. The TEO accounts for a series of technical, economic, and regulatory detail of the existing (and complex) Turkish energy economy. Assembling and understanding this detail was one of the benefits IICEC achieved with its outreach to Turkish energy experts. The TEO policy recommendations emerged after we drilled down into the details of and analyzed each fuel and energy sector in a holistic way.

The TEO benefitted from the insights and support of many respected energy leaders and professionals.

- Sabancı University Founding Chairman of the Board of Trustees **Güler Sabancı** encouraged the IICEC team to develop the TEO, as a unique product to serve the interests of the growing and developing Turkish energy sector.
- IEA Executive Director and IICEC Honorary Chairman **Dr. Fatih Birol**, the architect of the IEA World Energy Outlook, inspired IICEC to produce this report along the lines of IEA's flagship publication to cover similar questions for Turkey. Dr. Birol provided encouragement throughout the development of the TEO.
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Turkey Energy Outlook Executive Summary

Overview

The Turkey Energy Outlook (TEO) proposes energy policies to further improve energy security, increase use of domestic energy resources, advance energy efficiency, build clean energy infrastructure, develop a more competitive energy market with cost-reflective energy pricing and also to support all necessary steps towards achieving a sustainable energy system in Turkey. The main themes include increased energy efficiency, higher use of renewable energy, improving electricity and natural gas markets, building Turkey's first nuclear power plants, increased energy technology R&D and continuing and expanding the recent efforts to discover and produce more natural gas and oil.

Turkey's per capita energy and electricity consumption are less than half of the OECD average. As a country that is still developing, compared to Turkey's OECD peers, the growth of energy services per capita will be much higher. This is necessary to accommodate increasing incomes, population growth, industrialization, urbanization, increased mobility and wider access to modern energy services. The Turkey Energy Outlook (TEO) provides an independent assessment of changing technological opportunities and policy priorities to secure an efficient, competitive and sustainable energy future. Two TEO Scenarios quantify the consequences of two different policy pathways out to 2040.

TEO Scenarios

The TEO is built on a detailed bottom-up accounting of the Turkish energy economy IICEC recognizes that each component of Turkey's energy economy is interdependent. Before taking on the task of developing a TEO, IICEC developed a first-of-its-kind detailed modeling framework for Turkey using data from a wide variety of sources, including all open data available from relevant ministries and other public and private institutions. In order to reconcile the best sources of data into a consistent and integrated modeling framework, it was necessary to develop new data series and modeling frameworks, such as a new vehicle stock retirement model that was compatible with international fuel economy studies or estimating the value-adjusted levelized cost of energy to reflect the system costs of different power generating technologies.

Two TEO Scenarios are provided: a **Reference Scenario** outlining the continuation of current policies but not necessarily achieving the most ambitious and challenging long-term targets. The **Alternative Scenario** assumes additional policy initiatives that, while cost-effective, require more challenging policy obstacles to be overcome in order to serve energy policy goals including efficiency, competitiveness and sustainability, among others. The TEO Scenarios also take into account the current and possible future impacts of the Covid-19 pandemic on each sector and fuel including a long-term sensitivity analysis for assessing the most probable permanent impacts on the energy sector, notably in travel activity and oil demand.

TEO Scenarios Summary

In both TEO Scenarios, IICEC projects an increased share of renewables as well as nuclear in the power sector, more use of electricity, natural gas and renewables in all energy end-use sectors and increased efficiency in every aspect of energy production, transformation and use. The Reference and Alternative Scenario differ in terms of how much and how fast these gains can be realized with stronger energy policies assumed in the Alternative Scenario towards a more sustainable energy future.

Energy Consumption: In the Reference Scenario, final energy demand increases by one-half by 2040 compared to 2019. The wider efficiency gains in the Alternative Scenario reduce this growth to one-third. While the Reference Scenario includes many energy efficiency and renewable energy policies, the Alternative Scenario includes more ambitious policies that, for example, achieves more efficiency in the more difficult end-use sectors such as transport and stimulates more renewable energy uptake in the power, buildings, industry and agriculture sectors. The Alternative Scenario also shows faster vehicle fleet renewal and more use of high occupancy modes of travel, especially in Turkey's growing urban areas with a new urban transportation planning proposal. In terms of cutting Turkey's fuel import bill, the Alternative Scenario projects that more intensified E&P activities could cut Turkey's natural gas imports in half by 2040 and reduce Turkey's oil import dependency.

Fuel Mix: Turkey's energy supply becomes more diversified and less carbon intensive in the Alternative Scenario. The fuel mix shifts to more electricity, natural gas, and renewables. Renewables and nuclear provide 58% of Turkey's power in the Reference Scenario in 2040. These increase to 75% in the Alternative Scenario. Combined share of wind and solar in power generation increases from 11% in 2019 to 36% in 2040. The Alternative Scenario includes measures to rebalance oil products demand towards gasoline with limited growth in diesel in order to better match Turkey's refinery slate while increasing the uptake of electricity and natural gas vehicles as this was estimated to significantly reduce Turkey's fuel import bill. The primary energy supply mix significantly shifts through 2040 towards a more sustainable and less import-dependent structure with share of oil reducing from 29% to 24% while renewables show the fastest growth increasing their share from 14% to 33%. The electricity represents 28% of total final energy demand compared to 22% in 2019.

Investments and Advanced Technologies: The TEO underlines the importance of sustained investments to achieve a technology-driven transformation in all sectors, including the power industry. In the Alternative Scenario, average annual spending requirement for the power sector is $9 billion, around 10% higher than the Reference Scenario, to achieve wider gains by electrification. More investment is spent on the power grid to accommodate more intermittent renewables, more variable demand features, more decentralized generation assets and a rapidly advancing electro-mobility ecosystem. Every aspect of Turkey's changing energy economy provides opportunities to advance energy technology R&D and become an exporter of advanced energy technologies. The Alternative Scenario consistently reflects increased localization of global energy technology trends such as onshore and offshore wind, solar PV, electric vehicles, battery storage and many end-use applications. It also introduces a pathway for developing and deploying new energy technologies such as hydrogen production from Turkey's domestic coal through carbon capture and storage. Mobilizing the necessary investments along the whole energy value chain is critical for a secure, efficient and sustainable energy future.

Environment: In the Reference Scenario, energy sector CO_2 emissions increase by 30% by 2040 compared to 2019. However, with the more ambitious Alternative Scenario policies, a 10% CO_2 emission decrease is projected. Both scenarios demonstrate a significant reduction in the carbon intensity of energy consumption (14% in the Reference Scenario and 31% in the Alternative Scenario by 2040) mainly by increased energy efficiency and higher use of renewables and nuclear power. By 2040, carbon intensity of the power sector drops by 28% in the Reference Scenario and 54% in the Alternative Scenario. The Alternative Scenario emissions pathway also implies much higher reductions after 2040. These additional emission intensity reductions do not come about because of policies that explicitly target CO_2 emissions but instead result from policies to reduce Turkey's dependence on foreign energy imports and localize energy technologies in Turkey. Local air pollution is also reduced with much less oil and coal combustion in the buildings sector, removing high polluting diesel vehicles from the truck fleet, and limiting oil demand growth in transportation.

10 Policy Recommendations

Based on our TEO findings, the following policies can be recommended:

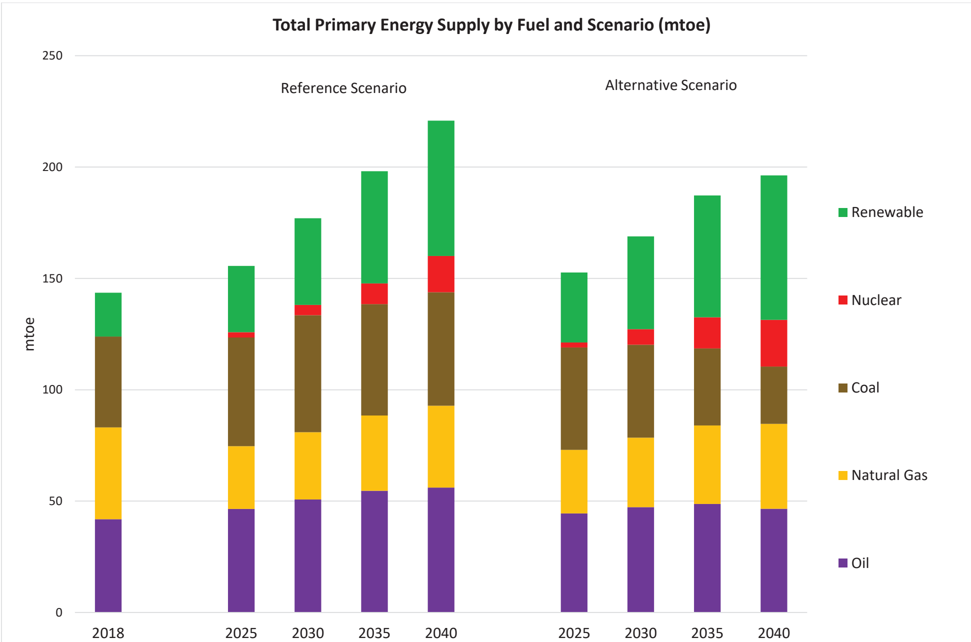
1. An attractive investment framework to mobilize investments for meeting increasing demand for modern energy services while achieving a more secure, efficient and sustainable energy future;
2. Faster progress towards competitive power and natural gas markets and wider private sector participation with cost-reflective energy prices while addressing the social dimension;
3. Increased renewable and nuclear power with more flexibility in the power grid including demand side services;
4. Increased energy and fuel efficiency across all sectors supported by fuel shifts towards further electrification and larger use of renewable energy;
5. Strong policy initiatives, market based and innovative financing and business models to exploit the energy efficiency potential in buildings and industries,
6. Faster uptake of electric vehicles and Turkey's recharging infrastructure and faster retirement of older, inefficient and polluting transportation vehicles;
7. Increased modal shifts from energy and oil intensive road to rail and marine as well as a data-driven urban transportation planning structure to ensure effective public transit capital investments and measures to discourage private automobile travel;
8. Sustained exploration and production (E&P) efforts and investments to discover and produce more domestic oil and gas;
9. Increased uptake of digitalization and advanced data analytics along the energy supply and demand chain; and
10. Increased innovation, R&D and manufacturing of advanced energy technologies.

TEO Scenario Highlights

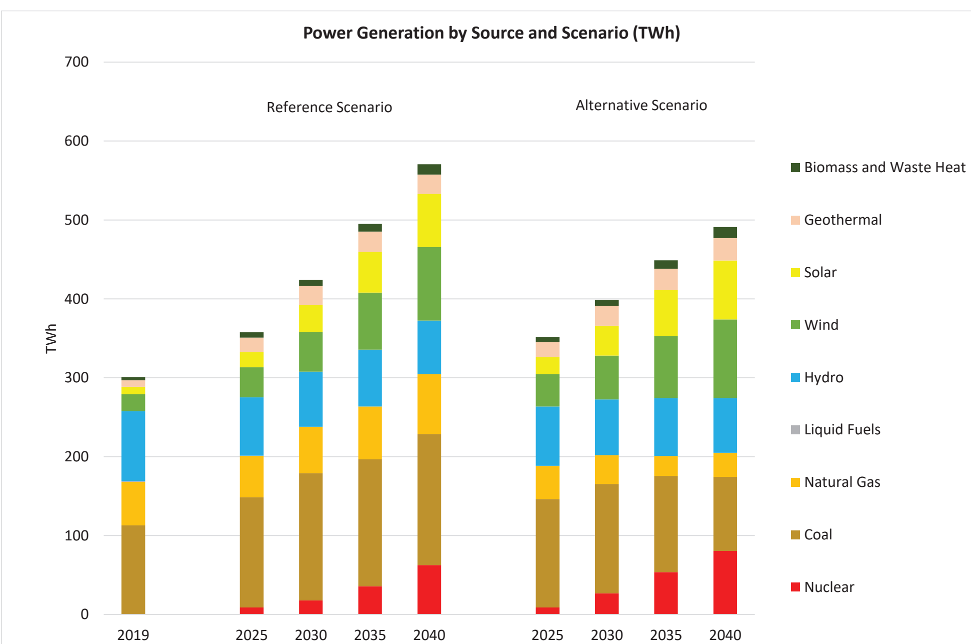
Key Indicators	2019*	2040 Reference Scenario	2040 Alternative Scenario
Total Primary Energy Supply (mtoe)	143.7	220.8	196.2
Total Final Energy Demand (mtoe)*	102.5	154.6	135.4
Primary Energy Supply from Renewables (mtoe)	19.7	60.8	64.8
Domestic Natural Gas Production (bcm)	0.48	15.5	28
Total Oil Products Demand (mtoe)	35.6	47.5	39.5
Net Electricity Demand (TWh)	258.2	493.8	434.4
Installed Capacity (GW)	91.4	183.4	172.5
Electricity Generation from Wind and Solar (TWh)	31.0	160.7	174.4
Average Annual Power Sector Investment Until 2040 ($2019 billion)	NA	9.0	8.2
Power Sector GHG Intensity (g CO_2-eq/kWh)	499.2	354.1	226.6
Transport Energy Demand (mtoe)	28.4	41.0	35.5
Industry Energy Demand (mtoe)	36.2	53.5	46.0
Buildings Energy Demand (mtoe)	33.4	53.7	48.4
Agriculture Energy Demand (mtoe)	4.6	6.3	5.5
Energy Related GHG Emissions (million tons of CO_2-eq)	369.3	477.2	332.3
Energy Related GHG Emissions Intensity (tons of CO_2-eq/toe)	3.6	3.1	2.5
Share of Renewables in Total Primary Energy Supply (%)	14%	28%	33%
Share of Electricity in Total Final Energy Consumption (%)	22%	27%	28%
Share of Renewables in Total Final Energy Consumption (%)	8%	10%	12%
Share of Oil in Total Final Energy Consumption (%)	35%	31%	29%
Share of Coal in Total Final Energy Consumption (%)	13%	8%	3%
Share of Natural Gas in Total Final Energy Consumption (%)	23%	24%	28%
Domestic Production in Total Natural Gas Demand (%)	1%	25%	51%
Share of Renewables, Local Coal, Local Natural Gas and Nuclear in Total Electricity Generation (%)	61%	78%	91%
Share of Wind and Solar Generation in Total Electricity Generation (%)	11%	28%	36%
Share of Wind and Solar in Total Installed Capacity (%)	15%	37%	41%
Share of Non-Oil Products Based Fuels in Transportation (%)	1%	3%	6%
Transport Sector Passenger Travel Energy Intensity (2018=100)	100.0	75.0	68.2
Transport Sector Freight Travel Energy Intensity (2018=100)	100.0	86.2	68.8

*Note: Some of the data are for 2018. Final energy demand excluding non-energy uses

Total Primary Energy Supply by Fuel and Scenario (mtoe)



Power Generation by Source and Scenario (TWh)



SUMMARY

Overview

Turkey's energy policies are improving energy security, wider use of domestic energy resources, causing more energy infrastructure to be manufactured in Turkey (localization) and moving Turkey to a more competitive energy market with an increased role for the private sector. The policies include many elements but some of the main themes are increased energy efficiency, more renewable energy, advancing electricity and natural gas markets, building Turkey's first nuclear power plants, ramping up energy technology R&D and manufacturing and undertaking intensified exploration and production (E&P) in the offshore and onshore to discover and produce significantly more domestic natural gas and oil.

Turkey's per capita energy and electricity consumption are less than half of the OECD average. As a country that is still developing, compared to Turkey's OECD peers, the growth of energy services per capita will be much higher. With population growth, continuing industrialization, urbanization, increasing incomes, higher automobile ownership, more housing and a wider uptake of air conditioning, Turkey will consume more energy services over the next two decades. Even with increased energy efficiency and innovations in providing these energy services, this also means that Turkey will need to consume more energy. In addition, we are likely to witness significant technological progress in the next two decades. Energy policies need to be dynamic to fulfill Turkey's expanding consumption of energy services while taking advantage of the rapidly changing technology landscape. The Turkey Energy Outlook (TEO) provides an independent analysis with recommendations to achieve a secure, efficient, competitive and sustainable energy future. Two TEO Scenarios quantify the consequences of two different policy pathways out to 2040. Each TEO scenario builds upon the progress of Turkey's energy policies and market development.

TEO Scenarios

The Turkey Energy Outlook (TEO) is built on a detailed bottom-up accounting of the Turkish energy economy. It is not focused on one aspect of Turkish energy, for example, renewable energy or natural gas. IICEC recognizes that each component of Turkey's energy economy, including renewable energy and natural gas, is interdependent. Therefore, each element cannot be understood, quantified and projected without analyzing all aspects of the Turkish energy economy as an interdependent system. That is why, before taking on the task of developing a TEO, IICEC developed a first-of-its-kind detailed modeling framework for Turkey using data from a wide variety of sources, including, all open data available from relevant ministries and other public and private institutions. In order to reconcile the best sources of data into a consistent and integrated modeling framework, it was necessary to develop new sets of modeling frameworks. This was necessary in each and every sector, such as an entirely new vehicle stock retirement model that was compatible with international fuel economy studies or estimating the value-adjusted levelized cost of energy for each power technology to reflect system costs in the Turkish power sector. In each and every instance, several analytic challenges had to be overcome in order to be able to develop the scenarios presented in this book. They are a necessary consequence of building an integrated modeling framework that has its own internal requirements. In addition, IICEC does not present its scenarios as a prediction of the future. Any projection is built on a series of assumptions, sometimes about important variables that are taken from another authority, such as population and economic growth. A large number of different policies were analyzed as to how effective they would be and estimates had to be made of the impact that they would have on energy demand or supply. These data and assessments have not been made just to make predictions of what Turkey's energy economy will look like in 20 years, although they are our best effort to paint that picture assuming that the policies described in the Reference or Alternative Scenarios are implemented. The important consequence of the analysis is to establish a robust basis for identifying what sets of policies and technologies are most likely to continue Turkey's progress in developing a secure, modern, competitive, efficient and sustainable energy economy.

Two TEO Scenarios are provided: a **Reference Scenario** outlining the continuation of current policies but not necessarily achieving the most ambitious and challenging long-term targets, especially those that require large investments or significant changes in consumer behavior. **The Alternative Scenario** assumes additional policy initiatives that, while cost effective, require more challenging policy obstacles to be overcome towards a more sustainable energy future.

TEO Scenarios Summary

In both TEO Scenarios, IICEC projects an increased share of renewables and nuclear in the power sector, more use of electricity, natural gas and renewables in all energy end-use sectors and increased efficiency in every aspect of energy production, transformation and use. The Reference and Alternative Scenarios differ in terms of how much and how fast these gains can be realized with the stronger energy policies that are assumed for the Alternative Scenario.

Energy Consumption: As mentioned above, Turkish energy consumption needs to increase to enable economic progress and social development. In the TEO Reference Scenario, final energy demand increases by one-half by 2040 compared to 2019. The wider efficiency gains in the Alternative Scenario reduce this growth to one-third. While the Reference Scenario includes many energy efficiency and renewable energy policies, the Alternative Scenario includes more ambitious policies that, for example, achieves more efficiency in the more difficult end-use sectors such as transport and stimulates more renewable energy uptake in the power, buildings, industry and agriculture sectors. The Alternative Scenario shows reductions in final energy demand in all sectors over the Reference Scenario: 14% less in industry, 13% less in transport and agriculture and 10% less in buildings by 2040. These gains are achieved by implementing and financing a suite of solutions such as stronger fuel economy gains and modal shifts in transport, a country-wide building insulation program, realizing the best available technologies such as the deployment of "net-zero" buildings that employ more rooftop PV, solar thermal and geothermal heating and programs to upgrade irrigation pumping.

Fuel Mix: Turkey's energy supply becomes more diversified and less carbon intensive in the Alternative Scenario. Fuel mix in final energy demand shifts to more electricity, natural gas, and renewables. In the Alternative Scenario, these three fuels represent over two-thirds of the total final energy demand up from slightly over one-half now. The primary energy supply mix significantly shifts through 2040 towards a more sustainable and less import-dependent structure with share of oil reducing from 29% to 24% while renewables show the fastest growth increasing their share from 14% to 33%. The largest percentage increase in final energy demand will be in renewable energy, including solar, biomass and geothermal heat (12% of final energy demand in 2040 compared to 8% in 2018). The electricity represents 28% of total final energy demand compared to 22% in 2019.

Renewables and nuclear provide 58% of Turkey's power in the Reference Scenario in 2040. These increase to 75% in the Alternative Scenario compared to 44% in 2019. Combined share of wind and solar in power generation increases from 11% in 2019 to 36% in 2040. For transport, the Alternative Scenario projects a very low growth of diesel demand (8% compared to 37% in the Reference Scenario) due to shifts to gasoline vehicles, gasoline hybrid vehicles and electric vehicles. The Alternative Scenario included measures to rebalance fuel demand towards gasoline with limited growth in diesel in order to better match Turkey's refinery slate while increasing the uptake of electricity and natural gas vehicles as this was estimated to significantly reduce Turkey's fuel import bill. In the Alternative Scenario, total oil demand increases by 11% compared to a one-third increase in the Reference Scenario until 2040. Oil savings are achieved in all sectors: 25% less in industry, 21% less in agriculture and 15% less in buildings. Although transport does not achieve the highest percentage savings (only 16% due to more limited fuel switching opportunities), the absolute savings achieved in transport provide the most oil savings gains in the Alternative Scenario compared to the Reference Scenario.

The fuel mix in industry, buildings and agriculture shifts to electricity, natural gas and renewables while shifting away from coal and oil combustion. Major shifts are increased renewables in agriculture and reduced coal in buildings. Renewables share in agriculture increases from 14% now to 34% in the Reference Scenario and 36% in the Alternative Scenario as a result of increased solar, geothermal and biomass supplies. Natural gas will remain the leading fuel in buildings. In the Reference Scenario, coal use in buildings drops from 12% in 2018 to 7% by 2040. The Alternative Scenario realizes a faster substitution, driving the coal share in buildings to only 2% by 2040. These developments also provide more localization opportunities and will increase Turkey's high-technology industrial sectors and exports.

Investments: Mobilizing the necessary investments along the whole energy value chain is critical for a secure, efficient and sustainable energy future. The TEO underlines the importance of sustained investments to achieve a technology-driven transformation in all sectors, including the power industry. In the Alternative Scenario, average annual spending requirement for the power sector is $9 billion, around 10% higher than the Reference Scenario, to achieve wider gains by electrification. In the Alternative Scenario, more investment is spent on the grid to accommodate more intermittent renewables, more variable demand features, more decentralized generation assets and a rapidly advancing electro-mobility ecosystem. Less investment is spent on increasing power generating capacity due to efficiency gains. The Alternative Scenario also results in more Turkish R&D and industrial activity. Increased investments are also needed for building and industry efficiency retrofits such as more insulation and replacing inefficient lighting and motor systems. The Alternative Scenario shows more efficiency retrofits due to government programs that target high payoff investments and facilitate energy performance contracts in buildings and smaller industries.

Both TEO Scenarios show progress to reducing Turkey's energy imports. Increased energy efficiency and renewable energy, achieved by a variety of policies in all sectors, contribute significantly to reducing Turkey's energy import bill. In addition, the recent government E&P investments have already paid off with a major Black Sea natural gas discovery. The Alternative Scenario assumes that E&P investments will expand and, by 2040, result in considerably higher domestic gas production than the 10-15 bcm/yr. estimated just for the recent Black Sea discovery and provide half of Turkey's natural gas consumption. These investments will also reduce oil import dependency.

Advanced Technologies: Almost every aspect of Turkey's changing energy economy provides opportunities for Turkey to engage further in energy technology R&D and become an exporter of advanced energy technologies. The Alternative Scenario consistently reflects increased investments in digitalization and localization of global energy technology trends. It also introduces a pathway for developing and deploying new energy technologies such as hydrogen production from Turkey's domestic coal through carbon capture and storage.

Environment: In the Reference Scenario, energy sector CO_2 emissions increase by 30% by 2040 compared to 2019. However, with the more ambitious Alternative Scenario policies, a 10% CO_2 emission decrease is projected. Both scenarios demonstrate a significant reduction in the carbon intensity of energy consumption (14% in the Reference Scenario and 31% in the Alternative Scenario by 2040) mainly by increased energy efficiency and higher use of renewables and nuclear power. The Alternative Scenario emissions pathway also implies much higher reductions after 2040. It should be noted that these emission reductions do not come about because of policies that explicitly target CO_2 emissions but instead result from more ambitious longer-term policies that aim to reduce Turkey's dependence on foreign energy imports, increase production and use of local energy sources, take advantage of global technology developments and localize energy R&D and technology manufacturing in Turkey. It is also worth noting that high-emission power sector investments could be at risk due to possible EU border tax policies as it pursues its Green Deal initiatives. This is likely to affect investment calculations by the private sector.

For transport, the Alternative Scenario shows much lower emission intensities: by 2040, 35% lower for passengers (gCO_2-eq per passenger-km) and 32% lower for freight (gCO_2-eq per ton-km) compared to 2018. The improvements in freight energy and CO_2 intensity in the Alternative Scenario are particularly challenging and require integrated policy planning and implementation especially for truck renewal and a larger shift to rail and marine freight. The Alternative Scenario also reduces local air pollution especially by reducing oil and coal combustion in the buildings sector, removing high polluting diesel vehicles from the truck fleet, and limiting oil demand growth in transport.

10 Policy Recommendations

Based on our TEO findings, the following policies can be recommended:

1. An attractive investment framework to mobilize investments for meeting increasing demand for modern energy services while achieving a more secure, efficient and sustainable energy future;
2. Faster progress towards competitive power and natural gas markets and wider private sector participation with cost-reflective energy prices while addressing the social dimension;
3. Increased renewable and nuclear power with more flexibility in the power grid including demand side services;
4. Increased energy and fuel efficiency across all sectors supported by fuel shifts towards further electrification and larger use of renewable energy;
5. Strong policy initiatives, market based and innovative financing and business models to exploit the energy efficiency potential in buildings and industries,
6. Faster uptake of electric vehicles and Turkey's recharging infrastructure and faster retirement of older, inefficient and polluting transportation vehicles;
7. Increased modal shifts from energy and oil intensive road to rail and marine as well as a data-driven urban transportation planning structure to ensure effective public transit capital investments and measures to discourage private automobile travel;
8. Sustained exploration and production (E&P) efforts and investments to discover and produce more domestic oil and gas;
9. Increased uptake of digitalization and advanced data analytics along the energy supply and demand chain; and
10. Increased innovation, R&D and manufacturing of advanced energy technologies.

The following are the main highlights of TEO policy recommendations.

Power Sector: IICEC recommends a long-term approach to address several developments such as a wider penetration of variable renewables, greater distances between supply and demand, electric vehicle charging, the emergence of prosumers, smart grids, energy efficiency management and an increasingly digitalized operating system. While the Alternative Scenario shows a greater uptake of battery storage, realistically, Turkey will need a significant natural gas fleet to ensure reliable power supplies. Capacity payments will be needed to economically justify natural gas generating capacity with lower load factors as natural gas retreats from its prior role of providing baseload power to a load-balancing role. The current emphasis on expanding renewable and nuclear generating capacity should continue.

IICEC shows that solar PV and wind will be the leading technologies in line with the cost reductions and technology advancements and endorses the Government's decision to add nuclear power to Turkey's generating mix to achieve energy security and clean baseload power. IICEC expects that nuclear cost competitiveness would improve compared to other baseline power technologies, especially if EU trade policies monetize Turkey's power sector CO_2 emissions.

Transportation Sector: Transportation energy use is dominated by road and oil, but there are important policy and technology options to reduce transport energy intensity and limit oil demand growth for a more sustainable energy economy. Turkey has low car ownership per capita compared to European peers (the lowest across Europe) and it should expand with economic growth benefiting consumers and the Turkish car industry. Turkey's freight activity will also grow in line with economic growth, the emergence of new demand centers and trade. These factors present a challenge to reduce oil demand in the Turkish economy. Accelerated fuel economy progress is needed to offset these trends along with shifts to natural gas fueled and electric vehicles (including battery electric vehicles and plug-in hybrid electric vehicles). However, simply focusing on new vehicle fuel efficiency and electric vehicles is not sufficient as the high fuel consumption and pollution of older vehicles needs to be addressed, especially the truck fleet that is older and dirtier than the car fleet. The average age of the Turkish heavy truck stock is 16 years, compared to 12 years in the EU. 45% of heavy trucks are older than 15 years and 15% of the heavy trucks on the road are over 30 years old. IICEC recommends that pollution standards be phased in to gradually force the retirement of older cars and trucks. This will bring Turkey's vehicle fleet fuel economy to be more in line with its new vehicle fuel economy and provide very important air quality benefits. While this approach requires careful implementation to maintain public acceptance, the benefits to Turkey's economy from the domestic motor vehicle industry should also be considered.

IICEC recommends that all urban areas should be given the resources and the methodologies to conduct a uniform, comprehensive and detailed travel survey, supported by the Government. New urban transportation planning centers would utilize this data to conduct analyses and establish long term plans using a process that includes effective public input. Capital outlays for public transportation and other investments to reduce traffic congestion and air pollution should be in line with these plans. These planning efforts could provide new tools to promote other elements of Turkey's transport policies such as providing privileged access for electric vehicles.

Buildings, Industry and Agriculture Sectors: The building sector has the largest efficiency potential among all final demand sectors. Turkey has already established a new building certificates program for new buildings but the majority of the existing stock is without energy performance labeling. The recent public buildings efficiency program should be followed up with programs for all commercial and residential buildings. These would increase insulation, replace inefficient appliances and ensure the purchase of the most-efficient HVAC systems. Another opportunity lies in replacing the relatively old household refrigerator stock with the best available models.

Although Turkey has various incentive programs to support energy efficiency investments in industry, there is no widespread program covering building energy efficiency. IICEC recommends that energy performance contracts become a more mainstream practice.

IICEC observes that the long-term nature of the energy performance contracts, a generic feature to achieve desired savings with bankable solutions, stands as a barrier. De-risking investments and addressing counterparty risks to the energy service company needs to be overcome by developing solutions to help predictability and security. Thematic investment programs can also be developed for high-payoff opportunities such as replacing the existing stock with more efficient electric motor systems and a much wider uptake of LED lighting.

The agriculture sector, including farming and fisheries, corresponds to less than 5% of final energy demand but it deserves special attention as it is vulnerable to adverse consequences of global climate change and remains critical for food security. Reducing diesel fuel use and achieving efficient power use are the priorities. IICEC suggests an innovative solution using shared services programs to increase utilization of the most efficient tractors, reducing inefficiencies in irrigation electricity use, deploying more solar PV, and establishing micro power grids. The TEO Scenarios also demonstrate the benefits of a larger use of solar and geothermal heating. Increased demonstration projects are also recommended to help phase-out traditional biomass with wider use of modern biomass such as biogas.

Energy Markets: Continued sustainable power-sector investments will be aided by a stronger role for the private sector. This will require continued steps in the Turkish power market toward cost-reflective pricing to increase private sector engagement. Recent steps including the Last-Resort-Tariff and the social tariff implementation are instrumental to address fuel poverty while permitting cost-reflective pricing for non-vulnerable customers. As the private sector gains a stronger role, the Turkish market framework should encourage flexible responses to a fast changing power sector. These changes include more emphasis on power grids, accommodating more variable generation, new power demands such as electric vehicles and other rapidly changing technologies.

Turkey has taken steps to establish an organized natural gas trading platform including day-ahead, intra-day, and weekly components. A futures market with physical deliveries is in preparation to be launched in late 2021. These markets, with a diverse set of different products, can transform the Turkish natural gas market into a more competitive structure. These developments also provide an opportunity to have the private sector play a greater role as a counterparty to natural gas import contracts if it can rely on cost-reflective pricing in Turkey's wholesale and retail markets. How quickly this can be achieved will depend on how retiring natural gas contracts are renegotiated or allowed to retire, something that is directly affected by the forthcoming Black Sea natural gas production and prospects for further discoveries. Similar to the experience in the European market, Turkish gas prices would become more closely linked to European hub pricing and de-linked from oil prices and, as the Turkish trading hub evolved, would gravitate to the Turkish hub price. Turkey can develop a more private sector driven natural gas market and also develop into a regional trading hub with its substantial gas grid infrastructure, high LNG regasification capacity, increased diversity of gas imports and entry points, and significant prospects for increased domestic natural gas production.

As stated, these are just TEO policy highlights. Additional IICEC analyses, scenario results and recommendations are presented in each TEO chapter.

CHAPTER 1:
POWER SECTOR

Summary

- Electrification is one of the strongest trends in the Turkish energy economy. The Turkey Energy Outlook (TEO) projects that electricity use will grow strongly but also that energy efficiency policies will limit the growth. The TEO Reference Scenario projects a 93% demand increase by 2040 while the more efficient TEO Alternative Scenario limits the growth to 64%. Electricity will also make up a larger share of Turkish total final energy demand: 28% in the Alternative Scenario, up from 22% now.
- The growth of per capita electricity consumption reflects the strong projected socio-economic progress in Turkey. Turkish electricity use per capita now stands at about half of the EU average. Still, because of Alternative Scenario policies, IICEC expects that Turkey's per capita electricity demand will be 20% lower than Europe's by 2040.
- The Turkish electricity market will continue to evolve to a more competitive, more localized and more diversified structure. While the market is currently oversupplied, with economic growth and a wider utilization of air conditioning and other consumer amenities, installed capacity still needs to be almost doubled by 2040.
- Both IICEC Scenarios substantially reduce fossil fuel imports. Large expansions of renewable and nuclear generating capacity will lower the reliance on fossil fuels. Other changes, such as increased domestic natural gas production (Chapter 4) will further reduce fossil fuel imports.
- Power grids will remain the backbone of the Turkish electricity system. IICEC shows a need to increase investment in the grid to accommodate more intermittent renewables, more variable demand features, more decentralized generation assets, and a rapidly advancing electro-mobility ecosystem.
- Solar PV and onshore wind are the fastest growing generation technologies in both IICEC Scenarios. Generation from these intermittent renewables increases to 28% (Reference Scenario) and 36% (Alternative Scenario) by 2040, up from 11% in 2019.
- Standby natural gas units will contribute to a flexible power system that will be increasingly necessary to accommodate the high penetration of variable renewables as electricity storage systems become more economically practicable and widely deployed (Chapter 6).
- A system-wide approach is required with long-term planning to balance supply and demand and ensure a secure, reliable and flexible Turkish power system.
- GHG emissions from the power sector will improve reflecting the increased dispatch of renewable and nuclear power, the lower share of fossil fuel generation and increased energy efficiency. By 2040, GHG emission intensity[1] drops by 28% (Reference Scenario) or 54% (Alternative Scenario). The larger reductions in the Alternative Scenario reflect higher efficiency gains and higher levels of renewable and nuclear power dispatch.

[1] Measured by terms CO_2-eq/MWh.

- The Reference Scenario shows a continual growth of power-sector GHG emissions: 34% higher than in 2018. In contrast, while the Alternative Scenario also projects a growth of GHG emissions, the growth stops in the late 2020s and then declines to 110 million tons CO_2-eq by 2040, 26% lower than in in 2019 and setting up a strong pathway to achieve net-zero emissions past 2040 (Chapter 6).
- Digitalization and data-analytics are key features that propel the more secure and efficient power sector projected for Turkey. Machine learning, the Internet of Things, cloud computing and blockchain will become more widely adopted. The increasingly competitive power market will also facilitate a nimble uptake of advanced technologies and their use in a wide variety of applications. Electricity consumers will also benefit from smart meters, smart home systems and devices, self-generation and electric vehicles. These all represent strong value creation avenues for an increasingly electrified and digitalized energy economy of Turkey.
- IICEC views localization as a central objective for Turkish energy policies following the Government's important initiatives to ensure that Turkish industry participates in the rapidly advancing energy technology landscape as opposed to relying on foreign technology imports. These initiatives include the Turkish car (TOGG) project supported by Turkish-built charging units, local production of wind turbines, solar PV modules and other local content requirements of other Turkish power purchase contracts. IICEC expects that localization policies will extend to new clean technology areas such as electricity storage and smart grids.
- Through 2040, IICEC expects the average annual investment requirement will be $9 billion[2] (Alternative Scenario). Of this only 68% is spent on power generation. The rest is spent on a more modern grid and a variety of associated technologies including more battery storage. In the Reference Scenario, 72% is spent on power generation and with less investment to achieve a truly modern electric grid and associated infrastructure as the annual investment requirement is lower at $8.3 billion per year, but without the gains in localization, efficiency and sustainability.
- IICEC recommends continued sustainable power-sector investments aided by a stronger role for the private sector. This will also require continued reform of the Turkish power market toward cost-reflective pricing to motivate private sector engagement. The outcome of this marriage of private sector participation and government policy leadership will provide Turkey a 21st Century power sector that features clean and reliable power supplies, distributed generation, demand side management, smart grids, battery storage, electric vehicles, and digitalization. It will also drive Turkish technological and industrial development resulting in broader economic advantages for Turkey.

[2] All $ estimates are measured assuming 2019 USD.

1.1 Global Developments

Electrification is one of the most significant trends shaping the energy industry. Both in Turkey and other developing economies, higher incomes will be increasing the demand for electricity. At the same time, the need to reduce world-wide greenhouse gas (GHG) emissions means that additional electricity services need to be provided while reducing CO_2 emissions. Despite flattening demand in most OECD countries, world-wide electricity demand has been growing faster than the demand for any other energy service and is expected to remain the fastest growing energy sector in the next 20 years. Global electricity demand is estimated to grow at 2.1%/yr. until 2040, that is two times more than the anticipated growth rate for primary energy demand in the same period (IEA 2019a). Electricity currently meets about 20% of total final energy demand globally and will increase its contribution to around a quarter by 2040[3] mainly by replacing fossil fuel use in buildings and across industries as well as by increasing electrification in transport services.

Modern urbanized societies are entirely dependent on reliable electricity services and, consequently, there must be continuous access to electricity. Providing this is an increasing challenge because electricity is not easily stored. In the past, the wide variations of demand were accommodated by maintaining excess electricity production capacity. More recently, the increased use of intermittent renewable energy has added to the variability problem. In addition, electricity market reform has often reduced the economic incentive to maintain excess electricity production capacity. Along with rapid technological change, all of these factors have made the modern power sector much more competitive and dynamic than it has been in past decades.

The importance of maintaining reliable energy services is not always appreciated until those occasions when they are interrupted. It is not an exaggeration to say that the power sector is the centerpiece of modern energy services and the key to achieving clean energy goals. The electricity sector, along with energy efficiency, is at the center of the energy sector transformation upon which a more prosperous and sustainable energy future depends.

The power sector will be shaped by several emerging trends and requirements. On the supply side, renewable energy is gaining an increasing share due to government incentives and reducing cost. The industry is also upgrading its transmission and distribution infrastructure. Turkey and other developing economies are experiencing a dynamic transition with new power generation investments, including an increasing share of renewables, growing demand centers and upgrades to the transmission and distribution infrastructure to more reliably serve their growing populations. Several measures to achieve secure and flexible operation are on the agenda of policy makers and the power industry especially as technological progress provides more efficient and cost-effective solutions in all aspects of the sector: generation, transmission, distribution, storage and demand services.

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[3] The IEA Stated Policies Scenario. In the IEA Sustainable Development Scenario electricity meets 31% of total final energy demand services by 2040.

Consumers are becoming participants in the operation of the power market through new market rules, rate structures, smart meters, business models and digitalization. Rooftop photovoltaics (PVs) have created a new class of "prosumers" that help to alleviate the need for additional grid based power supply but, at the same time, introduce new challenges for power transmission, distribution and grid balancing. These changes both create and reflect new business models that emphasize flexibility, changing electricity service needs and new technologies enabled by digitalization. These offer important opportunities for efficiency in both supply and use of energy as well as energy management solutions. Wider deployment of smart grids, demand side response and management, electrification of transportation services, and power storage technologies are some of the key trends that will create new investment opportunities and innovative business models

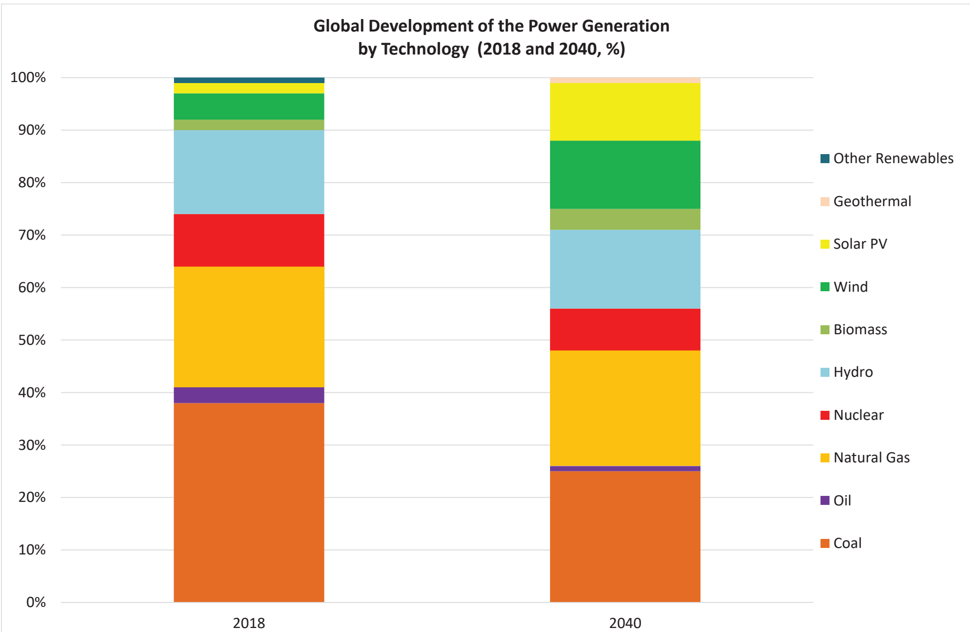
These dynamics have already made the global power sector the most prominent and dynamic energy sector with more investment than the oil and gas sectors combined in recent years. The rate of change and innovation will not slow, given the projected growth in electricity demand in a continuing evolution of power markets, regulatory frameworks and technologies. The potential downside of such a dynamic business environment is investment risk that will continue to concern governments to ensure that the sector provides an effective investment framework in each interdependent element such as new power generation investments, grid modernization, load management, energy storage and reserve capacity.

In order for power markets to anchor a secure and sustainable energy economy they must be reliable, efficient and provide services at a reasonable cost. Competitive markets allocate energy, capital and human resources in the most optimal manner but government also has a strong role to play. Cost-based pricing with limited intervention that distorts prices is the central philosophy aided by key market regulations, well-defined incentives and other rules in order to ensure investment and uptake of clean energy technologies while allowing market players to respond to the new dynamics of power markets. Security and reliability of power supply are pre-eminent in a strategy that also emphasizes flexibility, competitiveness, affordability and sustainability goals in a coherent way. While not often discussed in energy policy assessments, profitability and shareholder value are key ingredients to achieving success in all other strategy goals.

Although coal and gas remain the two leading fuels in global electricity supply, fossil fuels are decoupling from power demand due to the rapidly increasing investments in renewable energy and efficiency gains attained both in the supply and demand of electricity services. Wind and solar capacity additions have far outpaced new coal, natural gas and nuclear gains and this trend is expected to accelerate with solar PV outpacing all other power technologies by a wide margin. Renewable energy sources supplied 26% of global power generation up from 20% in 2010. Led by solar PV, wind and hydro, the renewable energy share in power production is expected to increase to 36% and 44% by 2030 and 2040 respectively. Together with an estimated 8% share for nuclear power (10% in 2018), non-fossil based generation will represent more than half of global electricity generation.

The intermittent generation technologies are anticipated to represent 24% of global power generation by 20404 compared to about 8% at present[4] (Figure 1.1).

Figure 1.1 Global Development of the Power Generation by Technology (2018 and 2040, %)



Source: IEA, 2019

As a result of decades of research, development and demonstration, wind and solar PV have become the most cost competitive forms of power generation in most markets depending on the local endowment of renewable resources and the cost of competing fuels such as coal and natural gas. As a result, the carbon intensity of the power sector is declining in many countries and should become much lower with additional onshore wind, offshore wind, solar PV, other renewables, nuclear energy and associated technologies such as smart power grids, electricity storage, digitalization and smart demand services. Coal and oil are both expected to lose ground in the power sector. Natural gas plants produce significantly lower air pollution than either coal or oil fired power and would improve the health of people in many of the world's most polluted cities, especially in Asia. In addition, natural gas plants flexible load following characteristics better match the dispatchability profile of wind and solar PV, power sources that are expected to achieve the highest growth towards 2040.

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[4] The IEA Sustainable Development Scenario, in line with Paris Accord climate targets, calculates that much more renewable energy will be needed and estimates a combined share of 40% for solar PV and wind by 2040.

1.2 Turkey's Power Sector Policies

The Turkish power sector currently consumes a quarter of Turkey's total primary energy supplies and provides one-fifth of total final energy consumption. Turkey's electricity share of final energy demand is set to increase, driven by strong fundamentals encompassing macro-economic and social development objectives, ongoing industrialization and urbanization trends. Further electrification of the energy economy will create new challenges and opportunities for a developing power market. The power sector also stands at the core of the National Energy and Mining Policy of Turkey (NEMP). NEMP is a comprehensive policy agenda featuring three main pillars: security of supply, localization, and predictability in the markets. Through this policy framework, Turkey aims to achieve a more localized and efficient power market with enhanced predictability towards a more competitive structure. Other key Turkish power sector policy documents considered in this study include the 11th Development Plan issued by the Presidency of Turkey in July 2019 and the Strategic Plan of the Ministry of Energy and Natural Resources for 2019-2023. Each of these documents focus on plans and goals through 2023. The National Energy Efficiency Action Plan also defines important goals for a more effective and productive power sector. The policies aim to foster a more secure, reliable and efficient power sector with improved predictability for sustaining investment to meet growing needs for electricity demand services.

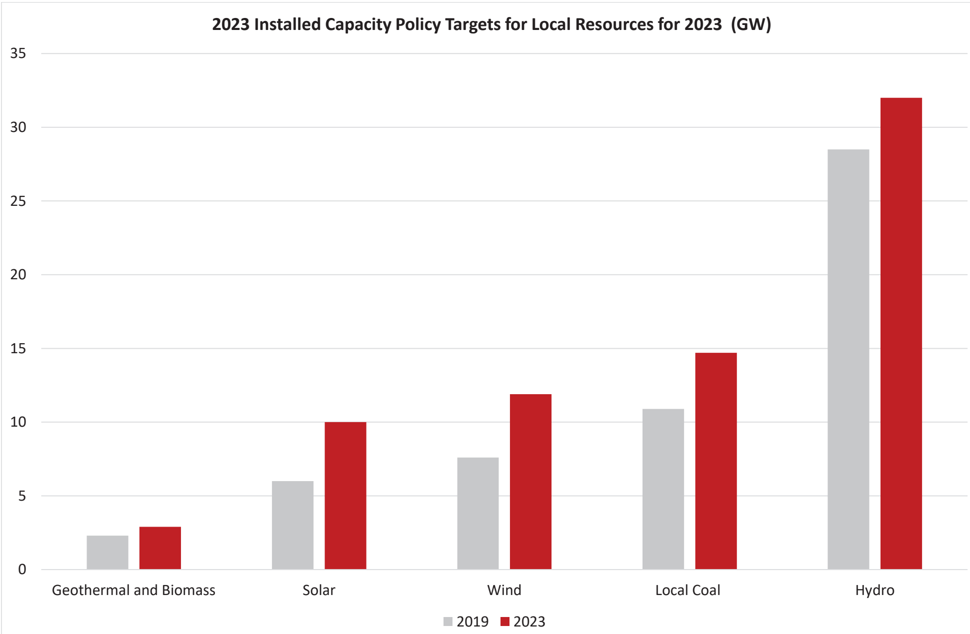
- Power Generation from Domestic Resources

Prioritizing electricity generation from domestic energy resources is one of the central elements of power sector policies. Turkey targets to nearly double generation from local coal and renewables until 2023 (from 150 TWh in 2018 to 220 TWh in 2023). This target is also translated into increasing the share of local energy sources to 65% of installed capacity by 2023. This requires substantial increases in all renewables, specifically, increasing solar capacity to 10.0 GW (6.0 GW in 2019), wind to 11.9 GW (7.6 GW in 2019), hydro to 32.0 GW (28.5 GW in 2019), geothermal and biomass combined to 2.9 GW (2.7 GW in 2019) (Figure 1.2).

Support mechanisms are necessary to facilitate required investments into Turkey's largely untapped potential in wind, solar, geothermal and other renewable resources. Turkey has local coal potential, mostly in lignite. Utilization of local coal resources in accordance with environmental (air pollution) standards is a policy priority driven by the targets to lower imported fuel dependency and increase employment. The policy target is to increase capacity from 10.9 GW in 2019 to 14.7 GW by 2023. The YEKA[5] model incorporating local content requirements has become the prime axis of Turkey's renewable capacity growth and will lead, in particular, to large wind and solar PV capacity investments.

[5] The YEKA Model is based on auctions and power purchase agreements for plants deployed in defined Renewable Energy Resource Zones and include equipment and technology localization targets.

Figure 1.2 Installed Capacity Policy Targets for Local Resources for 2023 (GW)



Source: TEİAŞ 2020, MENR 2020

- Introduction and Growth of Nuclear Power

Turkey's long lasting efforts to introduce nuclear power into the power generation mix has recently been realized with the Akkuyu Nuclear Power Plant now being constructed. Turkey aims to start trial operation of its first unit by 2023, the continued construction of Akkuyu's second unit, moving forward with two additional Akkuyu units and developing power purchase agreements or contracts to build nuclear power plants at other locations. Turkey is coupling this with a strong nuclear safety regime realizing that a nuclear safety culture employing the necessary institutional framework is the key to the safe and sustainable use of nuclear power.

- Power Grids

Expanding and enhancing the power grid to match with developments in generation and demand is essential for a secure and reliable power system. The policy documents include key elements for a more resilient and efficient power grid for transmitting and distributing electricity. Realization of the targets defined in the Smart Grid Road Map, ensuring reduction in grid losses and sustained improvements in grid quality in terms of duration and frequency of outages are among the central elements for providing modernized grid services to the growing electricity economy of Turkey. In supporting strong growth from intermittent renewables, enhancing flexibility and balancing capability of the power system will be a vital task that is reflected in the policy documents. Turkey's policy priorities also address the need for power system planning to integrate a growing fleet of electric vehicles, a broader policy and industrial objective for Turkish economy. Turkey also aims to develop power storage legislative framework reflecting global advancements and evolving business models and increased national efforts in R&D activities around power storage technologies. The SCADA system for the whole electricity system supports Turkey's technology localization increasing import and export opportunities. Expanding the cross border transmission capacities is another policy orientation that serves resource optimization and trade. All these objectives acknowledge the growing role of power grids and necessitate sustained investments backed by integrated and long term planning.

- Power Sector Efficiency

The power sector is among the key sectors with defined targets in Turkey's National Energy Efficiency Action Plan. With increasing electrification, weight of electricity in final energy demand services will significantly increase. The Plan targets to achieve increased efficiency performance in both power generation and grids. Public lighting, electric motors, pumps and appliances are key areas to realize untapped efficiency potential in power demand services. The plan underlines the importance of smart meters and demand side response in achieving a more efficient power system and also points to the need to manage Turkey's peak power demand stemming from cooling and heating services.

- Power Market Development

Elements in Turkey's policies that contribute to a more competitive power sector include the introduction of the Last Resort Tariff mechanism starting with large consumers, lowering the regulated customer base, efforts to increase bilateral agreements between market players and further advancing the organized power markets. The 2023 goal is to achieve competitive pricing.

1.3 IICEC Overview, Scenarios and Analysis

1.3.1 Introduction

IICEC's priorities for the Turkish power sector emphasize enhancing the security of supply, increasing localization of the production of power-sector capital equipment, improving power market predictability and ensuring sustainable economic and environmental performance. Renewable energy is a central feature that can encompass all of these priorities. Nuclear power, notwithstanding various controversies that have surrounded it for decades, also serves these priorities. While Turkey has domestic lignite resources and, as discussed above, Turkish energy policy emphasizes the expansion of domestic coal, coal cannot satisfy all of these requirements without the application of carbon capture utilization and storage (CCUS).

The economic challenges of CCUS are discussed later in this chapter and the future of Turkish coal use and CCUS is treated more broadly in Chapter 6 (the Energy Transition). The future role of natural gas is greatly affected by the recent advances in renewable energy technology. As renewable energy has become the least expensive form of electricity production (as measured by LCOE[6]) and meets all other Turkish energy priorities, it has reduced the former role held by natural gas. However, since Turkey's fastest growing sources of renewable generating capacity, wind and solar, are intermittent, there is a changing role for natural gas to provide flexible backup power instead of baseload power. Natural gas, among all power sources, is best able to provide power on demand and will be needed until electricity storage can be relied upon to balance out the supply of wind and solar to meet peak demand under all circumstances.

IICEC Scenarios analyzes how the Turkish electricity sector can best evolve to meet these policy goals (security of supply, localization, predictability in the markets and sustainable environmental performance) while powering a robust Turkish economy. The Turkey Energy Outlook provides a quantitative underpinning to its policy analysis in the form of two scenarios of all key Turkish energy and economic indicators through 2040. Each scenario reflects progressive policies aimed at providing the necessary expansion of energy services to a growing Turkish economy while achieving the pillars of Turkish energy policies and a sustainable environmental future.

The Reference Scenario reflects a baseline set of policy initiatives that can be reliably expected in future years, including years well past the near-term outlook provided in government documents. The Alternative Scenario adds more ambitious policy priorities that will require more sustained government and public support especially after the period that has been well documented by current government plans. Each scenario shows a significant increase in the share of domestic and renewable resources, adding nuclear power into the generation mix, utilization of the efficiency potential in the electricity value chain, and benefitting from technology advancements and localization. However, the achievement of these important targets is realized at differing rates and paces. The Alternative Scenario achieves more challenging targets for localization, a more progressive and sustainable power generation mix, local technology development and wider efficiency improvements. It also brings about a greater transformation of the electricity system with a stronger private-sector role in determining the allocation of power-sector investments. Implementing the Alternative Scenario provides substantial gains for the electricity ecosystem, the wider energy economy and environmental performance.

[6] LCOE is the Levelized Cost of Energy, the standard measure used to compare the capital, operating and fuel costs of different electric generating technologies. Later in the chapter, the "Value Adjusted Levelized Cost of Energy" (VALCOE) will also be discussed and analyzed.

Table 1.1 Summary of Electricity Supply and Demand in Scenarios (TWh)

Scenarios			Reference Scenario		Alternative Scenario	
	2000	2019	2030	2040	2030	2040
Gross Electricity Demand (TWh)	128	302	423	568	398	488
Net Electricity Demand (TWh)	98	256	364	494	350	434
of which						
Industry	49	117	157	202	152	179
Buildings	37	119	184	260	172	219
Agriculture	3	7	9	10	9	9
Transport	1	1	4	10	6	17
Electricity in Total Final Energy Consumption excluding non-energy uses(%)	14%	22%	24%	27%	25%	28%
Net Electricity Demand per capita (MWh)	1.5	3.1	3.9	4.9	3.8	4.3
Gross Electricity Generation (TWh)	125	301	424	571	399	491
Natural Gas	46	55	59	76	36	30
Coal	38	113	161	166	139	106
Nuclear	0	0	18	63	27	80
Renewables	31	132	186	266	197	274
Share of Imported Fossil Fuels (%)	45%	39%	31%	25%	26%	12%

Electricity supply and demand highlights per each scenario are presented in Table 1.1. In the Reference Scenario, gross electricity demand grows over the forecast period (through 2040) by an average of 2.8% per year. This reflects a growing Turkish population and an increased demand for electricity services per person. One factor driving increased per-person demand is the expected increase in households equipped with air conditioning. Partly as a result of more air conditioning, the consumption of other electricity services including further electrification of industries and a growing population, by 2040, gross electricity demand is expected to increase by 88% (an additional 266 TWh). Renewable energy supply doubles by 2040, underpinned by policy support, industry orientations, declining technology costs and other technical improvements. The fastest growth takes place in two technologies: solar PV and wind. Their combined share in generation increases from 11% to 20% in 2030 and 28% in 2040 (Figure 1.3). The contribution of nuclear power reaches 11% by 2040. Lignite capacity increases by 43% until 2040. However, despite additions of around 6 GW of domestic coal capacity, due to increasing demand, faster growth in renewables, addition of nuclear units and retirement of a portion of the existing fleet in the mid-2030s, the share of local coal in overall generation remains almost unchanged in 2040 at 18%. The share of imported fossil fuels in electricity generation falls to 31% in 2030 and 25% in 2040, down from nearly 40% in 2019. Solar, hydro and natural gas each attain an installed capacity of 20% followed by wind (17%). Renewables in total represent 61% of total installed capacity (Figure 1.4).

Figure 1.3 Breakdown of Electricity Generation by Technology in the Reference Scenario (2040, %)

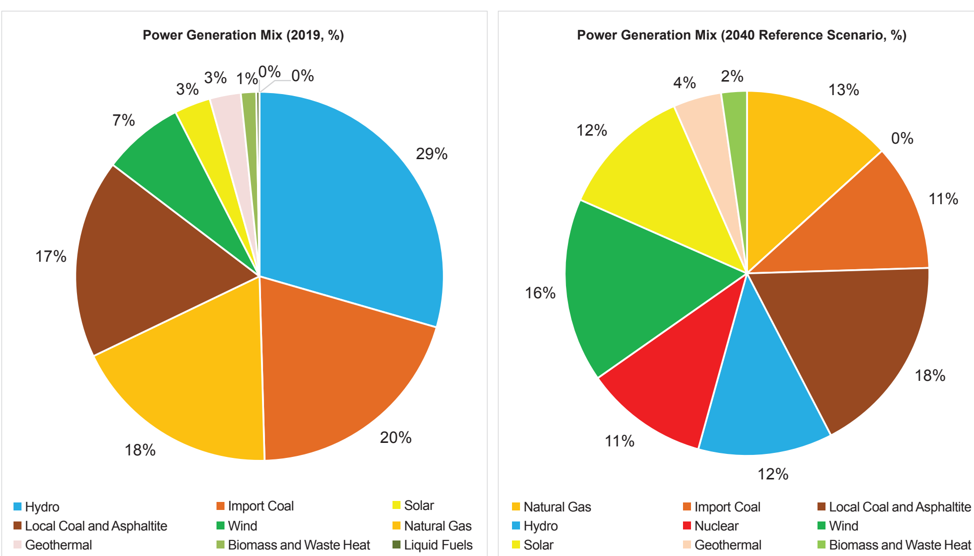
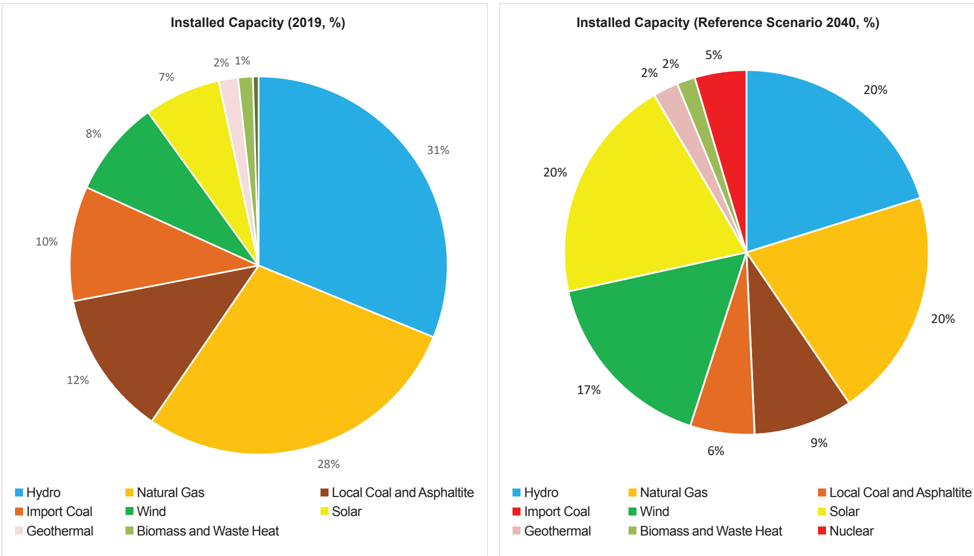


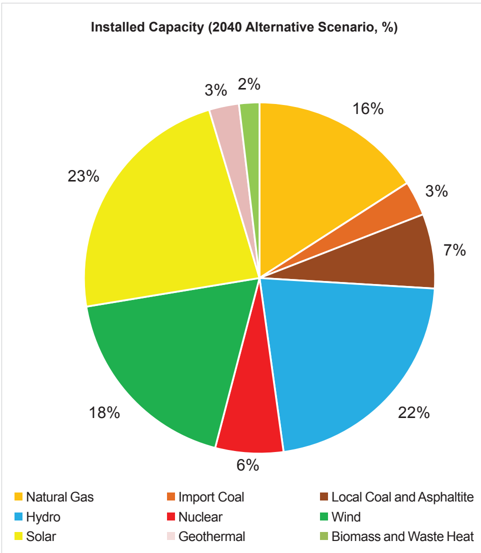
Figure 1.4 Breakdown of Installed Capacity by Technology in the Reference Scenario (%)

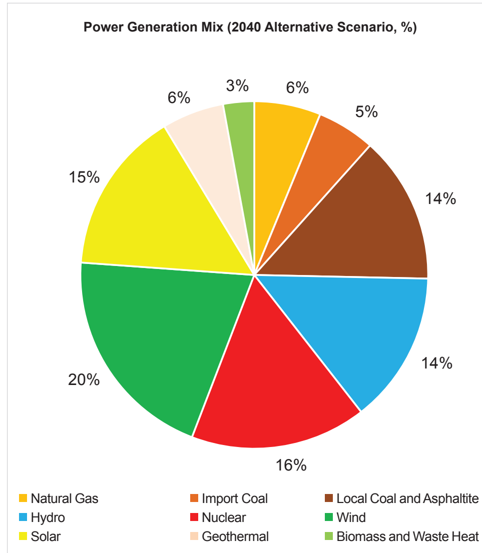


Improved energy efficiency in electricity end use has a large effect on the power sector when comparing the Reference Scenario to the Alternative Scenario. Due to improved end-use efficiency gained in the Alternative Scenario, 2040 gross electricity demand is 80 TWh less than the 266 TWh increase estimated for the Reference Scenario. In the Alternative Scenario, renewables account for 89% of net capacity additions from 2019 to 2040 and 81% of additional power generation. These renewable additions are significantly higher than the 72% capacity increase and 50% of the generation increase estimated for the Reference Scenario.

Faster technological progress in the Alternative Scenario yields higher capacity utilization factors for wind and solar PV, particularly after 2030. Also, nuclear power accounts for 13% of capacity additions from 2019 to 2040 and 42% of additional power generation (compared to 9% and 23% in the Reference Scenario). Lastly, coal capacity decreases by about one-third and power generation by 43% compared to the Reference Scenario by 2040 reflecting a partial retirement of the aging imported coal capacity. Wind and solar combined represents 41% of the installed capacity and 36% of generation by 2040. Renewables in total add up to two-thirds of total installed capacity and 58% of generation. Nuclear power takes a more significant role in the generation mix contributing to about one-sixth of total power production compared to one-ninth in the Reference Scenario by 2040 (Figure 1.5).

Figure 1.5 Breakdown of Installed Capacity and Power Generation in the Alternative Scenario by 2040 (%)

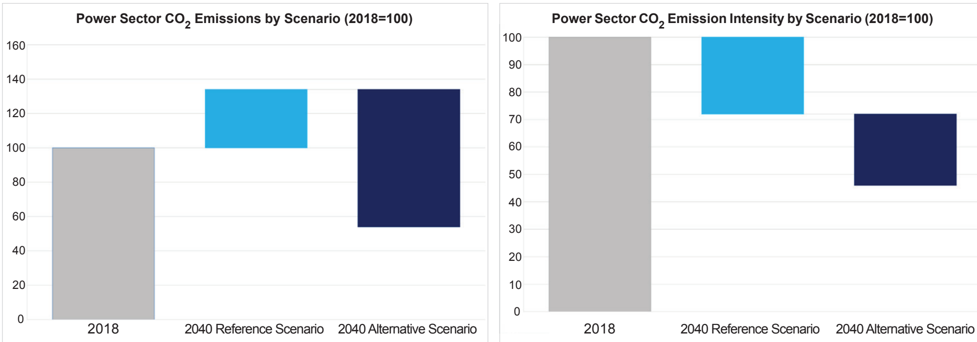




In the Reference Scenario, GHG emissions rise by 34% between 2020 and 2040. However, the CO_2 intensity decreases by 28% when measured per kWh of electricity production (Figure 1.6). The emissions intensity savings that were realized in the Reference Scenario were achieved by a strong uptake of renewable energy, new nuclear power plants and efficiency improvements in power generation. Further reductions of CO_2 emissions were restricted by the estimated dispatch of power from Turkey's coal fleet. The Alternative Scenario shows significant progress in reducing power-sector CO_2 emissions.

While the 2-decade 33% CO_2 emissions increase projected by the Reference Scenario is much lower than the 110% increase of the previous two decades, as a result of increased renewables, nuclear and improved efficiency performance, and a decreased coal share, the Alternative Scenario shows that Turkey's growth of power sector GHG emissions (in terms of CO_2-eq) stops in late 2020s and are 26% lower in 2040 than they were in 2019. Compared to the Reference Scenario, the Alternative Scenario CO_2 emissions are 17% lower in 2030 and 45% lower in 2040 as a result of a progressive clean power generation investment policy. CO_2 emissions intensity of the power sector is 36% less in the Alternative Scenario than the Reference Scenario by 2040 (Figure 1.6). The Alternative Scenario achieves 54% reduction in the CO_2 intensity of the power sector by 2040.

Figure 1.6 Power Sector CO_2 Emissions and CO_2 Emission Intensity by Scenario (2018=100)

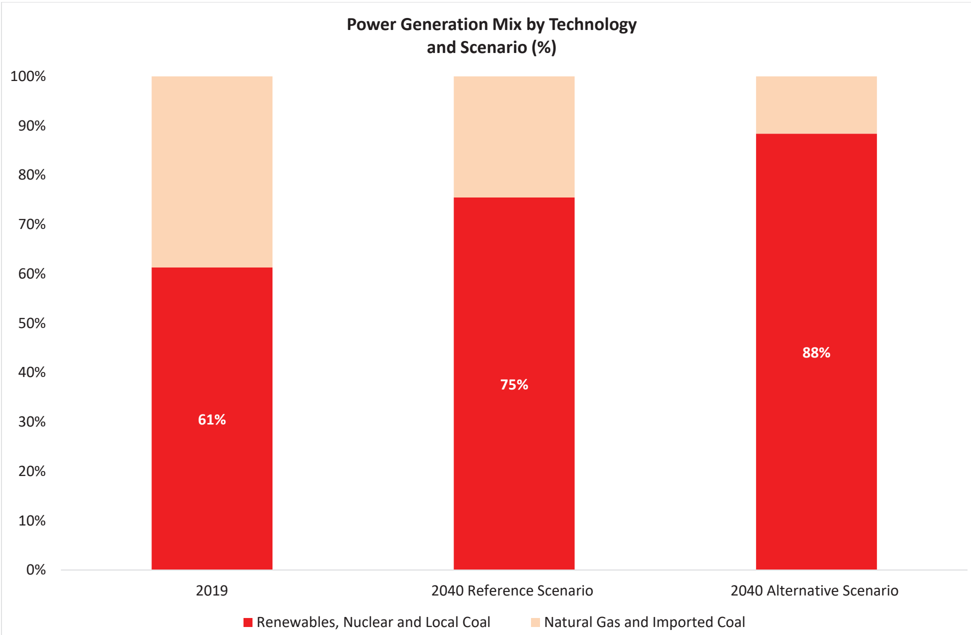


The more efficient and sustainable performance of the Turkish power sector, shown in the Alternative Scenario, results from a variety of changes compared to the Reference Scenario. These include additional technology improvements, grid and overall system flexibility related measures, government policies and clean investment choices that are encouraged by more predictable markets. As a result, wind and solar PV capacity share combined increases to 30% in 2030 and 41% in 2040 from 15% in 2019 while generation from these two particular resources increases to 23% and 36% of total (2030 and 2040). Despite the economic and environmental benefits of more renewable energy, intermittency becomes a more important factor affecting the power sector.

More variable renewables require additional grid investments and more power system flexibility to achieve reliability of supply. The Alternative Scenario anticipates lower capacity factors among natural gas plants (due to a higher share of peaker plants), more pumped storage hydro, and the more widespread use of battery storage. In both scenarios, capacity payments will be needed to ensure availability of efficient natural gas peaker plants. This need is more urgent in the Alternative Scenario as the average annual capacity factors of natural gas plants drops to 10-15% towards 2040 compared to the range of 20-25% in early 2020s.

The share of imported fossil fuels in power generation reduces to 12% until 2040 compared to 25% in the Reference Scenario and 39% in 2019. Thus, the Alternative Scenario also shows improved Turkish balance of trade. In it, the generation from imported coal and natural gas combined is cut by almost 60% compared to the Reference Scenario by 2040 (Figure 1.7). Not only do electricity consumers benefit from reduced electricity expenses from more efficient end-use equipment, the shift in investment away from fossil fuel power plants reduces fuel expenses and serve to lower Turkey's energy import bill.

Figure 1.7 Power Generation Mix by Technology and Scenario (%)



The Alternative Scenario realizes these significant gains in terms of localization, efficiency and sustainability with a total investment figure for the power sector that is only 8% higher than the Reference Scenario. In the Alternative Scenario, the average annual investment requirement until 2040 is approximately $9 billion (2019 $), of which about 32% is spent in areas other than generation, most notably in grids, and new technologies such as battery storage. This represents a shift in investment compared to the Reference Scenario where 72% of the $8.3 billion total is allocated to power generation. Reorientation of power-sector investment will be driven by successful business models that take advantage of emerging technological opportunities including renewable power, distributed generation, smart grids, demand side management, battery storage, and digitalization.

While the investment needed to achieve improved energy end-use efficiency is borne outside of the power sector in the appliances and other industries, the additional costs of their products is more than offset by consumer energy cost savings. When stimulated by regulation, the major impediment to improving end-use efficiency is eliminated as no manufacturer has to yield a competitive advantage to another by doing so. This subject is taken up in Chapter 5 (Other Sectors and Fuels) where a continued focus on optimal efficiency regulation is emphasized as the market cannot be relied upon to produce socially optimal levels of energy efficiency.

1.3.2 Demand

Electricity demand increases in Turkey at a faster rate than worldwide. For example, worldwide demand from 2000 to 2019 increased by 3% per year while, in Turkey, electricity demand rose at almost 5% per year. Turkey's economic growth and social development, including rising incomes, industrialization and urbanization, help explain this rapid growth in electricity demand.

Despite the impact of Covid-19 related measures on power demand observed through 2020, short to long term growth prospects remain strong compared to many advanced and developing energy economies. Nonetheless, Turkey's rapid growth of electricity demand is expected to slow over the next two decades compared to the last two decades as the sector advances towards a more efficient growth pathway. IICEC analysis estimates that, from 2020 to 2040, Turkey's net electricity demand will increase by 3.3% per year in the Reference Scenario and slow further to 2.6% per year in the Alternative Scenario.

While the growth of Turkey's electricity demand is expected to slow, the importance of electricity in its economy is expected to increase. For example, while the share of electricity in total final energy consumption is around 20% today, by 2040, increased electrification of the Turkish economy will drive up the share of electricity to 27% in the Reference Scenario and 28% in the Alternative Scenario. Even though the Alternative Scenario shows wider digitalization and electrification of Turkey's energy economy, increased efficiency partly offsets the wider use of electricity services especially in buildings and industry. Electrification of road transport and expansion of electrified rails, as discussed in Chapter 2 (Transport), contributes to increasing power demand, particularly from 2030 onwards in the Alternative Scenario.

Per capita gross electricity demand reaches 5.7 MWh per year in Reference Scenario and 4.9 MWh per year in the Alternative Scenarios. This is a 40% increase from the current 3.5 MWh per year consumption, a figure that is about 40% lower than the average for EU countries (Figure 1.8). Turkey's per capita electricity demand in 2040 will remain lower than EU's estimated 2040 per capita demand in both IICEC scenarios.[7] These reflect an efficient growth pathway for the electricity economy.

Buildings and industry are two of the largest electricity consuming sectors today, accounting for nearly 120 TWh each (with a combined share of 92%) while agriculture, mostly for irrigation, correspond to 3% of net electricity demand. Almost all transport related electricity demand consists of urban and intercity rail. Rail accounts for less than 1% of net electricity consumption.

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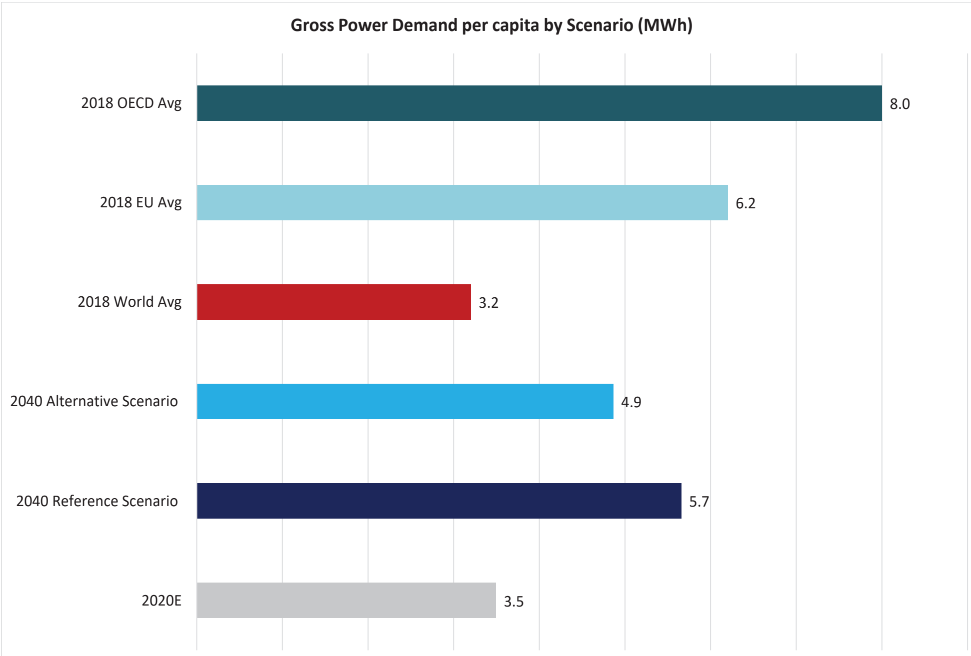
[7] In the Reference Scenario, Turkey's 2040 per capita electricity demand will be 9% lower than the current EU average and 7% lower than Europe's 2040 per capita electricity demand as estimated in the IEA *2019 World Energy Outlook*. In the Alternative Scenario, Turkey's 2040 per capita electricity demand will be 22% lower than the current EU average and 20% lower than EU's 2040 per capita electricity demand as estimated in the IEA *2019 World Energy Outlook*.

Figure 1.8 Gross Power Demand per Capita by Scenario (MWh)



Most of the electricity used in industry is for motor-driven systems including pumps, fans and compressors. Today, low efficiency motors represent about two-thirds of the current stock and motor systems account for 65% of industrial electricity demand. Improving the efficiency of motors and related systems by installing variable speed drives, improving motor sizing and employing energy management systems would collectively improve industries' electricity efficiency as discussed in Chapter 5 (Other Sectors and Fuels).

Another important factor affecting future demand in the industrial sector is the structure of Turkey's industrial growth. Average industrial sector energy efficiency can change considerably as manufacturing and service sectors increase in relationship to commodity sectors, a typical pattern in developing economies. The service sectors and some manufacturing sectors are less energy intensive and also add more value and growth to the economy than sectors such as cement and steel. While these traditional sectors will remain an important and necessary part of the economy, industrial energy consumption will not grow proportionally as new sectors become more prominent. Nonetheless, it is not sufficient to depend on structural shifts to improve the sectors' energy efficiency. Despite expected industrial efficiency improvements, electricity demand is expected to grow in the Reference Scenario by 2.0% per year (to 2040) despite a decrease of kWh/GDP consumption of about 1%/yr. due to structural and efficiency effects. In the Alternative Scenario, energy efficiency measures produce a much stronger result in slowing the rate of growth to less than 1%/yr. after 2037 and then to saturation around 2040 (Figure 1.9).

By 2040, the Alternative Scenario shows that the industrial sector will have 24 TWh less net demand for electricity compared to the Reference Scenario (or 12% lower) (Figure 1.9)

Buildings including households, public and commercial buildings continue to consume the most electricity in each Scenario. Buildings will also be the second fastest growing power demand sector after transport. Buildings sector demand will grow by 3.7%/yr. in the next two decades in the Reference Scenario and 2.8%/yr. in the Alternative Scenario (Figure 1.9). This is mainly driven by ongoing urbanization and rising welfare. Increasing ownership of appliances and air conditioning together are main drivers of growth in the buildings sector.

With a wealthier and increasing population, housing units are expected to increase in a more urbanized structure. Their insulation, windows and other factors affecting building energy performance will greatly influence the energy required for space heating and cooling. As the existing housing stock will remain important, it cannot be ignored and will need significant upgrades, as discussed in Chapter 5 (Other Sectors and Fuels). In the Alternative Scenario, where building energy efficiency performance is estimated to increase faster, electricity demand in buildings will be 41 TWh less than in 2040 or 16% lower than in the Reference Scenario.

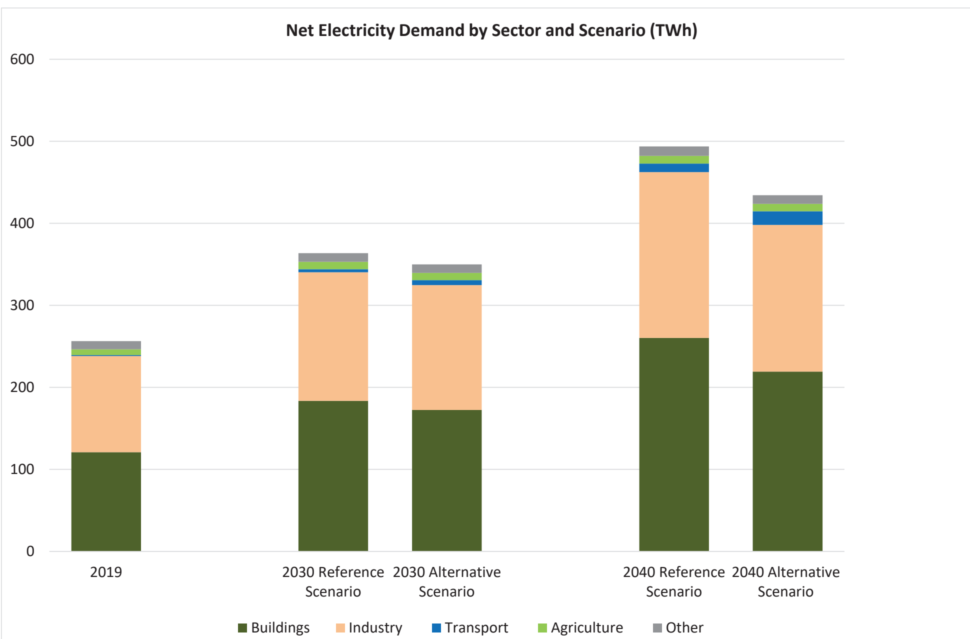
While the agricultural sector only accounts for 3% of electricity demand, irrigation accounts for the vast majority of total agricultural demand and is a good target for electricity savings. In the Alternative Scenario, electricity demand in the agricultural sector is expected to be 12% lower by 2040 compared to the Reference Scenario through more efficient pumps and pumping systems. Distributed generation with solar PV will provide system benefits and lower grid losses (Figure 1.9).

Among all power demand sectors, transport uses the least amount of electricity today (about 1 TWh), almost all of which is from urban transit and intercity railways. As the Turkish rail network expands and becomes more electrified, rail electricity consumption will increase. Road transport is now poised to an uptake in electricity use starting from mid 2020s as the electric vehicle fleet expands, underpinned by government fiscal policies, auto-industry drivers and recharging station investments by the Turkish power industry and others. Current battery electric vehicle (BEV) initiatives serve important policy objectives including the localization of Turkish industry and reduced oil import expenses. The Local Car (TOGG) is expected to be an important component of stock growth in electric vehicles. As discussed in Chapter 2 (Transport), the Reference and Alternative Scenarios show the total number of electric cars in Turkey growing to between 1.9 million to 2.8 million light duty vehicles until 2040. By 2040, transport sector power demand increases to 17 TWh in the Alternative Scenario, 6 TWh of which will be from BEVs including electric buses (Figure 1.9). It is important to note, however, that while this growth of BEVs in Turkey is important for a number of reasons, including improved energy security, reduced urban pollution and reduced greenhouse gas emissions, 6 TWh represents less than 2% of the total estimated net electricity demand in the Alternative Scenario. In addition, the growth of BEV power demand is quite gradual and is not estimated to cause difficulties for the Turkish electric grid.

A recent study suggests that, in the next ten years 2.5 million BEVs can be integrated to Turkey's power grid with a total annual consumption of 4.1 TWh by 2030 with almost no additional investments and limited impact on the operation of the distribution grids. The report identifies key focus areas for accelerated penetration and larger integration of electrified transport including smart charging mechanisms for load management, continuation of planned investments in distribution grids in line with the growth in electricity demand and region-specific measures to avoid overloading and voltage violations (SHURA, 2019).

Public lighting and other services constitute the rest of power demand services, about 5% of net demand today. In both Scenarios these uses are expected to decline to 2.5% by 2040 as a result of lighting efficiency improvements driven by policies and technology and relatively higher electricity demand growth from buildings and industry (Figure 1.9).

Figure 1.9 Net Electricity Demand by Sector and Scenario (TWh)



1.3.3 Supply

Turkey's power supply has rapidly grown since 2000. From 2000 to 2010, installed capacity increased from 28 GW to 50 GW and then increased to over 93 GW by 2020. Turkey has been one of the most dynamic power sectors worldwide in deploying new capacity over the past two decades. The makeup of installed capacity has also significantly changed. For example, the share of wind and solar PV has increased from just a few plants in 2000 to 15% of installed capacity by 2020 (WE, 2020). This progress has put Turkey as one of the leading countries across Europe in cumulative renewable energy development and deployment. Turkey is second only after Norway in hydro installed capacity, ranked seventh in both wind and solar installed capacity (IHA, 2020). Turkey is also among the leaders in geothermal power installments and ranked fourth after the United States, Indonesia and Philippines globally (TG, 2019).

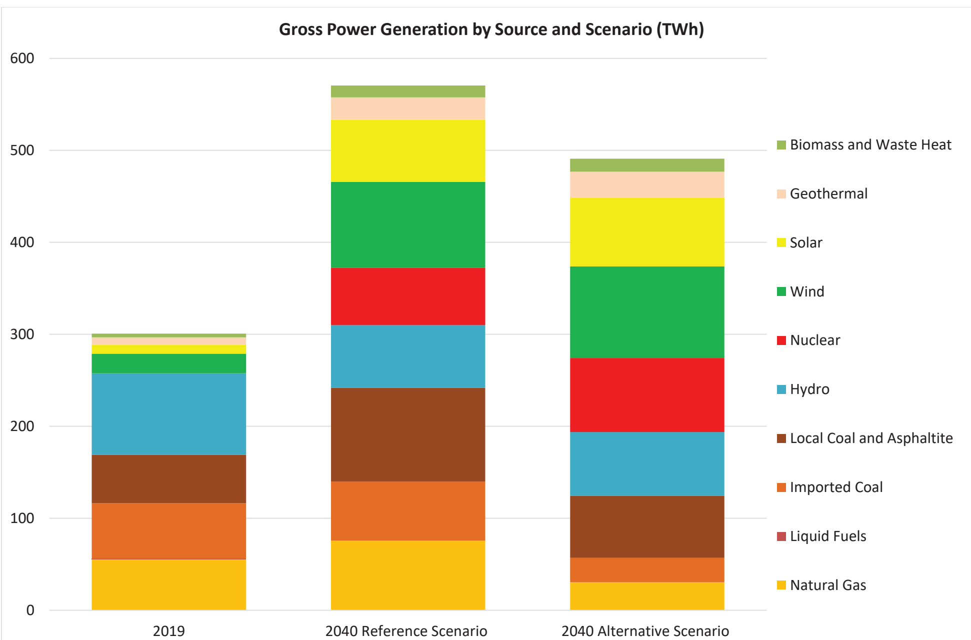
Energy policies have favored domestic resources, including local coal and all types of renewables, particularly after the NEMP. Renewables capacity has grown faster than any other fuel and technology as a result of lower cost and incentives, most notably the YEKDEM mechanism that ensures power sales at fixed prices denominated in U.S. dollars. Hydro is one of the key elements of Turkey's installed capacity and power generation (30% in both in 2019). Throughout 2020 and 2021, capacity increases by commissioning large dam projects are expected to increase hydro contribution to the generation portfolio of Turkey. It is a dispatchable power source but due to the variability of rainfall, average annual capacity utilization can swing dramatically between wet and dry years.

Government efforts to build power sector capacity have produced an intensive investment cycle in the past 12 years. As a result of slowing demand growth Turkey's current power market is oversupplied with ample reserve production capacity. The Covid-19 impact on power demand in 2020 adds on to the oversupply situation that is not expected to phase out until around 2025. The dispatch of this capacity reflects market operation, costs and pricing strategies, implementation of power purchase agreements and merit order dynamics. In recent years, the economic factors that underpin dispatch order have caused natural gas plants to operate at lower capacity factors.

Policies to achieve supply security, localization, efficiency and advanced technologies affect Turkey's investment and resource utilization choices. These policies will continue to shape installed capacity and power utilization in the coming decades. As a result, the Reference Scenario shows a strong decline in the use of imported fossil fuels but this is also strongly supported by the increased competitiveness of wind and solar PV power. Consequently, the Government's aims and the underlying economics of the power market are in sync with each other. This will continue since technological advances in renewable energy technologies, especially solar PV, are expected to continue over the next two decades. Government policies have also introduced nuclear plant projects to Turkey's power sector. As nuclear power capacity additions come in large chunks (over 1 GW capacity per generating unit, typically built in pairs), the addition of even one new nuclear plant project adds a notable addition to Turkey's total generating capacity and, as a 24/7 baseload power plant, dispatches even more electricity than its capacity share would suggest.

The most significant capacity growth is expected for solar PV and wind. In each scenario, 2040 solar PV power generation increases by at least 7 fold and wind power generation by 4 to 5 fold (Figure 1.10). As shown in Figure 1.10, wind and solar PV are estimated to produce 28% of production by 2040 in the Reference Scenario. Geothermal and biomass capacity also experience substantial growth, each tripling in the same period. Despite net capacity additions, the hydro generation share is expected to drop as a result of lowering hydrology and capacity factors until 2040. Total renewables production in 2040, including hydro, reach 47% (Reference Scenario). Generation from coal decreases to 29% in the Reference Scenario (38% in 2019). Wind will become the second largest contributor to Turkey's power generation after coal. Nuclear power generation reaches 63 TWh contributing to 11% of gross power generation in 2040. Power generation from natural gas increases by 21 TWh and provides 13% of total generation in 2040. Natural gas remains an important fuel in Turkey's power sector because there is a greater need for load following power due to a significant expansion in intermittent generation capacity.

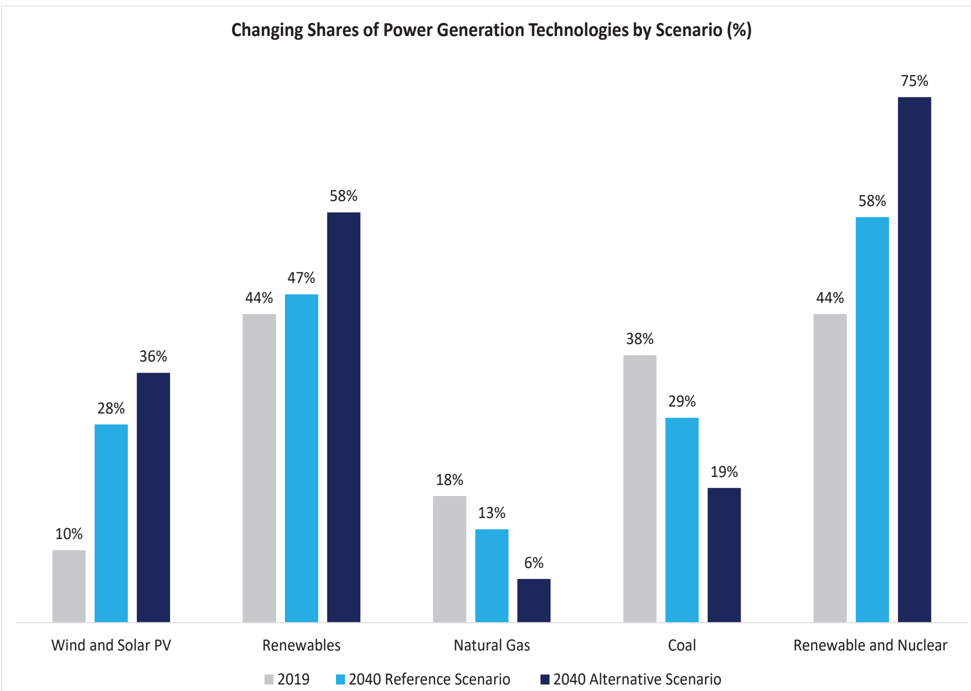
Figure 1.10 Gross Power Generation by Source and Scenario (TWh)



The Alternative Scenario assumes more challenging policy objectives, reflects further development of a competitive power market and increased uptake of clean power technologies. Generation from renewables is, in 2040, 20 TWh higher than the Reference Scenario and there is 18 TWh more generation from nuclear. Thus the share of 2040 renewable generation increases to 58% and nuclear power to 16%.

The Alternative Scenario shows that three-quarters of Turkey's power will be dispatched from essentially zero GHG emission sources (Figure 1.11). Wind will become the leading technology in terms of generation volumes. Along with the lower demand, resulting from end-use efficiency policies included in the Alternative Scenario, Turkey's use of coal in the power sector decreases by 43% compared to the Reference Scenario.

Figure 1.11 Changing Shares of Power Generation Technologies by Scenario (%)



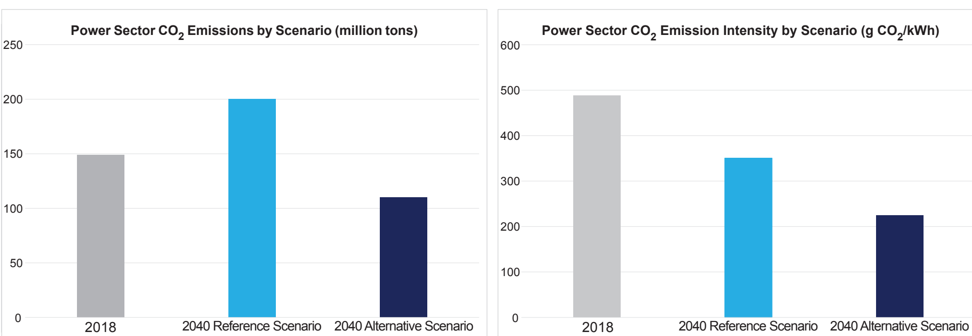
With reduced electricity demand, more nuclear power, more variable renewables and the need for more load following power or energy storage, investments in long-lived coal power plants are discouraged especially when considering the environmental sustainability of capital equipment that produces very high GHG emissions. Investors will likely consider the risk that future environment and trade policy developments, both in Turkey and Europe, could create expensive stranded assets. Added to our estimation that the LCOE of coal-fired power will be relatively expensive, the investment climate towards coal is not likely to improve.

Turkey recently took steps to introduce the green tariff where the interested consumers could opt for a special tariff to supply their power needs purely from renewable energy. Green Electricity Supply Agreements model to enable bilateral trading between renewable suppliers and consumers is also under discussion within the power market.

This market oriented model that relies on power purchase agreements (PPA) may play an important role in supporting renewable energy investments while providing consumers a tangible way to lower their emission footprints. How much such arrangements affect total renewable installed capacity or dispatch is another question that is not easy to answer.

Recent legislation also promotes hybrid power production to increase utilization of solar, wind and other renewables in fossil power plant sites under three different models: utilization of solar or geothermal thermal energy in thermal power plants, combined power production from at least one renewable energy source and another fuel at the same site and co-combustion of biomass with natural gas or coal. All these developments are in line with Turkey's efforts to benefit from the rich renewable energy potential and improve the sustainability of the developing power economy. The Alternative Scenario shows high levels of localization with renewables, local coal and nuclear representing 88% of total generation in 2040. As will be discussed in more detail below, in the Alternative Scenario, 2040 CO_2 emissions are 45% lower than in the Reference Scenario and 26% lower than the most recent current emissions data (2018). Emission intensity (gCO_2/kWh) is likewise 36% lower than in the Reference Scenario and 54% lower than current emissions data (Figure 1.12).

Figure 1.12 Power Sector CO_2 Performance by Scenario (million tons CO_2 and g CO_2/kWh)



The significant share of intermittent generation (36% of total) brings important challenges to ensure flexible and reliable operation of the power system as a whole. Natural gas power plants continue to be a critical component of the electricity system with their flexibility and efficiency merits. The existing natural gas fleet and addition of flexible gas fired units into the system are key balancers of increasing variable generation in a more competitive market. As is the case in most liberalized power markets, capacity payments are required to reflect the higher per kWh value of load-following capacity to the power market as a whole. This reflects the fact that even with lower average capacity factors, load-following plants provide offsetting variable supply and increased value for all generators and the overall power system.

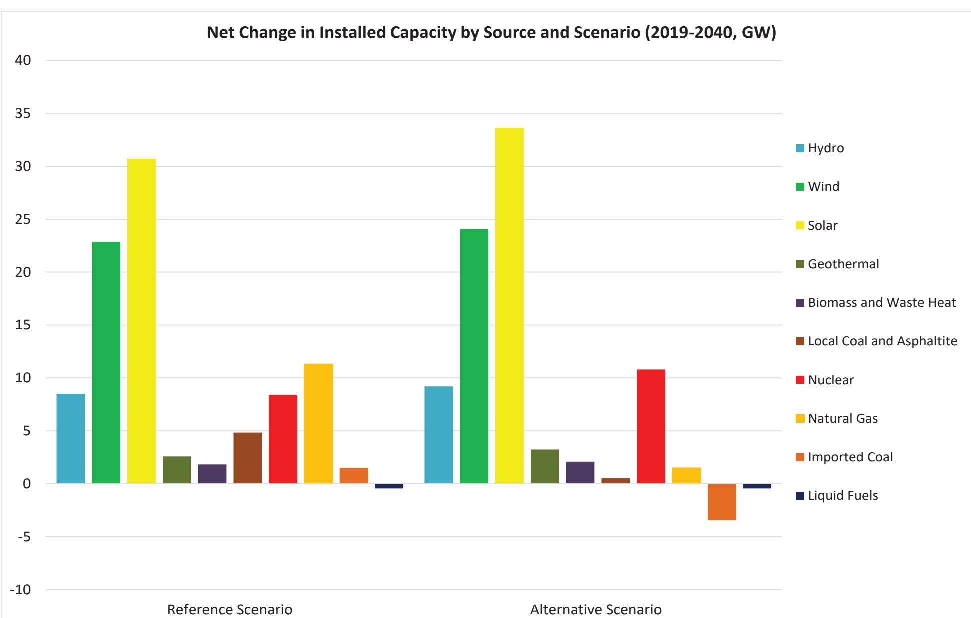
In both scenarios, pumped storage hydro plants and battery storage are also instrumental assets in addition to the prominent load following and peaker role of the gas fired fleet. However, their capacities and contribution to balancing and overall system flexibility differ among the scenarios.

1.3.4 Installed Power Capacity

Installed capacity almost doubles until 2040 in the Reference Scenario. This is only two-thirds over the past two decades. Due to reduced power demand in the Alternative Scenario, total installed capacity is 13% less than in the Reference Scenario. The two scenarios show a more dramatic difference of the distribution of types of installed capacity. Renewables capacity increases from 50% today to 61% in the Reference Scenario and rises further to 68% in the Alternative Scenario. Nuclear capacity grows from zero to 5% in the Reference Scenario and 6% in the Alternative Scenario.

In the Reference Scenario, 72% net capacity additions are from renewable energy sources, primarily solar PV (30 GW) and wind (23 GW). Solar PV becomes a leading technology in installed capacity by 2040 together with hydro and natural gas. The share of coal in total capacity decreases from 22% to 15%. Most of this decrease comes from imported coal as the local coal share only decreases from 12% to 10%. Nuclear capacity reaches over 8 GW until 2040 and corresponds to 5% of total installed capacity. Natural gas capacity also increases (Figure 1.13 and 1.14).

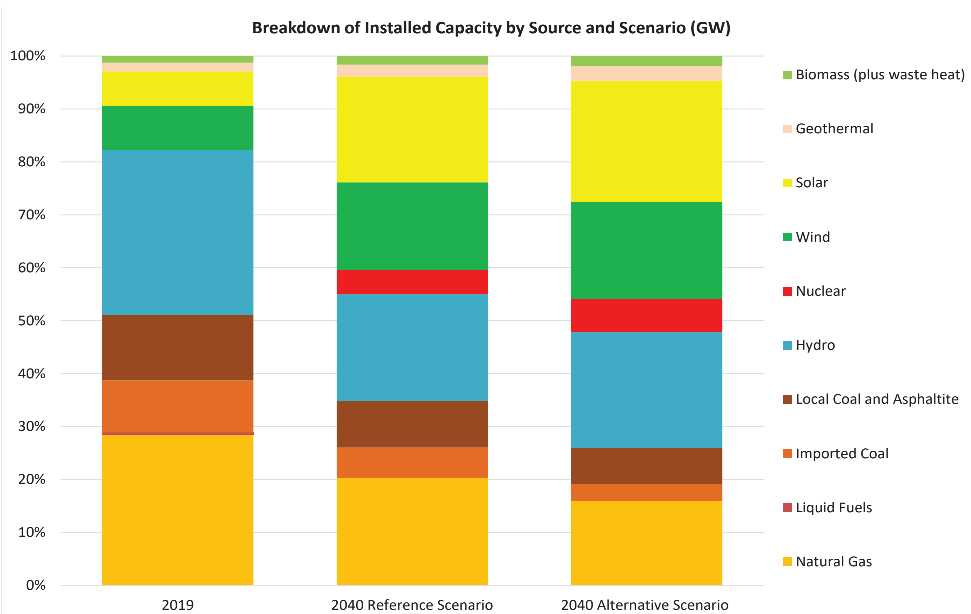
Figure 1.13 Net Change in Installed Capacity by Source and Scenario (2019-2040, GW)



In the Alternative Scenario, renewable capacity additions increase further and represent about 90% of the net increase in installed capacity. Solar PV and wind capacity additions increase by 4 GW and 2 GW over the Reference Scenario respectively. Both geothermal and biomass capacities also increase, about 1 GW combined, over the Reference Scenario.

Compared to the Reference Scenario, more of the coal fleet, particularly plants using imported coal, is also retired due to an aging fleet in relationship to wider penetration of renewable and nuclear capacities and the relative cost competitiveness and dispatchability merits of natural gas. However, the Alternative Scenario anticipates significantly less net additions of natural gas capacity (1.5 GW) compared to the Reference Scenario due to lower demand, increased nuclear capacity as a base load option and increased use of pumped hydro and battery storage for flexibility purposes (Figure 1.13 and 1.14).

Figure 1.14 Breakdown of Installed Capacity by Source and Scenario (GW)



1.3.5 Power Grid

Significant progress has been achieved in power networks particularly after the privatization of the distribution network. This has improved efficiency and service. Turkey's distribution network consists of about 1.2 million km of wire and 210 thousand transformers operating at 36 kV or lower voltage with a total capacity of 184 thousand MVA by the end of 2019. Since the finalization of the privatization tenders in 2013, the distribution sector has realized 40 billion TL investment from 2014 to 2019 (2019 TL). Turkey's transmission grid is state-operated with TEİAŞ being responsible for investments, maintenance and operation of a growing transmission grid that operates principally at 154 kV and 400 kV. It has grown to over 70,000 km of transmission lines and approximately 750 transformers (Figure 1.15).

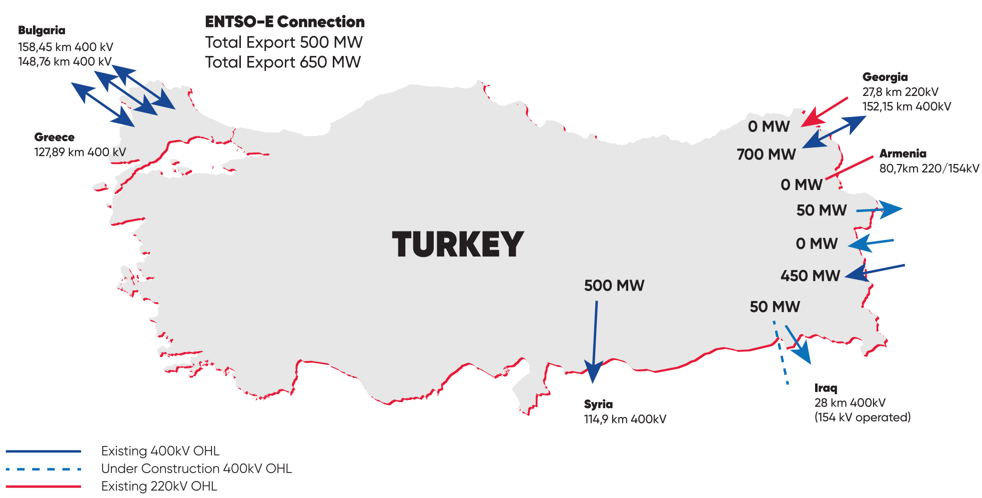
This grid establishes Turkey as one of the largest grid geographies across Europe and its wider region. As a comparison, Turkey's annual power consumption and peak demand figures correspond to about 10% of the wider European system, the ENTSO-E. Nonetheless, both transmission and distribution need to continue expansion and modernization to keep pace with Turkey's generation and demand growth, changing supply and demand patterns involving more variability, and numerous technological developments. Turkey is one of the most dynamic grid geographies in the world and as demonstrated by investment requirements and allocations in both TEO scenarios, power networks will increase their role as the backbone of Turkey's growing and developing electricity economy.

Figure 1.15 High Level Interconnected Transmission Grid of Turkey

Source: TEİAŞ, 2020

As the bedrock of Turkey's electricity system the high voltage network should continue to accommodate sustained growth in generation capacities and consumption points across the country. TEİAŞ investment planning strategies should ensure a powerful transmission system in any climatic and geographical condition. Cross-border interconnection lines are also an integral part of the transmission network and increasing cross-border capacities with neighboring markets, particularly Europe. This has long been a priority for Turkey. Since 2010, the TEİAŞ system has been synchronously operated with the European grid, ENTSO-E via three lines, each at 400 kV. The ENTSO-E connection allows for 500 MW of total export and 600 MW of total import capacity. On Turkey's Eastern side, none of the neighboring countries satisfy the standard conditions of ENTSO-E operations and synchronous parallel system operation is not possible. Trade via these lines can only be managed using unit dedication or island methods (Figure 1.16). Turkey has been a net power exporter in recent years although compared to Turkey's domestic electricity demand, imports or exports have been small. For example, net exports corresponded to less than 1% of domestic demand in 2017 through 2019. Expansion of interconnector capacities with Bulgaria and Greece would create market coupling and other cooperation opportunities with other European power sectors and the potential to increase Turkey's electric exports.

Figure 1.16 Existing and Planned Interconnections of Turkey



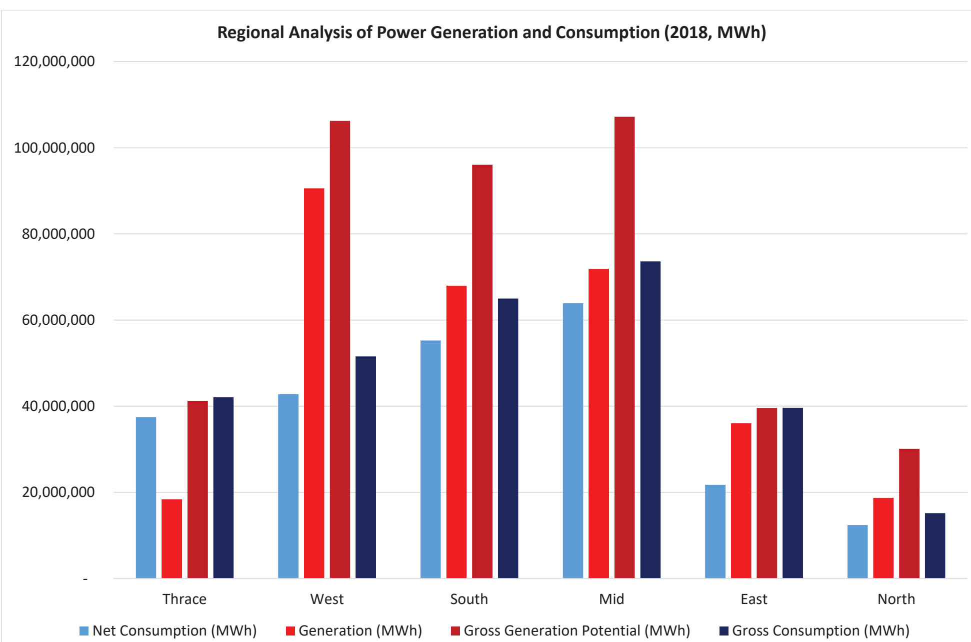
Source: TEİAŞ, 2020

The technological characteristics and regional distribution of Turkey's installed capacity will be critical for improving and maintaining supply security and increasing flexibility. Despite significant expansion of power generation capacity and grids so far, a number of bottlenecks already exist to match generation and demand centers, particularly at the transmission system level. This becomes a more challenging task with a higher share of variable and distributed power generation.

IICEC analysis based on clustering 81 provinces into 6 main regions that reflect a grouped representation of generation and demand patterns by a zonal perspective provides insights into locational mismatches between generation and consumption. Reflecting Turkey's economic centers and demographics, the largest power demand is in the Northwest, especially Istanbul, neighboring cities, the wider Marmara Region and Thrace. However, the distribution of Turkey's power generation is not similarly concentrated in these regions requiring significant power transfer from other parts of Turkey (Figure 1.17).

Supplying the needs of these high demand regions has been a major concern for some time. To complicate matters further, while there is a significant amount of natural gas-fired capacity in the high demand regions, due to lowering dispatch of natural gas as a result of current market conditions, natural gas power generation in the high demand centers does not reflect its power generation capacity creating a greater need for electricity import from less populated regions.

Figure 1.17 Regional Analysis of Power Generation and Consumption (2018, MWh)

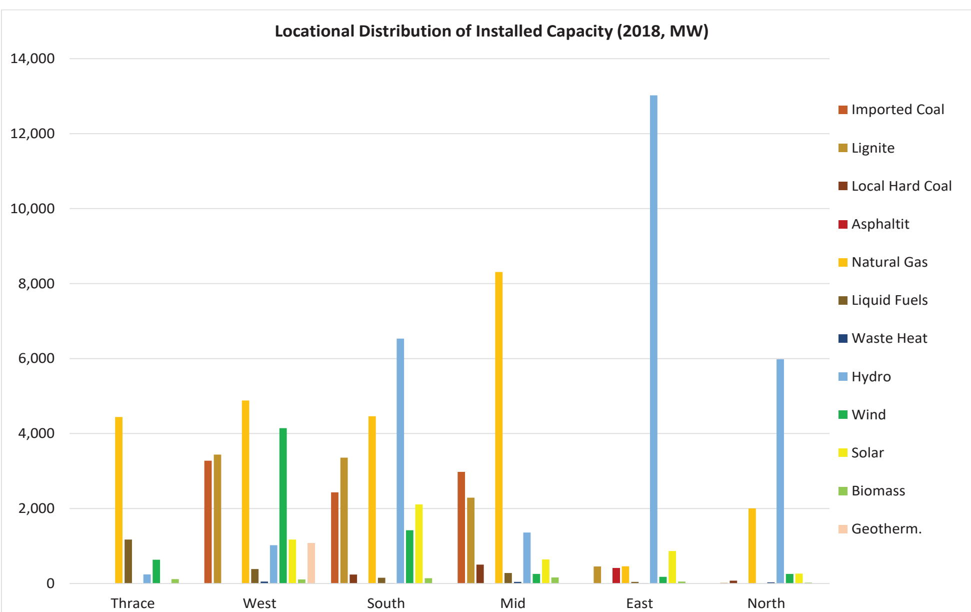


Note: Net consumption is in terms of invoiced consumption.

The distribution of installed capacities also differs significantly across these zones. As shown in Figure 1.18, the majority of total hydro installed capacity is in the East (46% in 2018) including Turkey's largest hydro plants and reservoirs. Wind capacity has also developed mainly in the West and South (81% in 2018) due to more favorable wind yields. Likewise, solar capacity has been mostly growing in West, South and central regions (78% in 2018), largely through small scale and distributed PV units.

These trends in renewable energy growth pose a further challenge in managing regional supplies with demands while providing reliable service regardless of shifting power inputs that can vary for a variety of reasons including breakdowns, variations in wind and solar resources and other factors. The transmission system also has to accommodate variations in power demand that varies significantly in all time gradients; hourly, daily and seasonally. Eliminating transmission grid bottlenecks is essential for sustaining supply security and achieving a level of service that goes beyond just maintaining adequate generation capacity. Raising reliability and flexibility requires continued generation planning and investment to accommodate more variable generation profiles. This will add to the existing challenges and requires a long term perspective.

Figure 1.18 Locational Distribution of Installed Capacity (2018, MW)



In addition to the existing geographical mismatch of distribution supply and end-user demand, both TEO scenarios show that this will continue and require further grid upgrades. However, there are some ameliorating factors, for example, solar capacity that is expected to also expand in Eastern and Central Turkey with favorable irradiation characteristics rather than be heavily concentrated in the Mid, West and South. Natural gas plants across the system should improve their dispatch in a more competitive and cost-based market framework that reflects their value as flexible resources providing power that follows demand. In both scenarios, grid planning with capacity expansion enables matching with power demand and capacity growth. This requires increased transmission investments in an increasingly fragmented and diversified landscape of generation sites and puts a premium on the flexible operation of the power grid and elimination of grid bottlenecks. As will be discussed below, it becomes a reason why, in the Alternative Scenario, with higher levels of variable renewable power (44% of total installed capacity in 2040) and increased end-use energy efficiency, investments shift from power generation to further grid development. These include a more technology and efficiency oriented approach that also involves Turkey's fully privatized distribution network. Private distribution operators will also need to make sustained investments. This shows that expanding the power sector with a system approach is essential for benefitting from the gains possible from increased clean and local power generation as well as advanced data and information technologies while addressing potential cybersecurity concerns in a more digitalized and electrified energy economy.

1.3.6 Growing Need for Power System Flexibility

The flexibility of a power system refers to its ability to keep uninterrupted services under any swings in demand or supply. It is required across a range of different timescales from hours to seasons and different flexibility assets that offer varying capabilities. Shorter flexibility timescales are needed to provide system stability and balancing related services. Solutions to serve in longer timescales should deliver measures to respond to seasonal supply and demand imbalances.

Two key challenges arising from increasing integration of intermittent generation are variability and uncertainty. Increasing penetration of variable generation requires that system operation should address the overall system load minus the varying output from wind and solar generation (net load). The net load considerations should reflect locational balancing in order to match locational loads and overall load profile of the system with available intermittent capacity. Flexibility needs are increasing due to the intermittent nature of wind and solar generation but are also affected by changing demand profiles. The electrifying energy economy will add complexity with less predictable load patterns. For instance, the seasonal variability associated with Turkey's heating and cooling demands is likely to increase. Electric vehicles could alter demand patterns at locations with high BEV penetration rates. BEV charging patterns are now unknown and have the potential to create new load peaks in particularareas.

In the longer term, the use of hydrogen as an energy carrier, in addition to its current use by the industrial sector for chemical processes, would provide new options for coupling the power, heat and transport sectors adding new requirements for system flexibility. These factors all suggest that long-term system-wide planning will be needed to balance supply and demand in all timescales, as well as ensuring secure, reliable and flexible expansion of the grid as the backbone of Turkey's electricity economy.

Although conventional sources of flexibility in the form of power plants, notably the flexible gas fired fleets and hydro power plants, have been traditionally the main tools for load balancing world-wide, emergence of more variable generation and demand necessitates a wider set of policy mechanisms and technologies such as electricity storage, demand side participation into the power market operations, maintaining firm and flexible generation capacities, and more emphasis on grid resilience and stability.

Currently, thermal power plants with load following capabilities provide the bulk of the flexibility resources required by many electricity systems globally. Conventional power plants are presently the principal source of system flexibility in modern power systems. Flexible power plant operation can take many forms including the more flexible use of existing conventional power plants through quickly changing plant output, starting and stopping more swiftly or reducing plant output without causing a shutdown. Changes to operational practices require relatively lower capital investment levels and are supported by digitalization, upgraded data collection and real-time monitoring. Flexibility retrofit investments could entail higher investment levels. However, they would permit existing assets to meet emerging flexibility requirements. Storing electricity and converting excess electricity to potential or chemical energy (to be used to generate electricity when needed), are also important strategies.

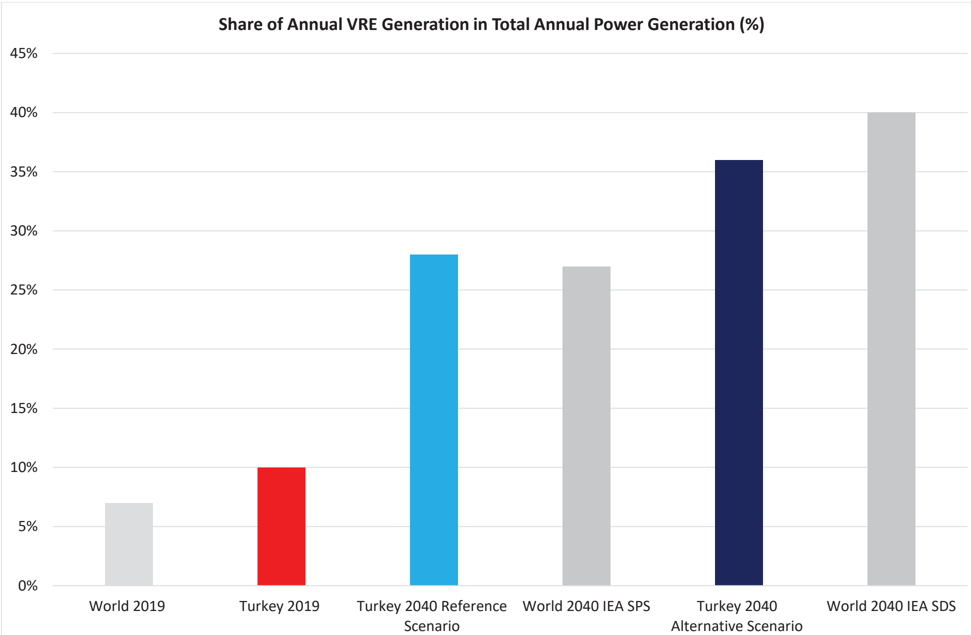
Pumped storage hydro (PSH) is a traditionally established power storage technology in regions where water inflow regimes and untapped potential is supportive. Turkey is relatively well endowed in potential pumped storage which is fortunate because of all energy storage technologies, it is well established, efficient and cost effective. Nonetheless, new flexibility sources will be needed to respond to the changing dynamics of the power system. Battery storage is an important emerging electricity storage technology for the power sector and can provide relatively efficient balancing needs at the shorter time-scales. This technology is supported by large global R&D and is expected to result in cost reduction with increased global demonstration and deployment. Hydrogen is often discussed, especially to provide longer term chemical storage with electrolyzers and fuel cells or electrolyzers and combustion turbines to convert electricity into hydrogen and then back into electricity. This approach faces cost challenges, partly because of thermodynamic losses that consume most of the electricity used to produce the hydrogen and then convert it back again to electricity as discussed in Chapter 6 (The Energy Transition). Compared to PSH or batteries, hydrogen storage is relatively inefficient. Synthetic fuels may also be used instead of hydrogen as the energy storage medium. The thermodynamic losses are similar although the net of storage and other costs might be lower.

The IEA categorizes variable renewable energy (VRE) integration in six steps from a marginal contribution of intermittent generation to a system dominated by variable generation outputs across different timescales (IEA, 2020a). Although the flexibility related impacts and requirements depend on country specific technical characteristics such as system size, available interconnections with neighboring markets, composition of the available generation capacity, these steps set out how an increasingly intermittent generation mix can be balanced for maintaining secure and reliable operation of evolving power systems.

- Phase 1: VRE having no more than a few % of the annual demand. This will not bring any noticeable impact to the system.
- Phase 2: VRE having 3-10% share in total annual generation. This situation has minor to moderate effect on the system and may be handled with changes in operating patterns.
- Phase 3: VRE share exceeding 10% of total annual generation. It causes greater variability of net load and introduces new power flow patterns. System flexibility becomes an important consideration for integrating more VRE.
- Phase 4: VRE makes up almost all generation in some periods. It requires power supply robustness under high VRE generation conditions. Advanced technical options and legislative changes to the market framework would be required. This phase corresponds to a 25-50% annual intermittent generation share.
- Phase 5: Increasing periods of VRE generation surplus or deficit on a daily and weekly basis causing longer periods of energy surplus or deficit in the whole system. The overall flexibility of the system should be enhanced including new electricity consumers such as transport and heating.
- Phase 6: Monthly or seasonal surplus or deficit of VRE supply. This requires seasonal storage capabilities. The excess electricity may be converted to synthetic fuels or hydrogen and stored seasonally.

Enhancing the system flexibility in a cost-effective, reliable and environmentally sound manner requires power system transition towards higher phases of system integration. Policy and market modifications and regulatory frameworks should ensure that complementary solutions including battery storage systems, distributed power, smart grids and demand options develop in an increasingly dynamic power system to timely deliver flexibility services. With its favorable resource base, energy policy and power market industry orientations, Turkey already achieved a larger share of wind and solar PV generation combined than the global average. Variable renewables increase from 11% in 2019 to 28% by 2040 in the Reference Scenario and to 36% by 2040 in the Alternative Scenario (Figure 1.19). Maintaining a secure and reliable operation of the power grid and the overall electricity system flexibility will become increasingly more challenging for Turkey, similar to the current experience in some European markets. As Turkey moves from Phase 3 onwards, complementing flexibility resources and tools will be needed to ensure system-wide flexibility of its growing power system. This can be achieved by a multi-faceted approach including accommodating market mechanisms in order to permit secure and flexible operation of the power system while meeting increasingly variable supply and demand patterns.

Figure 1.19 Share of Annual VRE Generation in Total Annual Power Generation (%)[8]



The two primary assets to achieve improved flexibility of the Turkish power system are flexible natural gas fired power plants and electricity storage technologies. These technologies pose different technical and economic merits and value propositions in serving as flexibility sources (Table 1.2). Pumped storage power plants are established cost-effective technologies but depend on suitable locations and high upfront capital spending while battery storage solutions offer modularity and scalability in installments. In both scenarios, these technologies play an increasing role to serve in an increasingly variable supply and demand environment. Their respective capacities and roles differ between the Scenarios.

Even though new solutions for short-term flexibility such as battery storage are advancing, most electricity systems still rely on flexible natural gas power plants that can rapidly support power generation both up and down, a role that underlines one of the significant roles that natural gas plays in energy transitions. Absent any particular arrangements, most of the gas power units could suffer a loss if they are utilized only from time to time to assist the system in adjusting to needs for more or less generation. Strong growth in intermittent renewables in both scenarios require maintaining availability of efficient natural gas plants with strong ramp up capabilities for balancing the increasing variability and uncertainty in output from wind and solar PV units. Flexible gas fired units are currently in a tough survival battle

[8] SPS is the IEA Stated Policies Scenario and SDS is the IEA Sustainable Development Scenario

financially. The existing capacity payment mechanisms supporting the CCGT investments can only help marginally since some of the high efficiency power plants are still under a debt service burden. In addition, the gas-fired power plants have exchange rate exposure limiting their ability for long-term price and volume agreements. In addition, fast-ramping and more frequent cycle operations increase their maintenance and operating costs per kWh. However, maintaining reliable operation of Turkey's flexible CCGT can promise the most significant contribution to a more flexible power system for Turkey, a practice in many electricity systems worldwide. This also avoids a significant saving from capital spending in other hardware solutions to meet increasing flexibility requirements at the system level. In both scenarios, load following CCGT capacities will be the largest contributor of the flexibility resources through 2040. The Alternative Scenario shows about 12 GW less CCGT capacity (30% lower) compared to the Reference Scenario until 2040 but with higher value contribution from flexible capacities that reflect larger hourly and daily variations in supply due to the higher share of VRE resources. In addition to capacity payments to guarantee availability of the flexible peaker gas fleet, power pricing regimes in short term markets should also reflect the value of these flexible capacities.

Battery storage is the fastest growing source of power system flexibility today but this is measured from a limited current role. Their modularity and simpler design allow installments where needed. They can provide fast response and help to balance the network through the provision of various remunerated services. They can also increase the value of variable renewables by enabling the electricity produced from solar and wind to be stored and distributed when prices are higher. Nonetheless, battery storage technologies need to deliver substantial cost reductions to be deployed at a wider commercial scale. Other storage technologies such as compressed air energy storage (CAES), flywheels, supercapacitors and superconducting magnetic storage are only at the early stages of development before being ready for demonstration and commercialization. Depending on global technology advancements, these technologies could be instrumental in addressing flexibility challenges for the Turkish power system but the uptake of these technologies would likely only occur near the end of TEO's projection horizon. The Reference Scenario adds 5.5 GW battery storage capacity into the system through 2040. Significant expansion of the battery storage capacity is projected for the Alternative Scenario where battery storage becomes the second largest flexibility tool in terms of total installment of capacities after flexible CCGTs. The additions in the Alternative Scenario reflect realization of multiple tasks towards wide deployment of battery storage including a dynamic legislative framework to reflect technology and market developments and integrated planning to drive and allocate battery storage investments mainly at grid scale. Compared to the Reference Scenario, behind-the-meter deployments are 16% higher and driven by more than 3 GW more rooftop PV capacity in a more decentralized power system compared to the Reference Scenario until 2040. Battery storage systems are not suitable for seasonal storage requirements. Nonetheless, these technologies play an important flexibility role for the short-term timescales.

PSH is the predominant energy storage technology worldwide with around 95% of global installed power storage capacity. Turkey, with an installed hydro capacity already exceeding 30 GW, has a good potential to develop a number of PSH plants in some of the important water reservoirs. Despite several studies to launch an expanding PSH plants program starting from demonstration projects over the last decade, there is no PSH plant in operation yet. Currently, a few projects are in development stages. The construction works for Turkey's first PSH plant would commerce in the next few years for a capacity range of 1-1.5 GW. A number of other projects at different locations have also been identified for additional PSH projects. Depending on future needs and economics, Turkey would ramp the total PSH capacity up to 10 GW compared to additions of 1.5 GW in the Reference Scenario and 2.7 GW in the Alternative Scenario. In selecting from potential candidates, locational proximities to load centers and main consumption points, key transmission lines bridging power flows from East to West, concentrated intermittent generation regions as well as nuclear power plant sites are key considerations. As these plants would require high upfront costs and long lead times, innovative remuneration options would be considered. Cost and benefit evaluations should reflect the value proposition for the required flexibility services. Supported by legislative and technology developments including incentives in the Alternative Scenario, the scalable and portable nature of battery technologies provide economic opportunities compared to the high investment costs of PSH options.

Table 1.2 Comparative Assessment of Major Technologies for Balancing Services and Flexibility

	Battery Storage	Pumped Storage Hydro	Flexible Natural Gas Peakers
Location Dependency	●	○	●
Electricity need from the grid	○	○	●
Unit investment cost	◑	◔	◕
Construction duration	●	○	◔
Scalability	●	○	◔

System level planning with a long term perspective to accommodate rapid growth in variable generation will be one of the major tasks for the system operator, TEİAŞ. Enforcing the grid capabilities will also require continuous improvements in the distribution networks that expand and modernize to serve a growing population and more electrified energy services. In both scenarios, future investment and planning frameworks for the distribution systems should well prepare for accommodating continuous growth in power flows arising from distributed renewables such as rooftop PV and increasingly variable loads due to heating, cooling and electric mobility at low, medium and high voltage levels. These investments should also reflect the growth potential from distributed energy resources with flexibility capabilities.

Turkey's strategies to manage flexible loads by developing effective demand side management platforms and realizing a smart grid deployment program that includes a majority of the grid users will be instrumental in overall load balancing to meet system flexibility requirements. Recent examples in various power markets also suggest that variable renewables power plants can also be required to provide flexibility services.

The design of the power market should reward each flexibility source based on value merits for their contributions to a secure and flexible power system. Performing analysis at system level requires development of value-based cost metrics for generation technologies as shown in cost discussions below. The market mechanism should also enable market participants in generation, grids and the demand side to act in a coordinated way.

1.3.7 Investments

In order to meet the increasing demand for electricity in secure, efficient and sustainable conditions, a significant amount of investment will be required in the electricity system. This is in line with world-wide trends, for example, the IEA's 2019 *World Energy Outlook* projects that 50% of total world-wide energy investment will be in the power sector (IEA, 2019a). While the overall level of capital spending in the power sector is similar between each TEO Scenario, the spending among particular types of investments differs more significantly.

In the Reference Scenario, the amount of investment in the electricity sector is $174 billion by 2040. Of this, 72% is for power generation capacity, 8% for electricity storage, and 20% for the grid including load-leveling information systems (metering and digitalization) (Figure 1.20). Among power generation, renewable energy has the highest share at 55%. Wind and solar PV represents 80% of total renewables based capacity additions but they contribute to half of total renewable generation investments due to significantly lower capital spending required per MW installation compared to the capital costs of hydro, geothermal and biomass. Nuclear accounts for 20% of the total power sector investment (Figure 1.21).

In the Alternative Scenario, the cumulative investment over 2020-2040 is $188 billion ($2019), only 8% higher than the Reference Scenario mainly due to more investment required on grids and flexibility oriented technologies to accommodate a larger share of intermittent renewables (Figure 1.20). Investments for power generation represents 68% of total investments compared to 72% in the Reference Scenario. Each scenario estimates an average annual investment requirement of $6 billion (2019$) into power generation until 2040. Grid investments increase substantially over the Reference Scenario. They represent 22% of the total power sector investment. In the Alternative Scenario, compared to the Reference Scenario, battery storage investments increase by 40%, transmission and distribution investments increase by 20% and renewable energy investments increase by 9%. Coal investments are cut almost by 60% from the Reference Scenario and natural gas declines by 80%. Nuclear investments increase by 25% but considering that these plants are anticipated with a long operational life compared to many other generation technologies (at least 60 years with current technology), this difference would pay off in future years with additional benefits to a sustained decrease in GHG emissions beyond 2040 (Figure 1.21).

Figure 1.20 Power Sector Investment by Sector and Scenario (2019-2040, 2019$ billion)

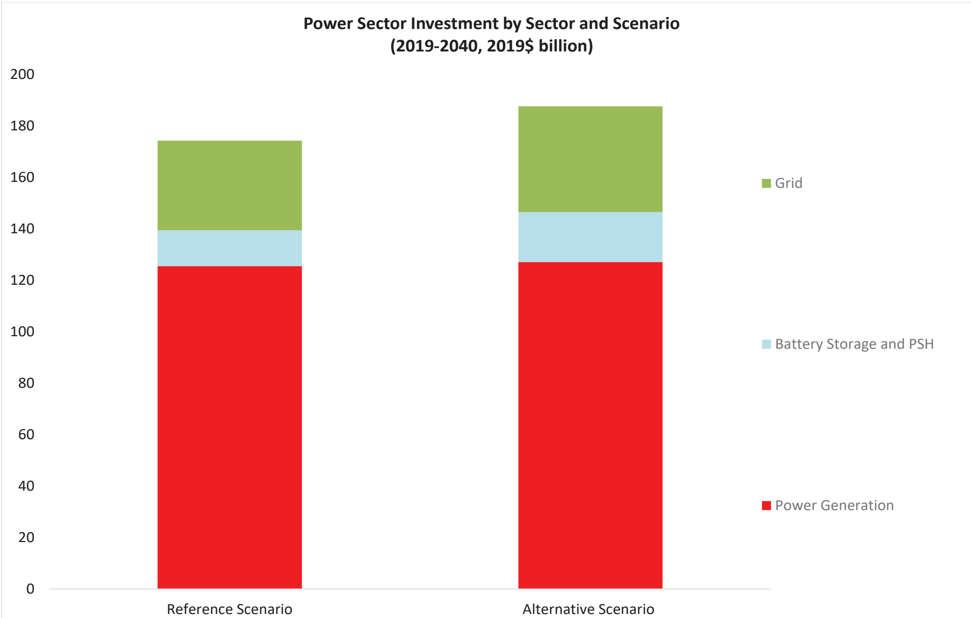
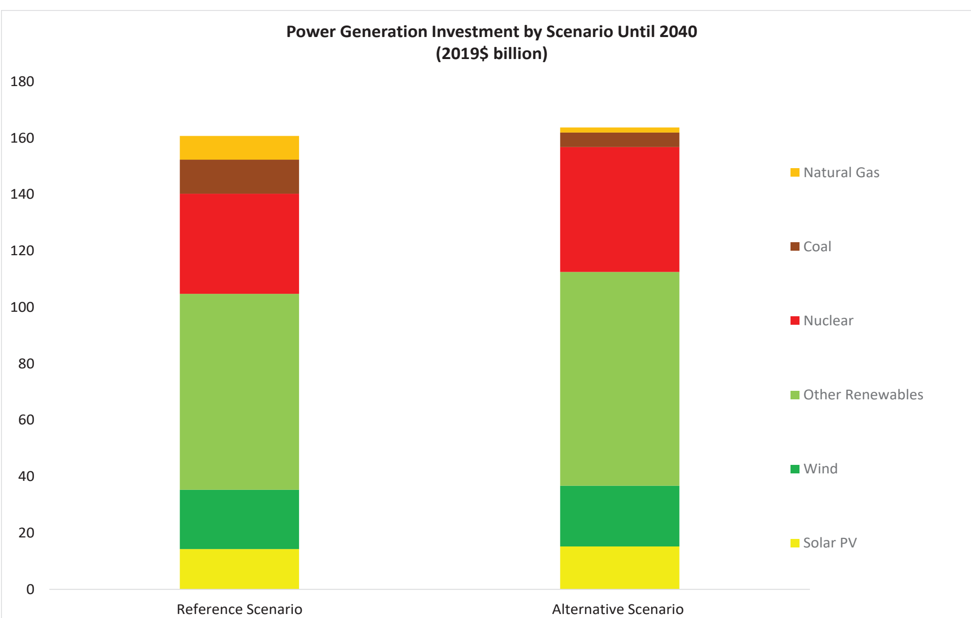


Figure 1.21 Power Generation Cumulative Investment by Scenario until 2040 (2019$ billion)



1.3.8 Competitiveness of Power Generation Technologies

The factors that have been discussed (more intermittent renewables, load following capacity, energy storage and methods to manage demand profiles) will change Turkey's power sector as it continues to ensure supply security and system reliability. At the same time, Turkey's power sector will likely continue its transition to cost-reflective electricity prices and a more liberalized market structure where capital formation is determined in the marketplace. As this proceeds, a comparative cost and performance assessment of power generation technologies will more directly affect their uptake in the market.

The levelized cost of energy (LCOE) is the most commonly used metric for this assessment. In addition to LCOE evaluations, consideration of new metrics that reflect system level costs is essential to realistically estimate technology uptake. The value-adjusted LCOE (VALCOE) considers generation costs as well as the value of that generation at the power system level. Since Turkey follows the "shallow connection policies" of most industrial power markets (where a power provider need only pay to connect the plant to the nearest grid connection point), the network integration costs are borne by the grid operator. As is common practice, these investments do not affect the market economics of dispatching power sources. Consequently, VALCOE does not include them. Nor does VALCOE include environmental externalities apart from the fact that the costs of meeting all established environmental regulations are already included in the plant investment and operational costs included in the LCOE estimates.[9] Because of these features, VALCOE has become an important metric to make competitive assessments at the system level, especially with increasing variability of power generation and demand.

Table 1.3 Key Cost Figures for Power Generation Technologies

2019$	CAPEX ($/kW)		LCOE ($/MWh)		VALCOE ($/MWh) Reference Scenario	VALCOE ($/MWh) Alternative Scenario
	2019	2040	2019	2040	2040	2040
Nuclear	4800	4000	90-95	80-85	80-85	80-85
Hard Coal	1300	1300	50-55	55-60	55-60	55-60
Lignite	1700	1700	70-75	70-75	70-75	70-75
Gas CCGT	750	750	50-55	55-60	50-55	45-50
Hydro	1700	1700	75-80	80-85	75-80	75-80
Solar PV	550	400	50-55	40-45	55-60	50-55
Wind onshore	950	900	45-50	45-50	50-55	50-55
Wind offshore	3000	2400	80-85	65-70	85-90	75-80
Geothermal	3750	3500	100-110	95-105	100-110	95-105
Biomass	3200-5500	3200-5500	105-125	105-125	105-125	105-125

[9] Nonetheless, VALCOE estimates are easily integrated into policy analyses that reflect all social costs whether or not current regulations internalize full emission or other externalities.

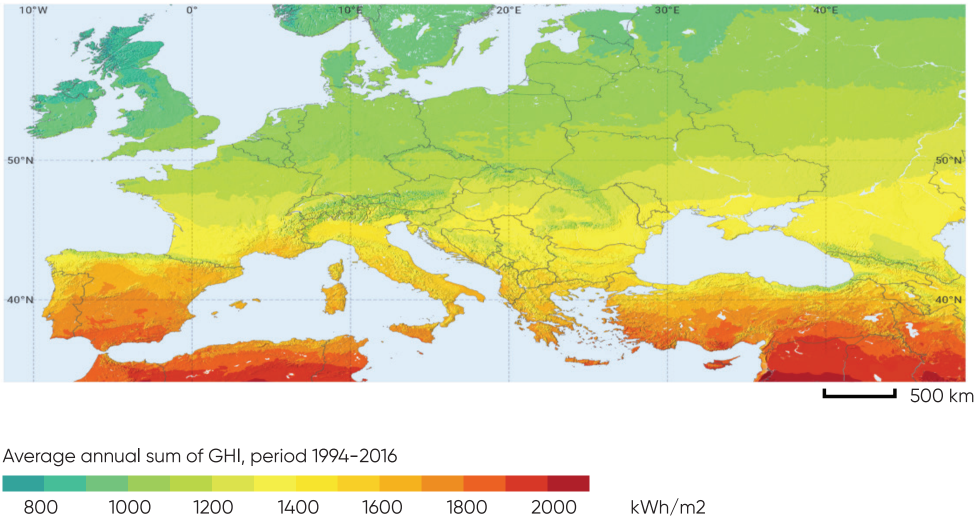
Key cost estimates for power generation technologies are presented in Table 1.3. Major CAPEX declines are expected in solar PV, offshore wind and possibly nuclear technologies. Solar PV becomes the most cost-competitive power generation technology by the late 2020s. Turkey's favorable solar irradiation characteristics that provides larger capacity factors, on average, than many of the other European countries will drive cost-effective investments together with ongoing technology learning (Figure 1.22). Onshore wind is also expected to enjoy further cost and performance improvements. However, these are largely offset by the use of the best wind sites forcing onshore wind expansion to sites that typically have less wind yield. Nonetheless, onshore wind continues to be one of the most competitive technologies supported by technology advancements.

While now very expensive, offshore wind is expected to become one of the most competitive technologies due to significant CAPEX improvements and productivity gains and the ability to use good wind regimes by 2040. The International Energy Agency projects a significant penetration of offshore wind in the EU by 2040 especially in Northern Europe with sites, for example, in the North Sea and relatively poor solar radiation and limited land availability for solar making offshore wind competitive with solar PV (IEA, 2019b). For Turkey, however, by 2040, offshore wind is expected to have a higher LCOE than onshore wind and an especially higher LCOE than solar PV[10] making a high level of Turkish offshore wind investment by 2040 less likely. Nonetheless, a progressive pathway in onshore wind resource utilization together with cost reductions would yield in offshore wind installments starting from towards 2030 if backed by support mechanisms reflecting their higher LCOE. Offshore wind investments would also aid in regional power security in the Thrace and Marmara Regions given the high-demand centers and limited indigenous resources in these regions.

Hydropower measured by LCOE will become more expensive and join the most expensive power technologies except for geothermal and biomass due to the difficulty to expand large reservoir areas and lowering precipitation and hydrology expectations. VALCOE estimates for hydropower are lower, due to hydropower's load following abilities, but hydropower still remains among the costliest power technologies even at the system level. Power generation from geothermal and biomass is more sensitive than solar and wind energy to energy resource quality and other characteristics. For both geothermal and biomass, achieving average VALCOE levels below $100/MWh before 2040 is not anticipated unless there are major technology breakthroughs. Fossil fuels' LCOEs are very sensitive to fuel prices, especially for natural gas and hard coal, where Turkey is exposed to global and regional fuel price developments. Both technologies become less cost competitive when compared to solar PV and onshore wind in terms of LCOE. Due to technicalities impacting fuel and other operational costs, LCOE of lignite remains higher than many other technologies, most notably solar PV and wind.

[10] The VALCOE estimates for offshore wind are also expected to be higher than for onshore wind and an especially higher than for solar PV.

Figure 1.22 Global Horizontal Irradiation in Europe



Source: SOLARGIS

Together with cost improvements in nuclear technology and reduction of FOAK costs, there are strong prospects that nuclear energy would become a more cost competitive technology, largely on par with hydro and close to lignite by 2040. The cost comparison with lignite and even hard coal is significant considering the potential risk that coal plant investments could be devalued by future dispatching restrictions. These could come about either because future Turkish policies might explicitly price carbon emissions or because of EU tariffs that would scale with Turkey's carbon emissions. For example, it is estimated that a carbon pricing range of 20-30 $/t could increase the LCOE for new coal plants by $17-33/MWh. This would be a very small carbon charge compared to the carbon prices (whether explicit prices or "shadow" prices[11]) that would be needed to achieve Paris Agreement level global climate goals. Most models show that carbon prices would be in excess of $100/t (for example, IEA 2019a) for this objective. Even without an explicit Turkish carbon pricing policy, EU tariffs could essentially produce a similar economic outcome as they aim to force trading partners to engage in similar GHG reduction policies as the EU. Investors could anticipate a likelihood of a future "shadow price" of carbon that would strongly discourage coal plant investments and increase the rationale for additional baseload nuclear power.

[11] Shadow prices reflect the effective price that would otherwise be necessary to incurred to comply with regulations or other incentives to reduce carbon emissions.

Due to their ability to load follow, the VALCOE of natural gas fired power generation is lower than their LCOE. Existing gas fired capacity with high efficiency characteristics is a key element of the power system, particularly in the Alternative Scenario where the generation share of variable renewables is over 30% in the years approaching 2040. Reservoir hydro power plants also provide lower VALCOE figures than their LCOE estimates by contributing to system balancing. The intermittent nature of solar PV and wind increases the VALCOE of these technologies. Nonetheless, wind and solar remain very competitive. Regardless of the relatively high cost of additional hydro, Turkey's substantial hydro capacity will remain important for load balancing although there will remain concerns about future dry years. The VALCOE figure for nuclear power generation would not be significantly different than its LCOE as they will likely continue to operate as base load plants. Even if some plants did load follow, the relatively low share of fuel costs and unchanged operating costs would not provide cost reduction when operating at lower capacity factors.

VALCOE evaluations depend on several factors about shaping of the power system as a whole, in particular the evolution of transmission and distribution grids. In addition to deployment and utilization of pumped storage hydro and battery storage technologies, demand-side response is also instrumental to match variable supplies and demand variations.

The competitiveness of power generation technologies is influenced by several factors driven by energy policy objectives, power industry structure and power economics. As mentioned in the context of nuclear power, pricing carbon emissions would alter the uptake of these technologies as those additional costs or savings would add new economic factors beyond LCOE and VALCOE, adversely affecting coal and positively affecting renewables and nuclear.

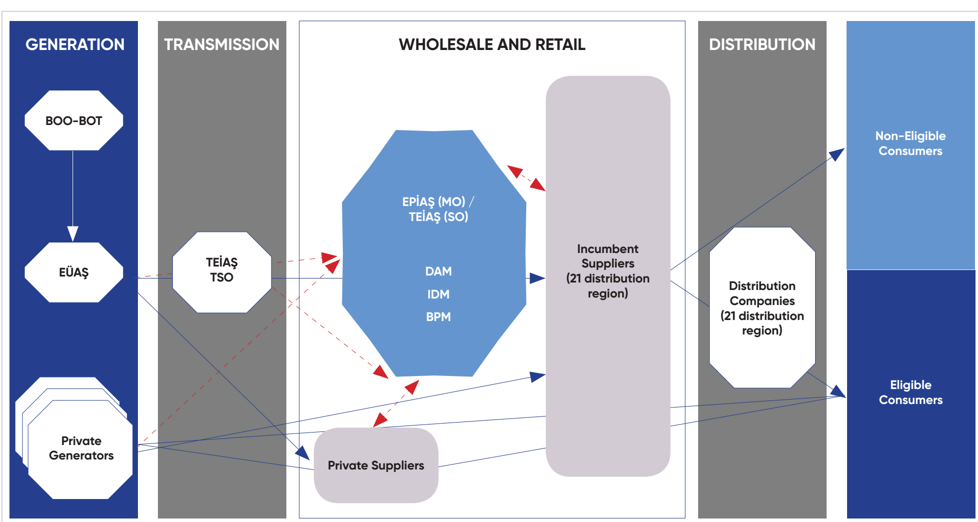
The LCOE and VALCOE figures presented in Table 1.3 are based on technology-specific capital cost estimates that considers factors such as potential offtake arrangements and other major incentives specific to any technology, and technology-specific risk-return considerations by the power sector investors and financing community. They also assume a predictable power market with cost-based pricing and competitive financing costs for all technologies. In reality, however, financing costs will not be competitive for all technologies. As mentioned, future risks associated with coal's high carbon emissions per kWh could increase coal plant financing costs. Nuclear plant financing costs are very high due to the risks of cost overruns and construction delays. Consequently, nuclear plant construction typically involves government support. In the case of Turkey's Akkuyu nuclear power plant project, construction risk is borne by the vendor, Rosatom, due to the innovative build, own and operate model employed for this project. IICEC assumes that future nuclear plant projects will be more conventional purchase models for which the estimated LCOE reflects the cost of nuclear power to the grid rather than a power purchasing agreement.

1.3.9 Market Development

The Turkish power sector has been undergoing transition from a State owned and operated sector towards a liberalized power market with greater participation of private companies. Thus far, market reforms have provided the benefit of competition and efficiency in the construction and operation of Turkey's installed power generation capacity and expansion and upgrade of distribution networks. The reforms stem from the 2001 enactment of Electricity Market Law (EML) establishing the regulatory authority, EMRA, and other institutions. EML's regulatory framework, as well as major strategies and policies, have gone through many changes in the last two decades reflecting changing market dynamics and greater emphasis on providing more reliable and affordable power for Turkey's growing economy and electricity consumers.

The current market structure entails fully regulated transmission and distribution grids and increasingly competitive generation, wholesale and retail supply segments. TEİAŞ and EPİAŞ, the Energy Exchange, are responsible for system and market operation respectively. 21 distribution companies and incumbent suppliers operate in distribution regions. In the generation market, largest player is EÜAŞ, the state owned generator with about 20% share. More than 950 companies are active in the generation market. More than a hundred suppliers operate to serve consumers out of the regulated tariff regime. Figure 1.23 presents both physical and financial flows in the current market structure.

Figure 1.23 Players and Flows in the Power Market Value Chain



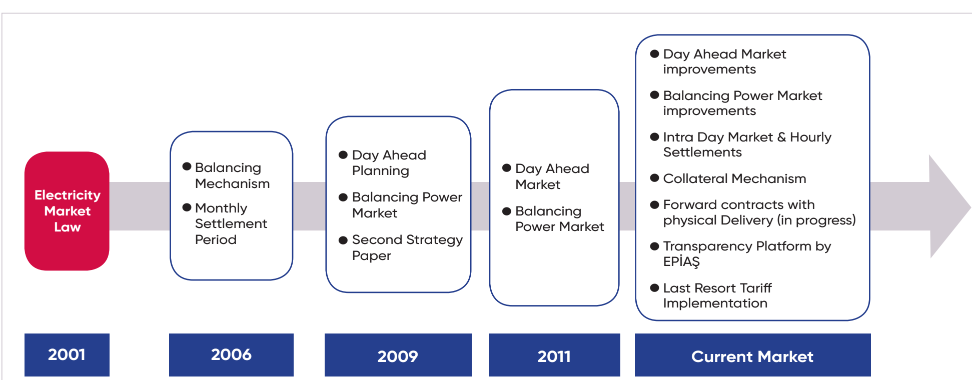
Overall, substantial progress has been achieved in increasing the private sector role in the electricity economy. The share of privately owned and operated power generation, the independent power producers, has reached to two thirds of total installed capacity. This has been accomplished through privatizations of a large portion of existing generation and new power plant investments. In addition, all power distribution has been privatized.

The essence of the market framework defined in 2001 was a substantial shift from "competition for the market" to "competition in the market", particularly for power generation investments and operations. Turkey had pursued the privatization of power sector back in 1980 and 1990s to attract power sector investments by utilizing four different models providing a power purchase guarantee and full privatization: build, own, operate (BOO) contracts, transfer of operating rights (TOOR), build, own, transfer (BOT) and full privatization. Some of these models were abandoned as effective mechanisms to achieve the desired priorities for energy security, affordability and system sustainability.

A new regulatory framework from 2001 has secured over $100 billion of power investments, mostly from the private sector. It is estimated that about $90 billion of this investment has been directed to the power generation via greenfield projects and privatizations. As a result of these investments, installed capacity has tripled: 27 GW in 2000 to over 93 GW in 2020.

The power grid has also been expanded to address growing demand and new capacity additions. Privatized investments and operations in distribution networks have improved efficiency, reducing grid losses (transmission and distribution combined) from 18% in 2010 to less than 12% by 2019. Supply security, which used to be a prime concern for Turkey's electrifying energy economy, has been improving through expansion of generation capacity (about 5 GW average annual additions in the last decade) and additional improvements in power quality, reliability and environmental sustainability.

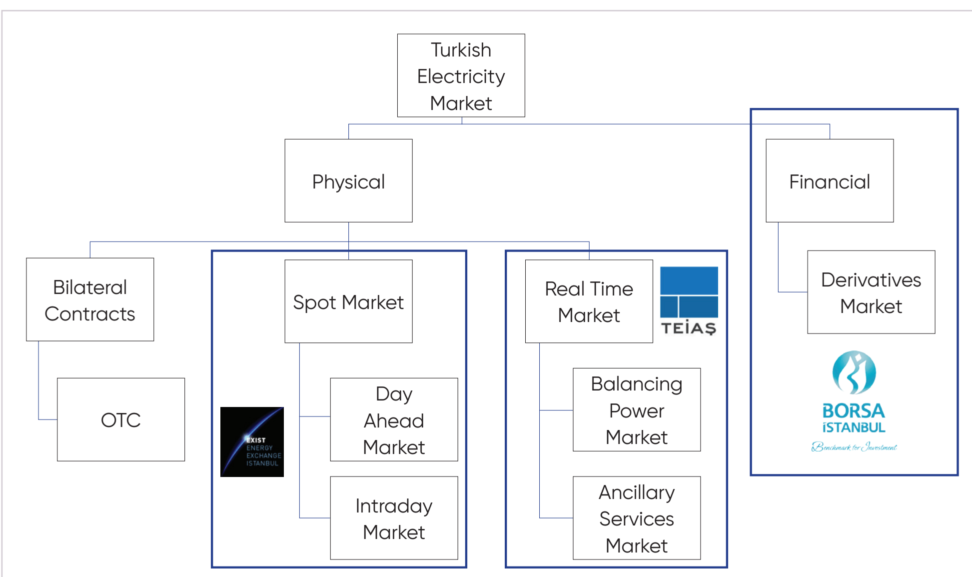
Figure 1.24 Key Innovations and Institutions Introduced into the Turkish Power Market (2001-Present)



Marketplaces are emerging in phased steps (see Figure 1.24) as a key enabler for a more competitive market. These include the Balancing Power Market in 2009, the Day Ahead Market in 2011 and the Intra Day Market in 2015. EPİAŞ was established in 2015 as an energy exchange market to manage and advance power market operations in an organized market framework. The launch of the Transparency Platform in 2016 was also a key step to advance the competitive merits of the power market with improved data transparency in an increasingly sophisticated market involving more market participants. The cleared Day Ahead Market quantity has increased threefold from 2012 to 2019 and reached to around half of gross power generation.

A well-organized wholesale market is essential for the operation of any competitive power market. It requires rules and regulations governing physical and financial flows to manage the supply demand balance and transactions in different timescales. In addition to short term spot markets and real time balancing and ancillary services, Turkey has established an organized Futures and Options Market for derivatives. The Over-the-Counter (OTC) model has been in use among market participants for power trading activities (see Figure 1.25).

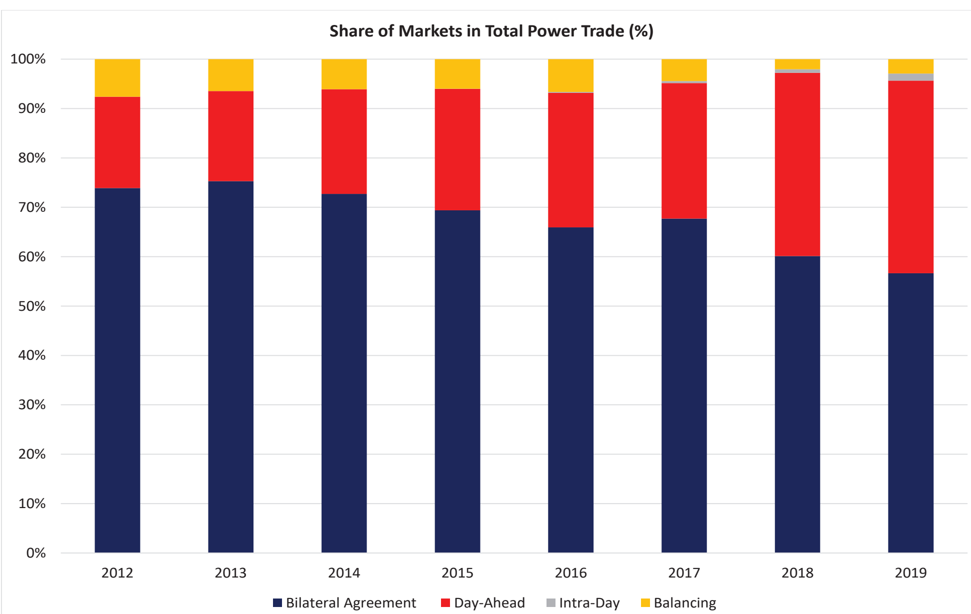
Figure 1.25 Physical and Financial Framework for the Current Wholesale Power Market



Source: EPİAŞ

Despite these achievements, development of a more competitive power market necessitates further platforms that extend power markets into medium term trading. Studies to launch an organized futures market with physical deliveries is a key step to advance the Turkish power market in this direction. This market is expected to be launched soon after final tests and simulations and will improve predictability by allowing for improved price discovery in an organized market structure. It will be a platform where the market participants can manage their costs and risks where EPİAŞ is the counter-party. Participation of large customers would also enhance the functionality of this market as such players can manage their power procurement costs and associated risks in a predictable environment with forward price information. The increasing liquidity of the market would encourage its use as a reference for new power investment decisions. Participation of the demand side is essential to develop the scope and functionality of the market. The Turkish power market design that was originally aimed to establish bilateral agreements among market participants is now evolving to a more organized market with complementary functions. However, due to limited progress in achieving market openness at the end user level and limited developments and lack of sufficient depth and liquidity in the OTC market, the share of bilateral agreements in total power trading has been continuously declining and represented less than 60% of traded volumes in 2019 (Figure 1.26). Therefore, achievements in creation of medium term marketplaces would also foster development of the wholesale power market with bilateral agreements supplemented by the medium-term market that would provide clearing prices with forward signals.

Figure 1.26 Share of Markets in Total Power Trade (%)



Source: EPİAŞ, 2020

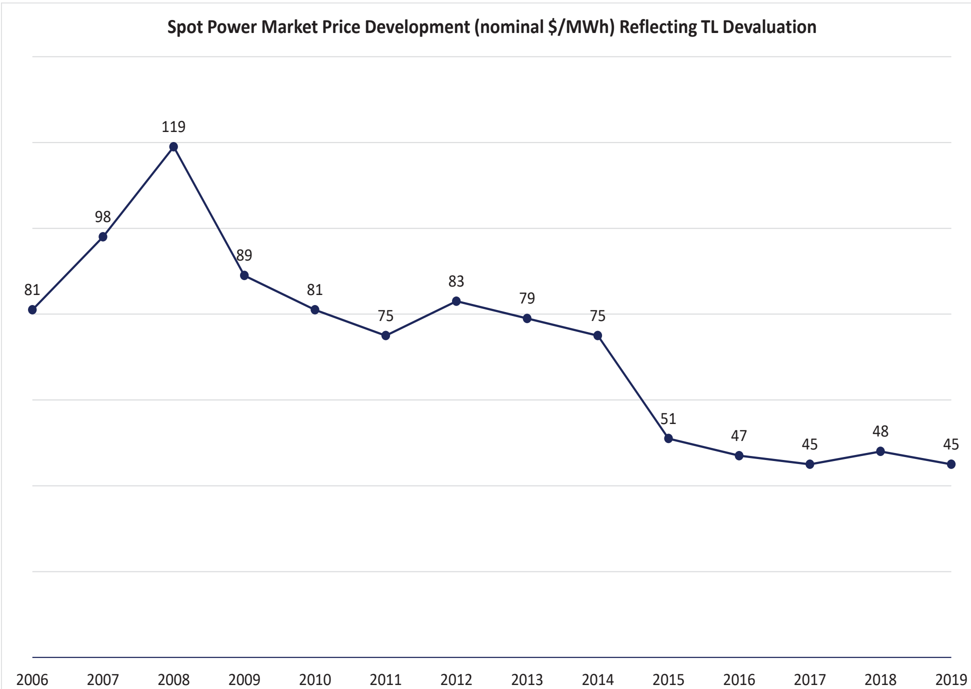
A number of challenges still remain to advance the power market towards a more competitive structure where the financial performance of energy markets is sufficient to stimulate Turkey's energy investment needs. This will require cost-reflective wholesale and retail energy prices along with policies to enhance the predictability of markets, achieve localization and security of supply, and foster efficiency and environmental sustainability.

Financial sustainability is an important performance parameter in power sector policies and market frameworks. A power market that requires investment in activities that are not financially viable will fail to provide reliable services or grow in relationship to a dynamic Turkish economy. Since 2000, over $100 billion has been invested in the power market with debt-to-equity ratios of around 70:30 to 80:20. Out of $70 to $80 billion accumulated credit, current outstanding debt is estimated at $47 billion. A number of factors have caused accumulated debt in the Turkish power market. These include an oversupplied market. In addition, the devaluation of TL against reserve currencies such as the $ or € has increased imported fuel costs and debt financing without corresponding increases in TL-denominated electricity prices (Figure 1.27). Turkey's spot market electricity prices have reduced by a half since 2009 in $ terms. While most of the debt stock (estimated at $40 billion) is in the generation sector, there is also a significant debt stock in the distribution sector (estimated at $ 7 billion).

The financial burden of this debt, as well as the underlying financial viability of different private power suppliers, varies considerably depending on power generating technology and feasibility of the investments. Most renewable power generation today results from participation in the YEKDEM mechanism. YEKDEM has provided long-term power purchase agreements (PPAs) at fixed $-denominated prices. These prices have also been significantly higher than the spot market electricity prices for the last five years, as these spot prices (below $50/MWh since 2016) have been much lower than the wind base rate of $73/MWh and the solar base rate of $133/MWh. In addition, there are additional local content premiums. YEKDEM power plants correspond to around 60% of generation financed debt. Due to the nature of these PPAs, this debt has mostly not suffered from TL devaluation. In addition, the merit order of dispatching renewables is high. Consequently, this debt is relatively well secured.

Thermal generation is however largely merchant and exposed to spot market prices in an increasingly oversupplied market with strong renewables penetration. There are, however, PPA mechanisms for domestic coal, and capacity payments for coal, natural gas and certain hydro plants. On balance, about half of the debt stock of thermal power generation, or $8 billion, was estimated to have difficulty to pay debt services. Summing up over all power-sector debt, $13 billion was considered to be "non-performing". However, most of this portfolio has been under restructuring since 2018 that has advanced the debt payment terms resulting in an improvement in financial sustainability in the market.

Figure 1.27 Spot Power Market Price Development (nominal $/MWh) Reflecting TL Devaluation



The negative debt experience for past power plants can have adverse consequences on the terms required to finance new power plants. The average annual investment needed for power plants through 2040 is $6 billion in both scenarios. Consequently, financial sustainability is not only needed to satisfy existing debt services but to also attract and allocate required capital to fuel investment needs through 2040. An evolution to cost-reflective energy prices would greatly contribute to financial sustainability since competitive market forces would provide transparency and predictability, if not necessarily guarantee financial success. Other mechanisms are likely to be required to support the private sector's ability to raise the necessary capital to meet Turkey's growing electricity demand and to take full advantage of rapidly evolving power-sector technologies.

Key factors that will impact the future evolution of the power market are generation and supply costs, pricing strategies and government tariffs. The Turkish power market has a complex system of electricity prices *paid* by different classes of consumers. In addition, the prices *received* by private generators depend on which market they serve and, in particular, whether they enjoy YEKDEM and YEKA models or similar purchase price guarantees (Table 1.4). In recent years, power purchase agreements have become the main axis for growth in the electricity market for new generationinvestments.

In line with the policies to support generation from local energy sources and similar to the practice in many emerging power markets, renewables based generation is supported by fixed price terms defined as feed-in tariffs in the YEKDEM mechanism. The current YEKDEM period that offers fixed price guarantees that are well above merchant prices will expire by the end of the first half of 2021. The future design of YEKDEM mechanism or any support scheme dedicated to renewable investments will be important in shaping capacity growth as well as electricity pricing. Renewable Energy Resource Areas (YEKA) Model, incorporating localization objectives based on use of domestically manufactured equipment for renewables based generation, have competitively-determined $-denominated prices resulting from bidding on Government tenders. A recent YEKA auction on solar PV was announced in 2020 with a TL based ceiling price that is linked to spot market prices. YEKA will be the main growth line for new wind and solar investments. The YEKA model requires local manufacturing of equipment and know-how transfer while also incentivizing renewable generation investments while creating a more competitive electricity market through its use of capacity auctions. This should bring PPA prices more in line with the competitive costs of generation. Another objective is creating a scale in the market to meet conditions of local equipment manufacturing plants and R&D facilities. Throughout the last decade, a number of local and international companies have built wind turbine manufacturing capacity starting with towers, blades, rotor and stator frames and generator frames in Turkey. YEKA mechanism requirements of 65% local content will be taking the wind turbine manufacturing capacity to the next level. Similarly, on the solar side several manufacturing companies have been involved in solar module and cell production and the last YEKA tender defined a 70% local content target Looking ahead, an impact assessment of localization incentives would be timely in order to define next steps and fine-tune the bidding process. Key considerations should include employment, exports, cost, competitiveness, transportation savings, integration of local suppliers, engineering and R&D priorities including software, digitization, cybersecurity and system flexibility. Local content related objectives should also accommodate external financing requirements.

The Akkuyu nuclear power plant, Turkey's first nuclear project, will also receive a fixed price PPA for 50% of its total generation for the four units combined (70% for the first two and 30% for the last two units). Unlike most nuclear power plants built around the world, Rosatom is using the build, own and operate model. Instead of purchasing the reactors, Turkey's financial obligation is limited to the PPA just cited. The considerable financial risk associated with nuclear power, in particular, cost overruns and construction delays, is therefore being assumed by Rosatom rather than a Turkish entity that would have contracted to purchase the reactor under a conventional nuclear power plant contract. Recent experience with conventional reactor purchase contracts has been especially negative in most OECD countries (South Korea being a notable exception). For example, a U.S. consortium abandoned a Westinghouse-Toshiba project *after* spending $6 billion.

In addition to renewables, part of the existing generation from local coal resources (around 50% in 2019) are also offered PPAs as well as new local coal projects. The merchant segment of the generation market is limited to natural gas and imported coal plants and currently represents less than one third of the total installed capacity (Table 1.4).

Table 1.4 Current Pricing Mechanism for Power Generation Technologies

Power Generation Technology	Merchant	PPA
Local Coal	x	x
Hydro		Mostly YEKDEM
Other Renewables		YEKDEM and YEKA
Natural Gas	x	
Import Coal	x	
Nuclear	x	x

In electricity sectors where competitive markets are developed, end user prices are based on actual cost of energy. However, governments have traditionally been involved in the setting or regulation of electricity prices to serve the public interest, address fuel poverty and social considerations and to ensure that electricity prices are not excessive in relation to costs. Turkey's current tariff setting regime differentiates customers based on their annual consumption volumes (Table 1.5). Small consumers (with consumption lower than 1.4 MWh/year for 2020) are subject to regulated tariffs. Consumers with consumption over 7 GWh/year for 2020 (most of the large and medium scale consumers) are subject to the Last Resort Tariff (LRT) scheme and pay based on the Day Ahead Market prices and unit YEKDEM costs from the market participants. Consumers over the regulated tariff but below the LRT threshold are eligible to procure electricity based on bilateral agreements with power suppliers but can also choose to instead pay regulated tariffs. The competitive element in Turkey's electricity pricing is established in the LRT segment as those customers are obliged to pay based on the Day Ahead Market Price and unit YEKDEM costs, regardless of the regulated tariff levels. The Government plans to gradually reduce the LRT threshold, thereby increasing competition in electricity pricing. The recent decrease of the threshold from 50 GWh/year to 7 GWh/year from 2018 to 2020 has been a significant move in this direction. However, it is important to note that an expansion of the LRT segment does not necessarily make these more competitive electricity prices cost-reflective since the supply and demand factors operating in the Day Ahead Market do not completely reflect the generator costs of the power sold via YEKDEM or costs of power sold through other mechanisms.

Table 1.5 Current Tariff Structure in the Power Market (2020)

Annual Consumption Level	0-1.4 MWh	1.4 MWh -7 GWh	>7 GWh
Consumption Group	Regulated Consumers	Eligible Consumers	LRT Consumers
Applied Prices and Tariffs	Regulated Tariff	1-Regulated Tariff 2-Bilateral Agreements	LRT

As can be seen from this complex structure of supplier sales prices and various consumer market prices, there is no one-to-one match up of electricity industries' supply costs and any particular market prices whether they be in the retail markets, Day Ahead Market or YEKDEM prices. The full costs of electricity supply also include the Government's net expenditure on feed-in tariffs and other incentives. An analysis of regulated tariffs and actual market costs in the electricity sector shows that regulated tariffs, on average, had been lower than the market cost since 2016 until late 2019 for most customer groups indicating that the government has been subsidizing end user electricity prices below the actual cost of power. Different classes of customers have been subsidized to a greater or lesser extent (see Figure 1.28 and 1.29).

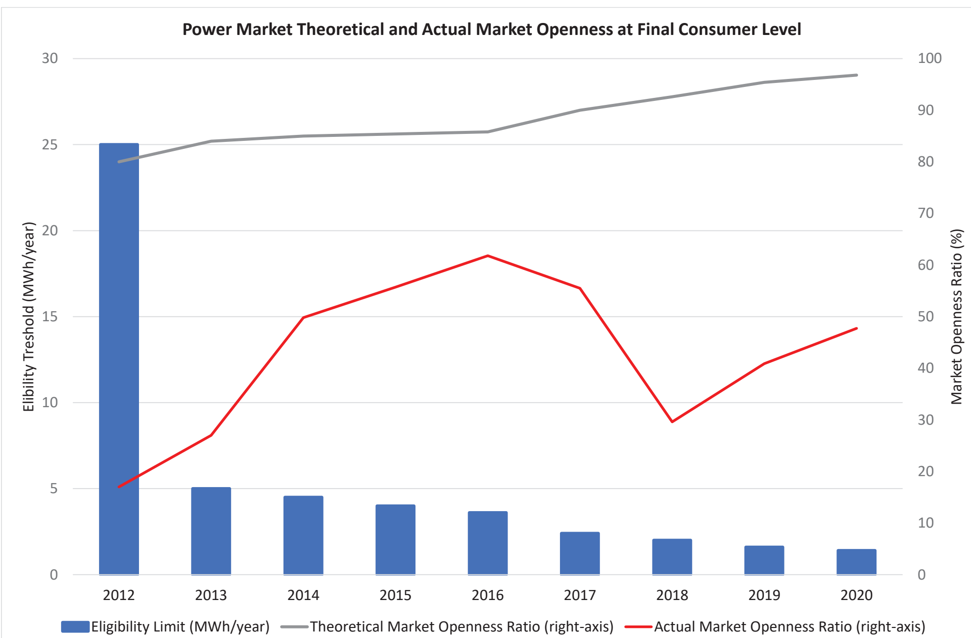
As the regulated tariff levels remained below the actual costs in the market, the number of consumers who exercised their eligibility rights to procure power based on bilateral agreements under more competitive conditions began to decrease. Market openness rate decreased rapidly as these consumers choose to benefit from the more advantageous regulated tariff. Consequently, actual market opening decreased steadily back to 2012 levels. As a result of the tariff increases in 2019, the regulated tariffs of commercial and industrial customers started to better reflect market costs while residential customers remain protected and the actual market opening started to increase, a positive development towards gaining competitive merits of the supply market (Figure 1.30).

As discussed above, the LRT Mechanism, a relatively recent feature in Turkey's electricity market (since 2018), is the vehicle for competitive electricity pricing. If it were the only basis for electricity pricing, then it would better reflect costs of supply. So expanding the LRT and adjusting regulated tariffs would encourage the use of the LRT mechanism and help establish cost-reflective electricity prices. Cost-reflective prices would support Turkey's needed investment, especially for merchant plants, and require lower Government subsidies. Of course, this is not something that should be attempted abruptly so the various steps to expand the LRT and modify other arrangements should be prudent.

Currently, there is a structure in which residential consumers can access electricity under actual cost, and large consumers can perform sourcing under the LRT mechanism. While developing a more competitive pricing mechanism, social and macroeconomic objectives should be taken into consideration. This is particularly important to mitigate consumer inflation, to support low-income families, prevent fuel poverty for any citizen, and maintain competitiveness for Turkish industry. One recent innovation is an electricity consumption support mechanism to certain residential consumers. This is in the form of direct payments and applicable to vulnerable families for their consumption up to 0.15 MWh/month. This approach will become more important as the power market becomes more liberalized and eventually allow retail prices to reflect the full costs of generating and delivering electric services while meeting social obligations. The current strategy of the Government towards a gradual transition to have large customers, mainly in the industrial and commercial sectors, switched to fully competitive sourcing is a positive development to achieve wider benefits from competition andefficiency.

Regulated tariffs could also be eliminated with a phased approach for all customer groups including residential consumers and with well-defined exceptions to address fuel poverty considerations. However, when supporting the electricity needs of low-income consumers, it would be more efficient to do so using direct offsetting support payments instead of lower tariff classifications, so as to avoid distorting electricity pricing. This current approach would increase transparency, predictability and efficiency in the power market and, along with other necessary factors, help stimulate private sector investment to grow and modernize the Turkish power sector while achieving the pillars of Turkish energy policy and environmental sustainability. The future competitiveness of the electricity supply market will be determined by the future development of regulated tariffs and the pace and timetable for which the LRT threshold will continue to be reduced.

Figure 1.28 Power Market Theoretical and Actual Market Openness at Final Consumer Level



LRT Threshold/yr. : 50 GWh 10 GWh 7 GWh

Figure 1.29 Evolution of Market Price vs. Active Energy Cost in the Regulated Tariff (TL/MWh)

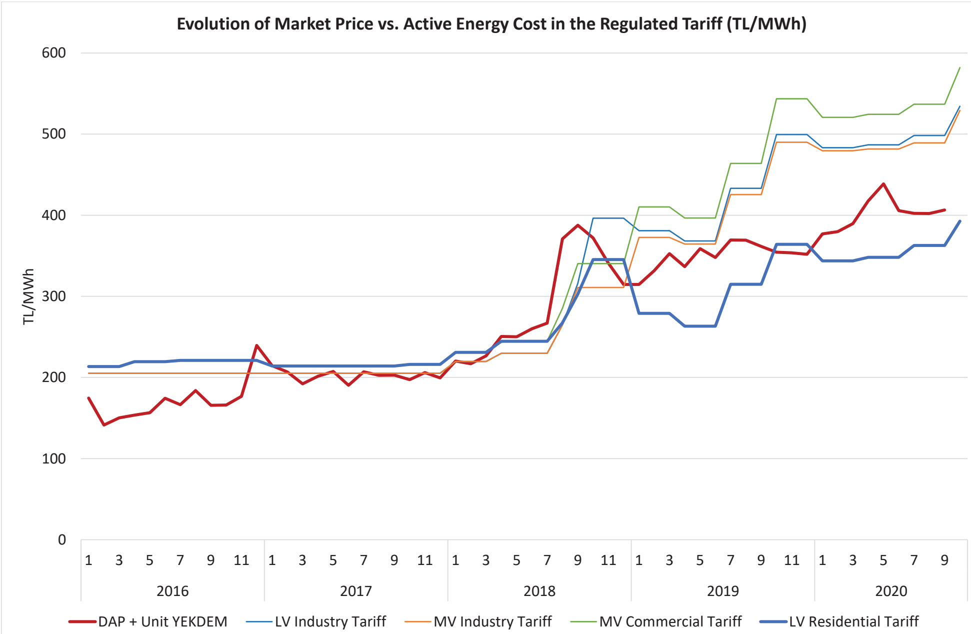
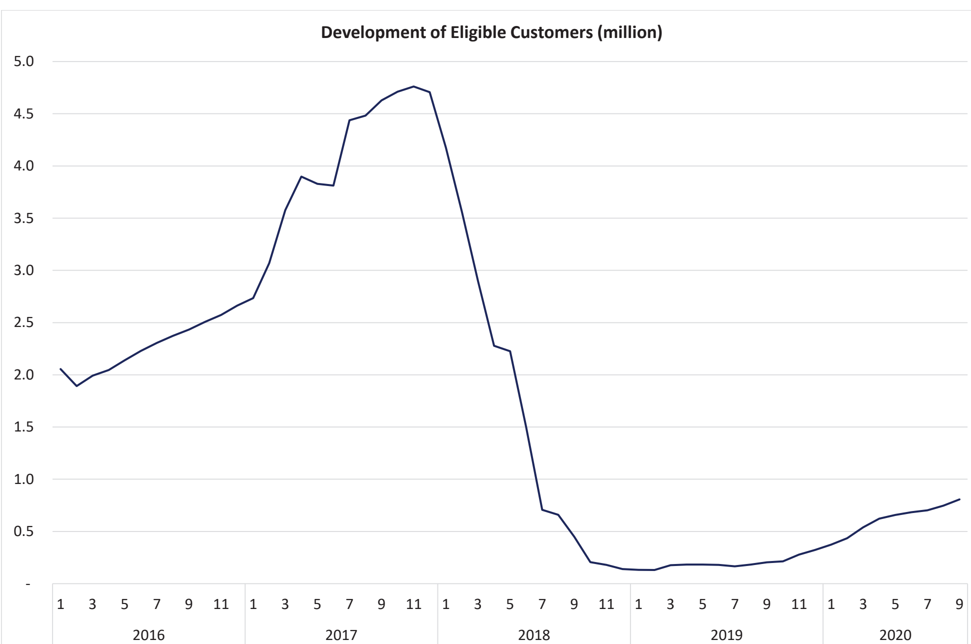


Figure 1.30 Development of Eligible Customers (million)



In a more liberalized power market, the government would have less control over electricity wholesale prices. Implemented effectively, this should provide net benefits for the economy but, like many changes, the benefits would not be evenly distributed among all stakeholders. While the average benefit would increase, there would be winners and losers stressing the need for careful implementation. Regardless, the priority remains to advance a deregulatory agenda that creates value-based pricing, transparency for investors and market-driven sector investments. Several actions would also be needed to advance this agenda by state-owned market actors, EÜAŞ and BOTAŞ, to enable transition to a pricing strategy that reflects marginal costs, opportunity costs, and global as well as regional developments in commodity markets and optimization of their large supply portfolios. By way of transition, auctions or other tender mechanisms could divest more EÜAŞ and BOTAŞ contracts and assets.

Pricing electricity so it reflects suppliers' true costs is essential to continue the path towards further liberalization and privatization of the Turkish energy economy. This provides the most predictable power market as investors could then evaluate how their projects measure up against the expected competition and whether future revenues are likely to return value to shareholders. As long as government sets retail energy prices, such evaluations are not possible. This increases investment uncertainty to the point that government can only ensure investment through long-term tenders. While a necessary expedient to meet Turkey's growing energy needs, these tenders increase the government's role as a power supplier in addition to the power generating capacity that it already owns and operates. Continuing on the Government's path towards further competitiveness of the Turkish energy economy is essential to achieve the necessary private sector investment to meet Turkey's growing energy needs. If government tenders become a permanent feature for Turkey's long term energy future, it will not be possible to make the transition to market based investment decisions. Continuing on Turkey's competitive power market pathway does not mean that government abandons its social, environmental and energy security responsibilities. It only means that it accomplishes these obligations using other mechanisms than being a major market player and controlling retail and wholesale prices for different types of customers. There are numerous examples of regulatory and social safety-net programs in world-wide power markets that address fuel poverty and ensure consumer protection, environmental progress and energy security in the context of cost-reflective electricity pricing in all wholesale and retail markets.

A more competitive power market also goes hand in hand with fostering a new approach in market design that transitions smoothly away from guaranteed power purchase agreements to more merchant play. Currently merchant capacity provides about one third of Turkish power generation but could reach as high as 80% in the Alternative Scenario after 2035 when early 2020 PPA's from YEKA and YEKDEM mechanisms and Turkey's first nuclear project, Akkuyu, are expected to mostly expire. Several developments would support this transition including the emergence of electricity futures contracts to provide price security and hedging tools for both suppliers and consumers. The newly establishing, market based renewable energy based PPA schemes among producers and large consumers would also facilitate a financially and environmentally sustainable transition.

This process will be aided by advancing technologies that lower cost, increase performance and offer a wider range of energy services. Continuing to advance a more competitive power market is essential to achieve these benefits.

Achieving benefits from more competitive markets and global technological advances depends on success along these policy and technology lines. These achievements should go hand in hand with optimal allocation of investments in an increasingly digitalized and electrified energy economy. Advancing the power sector to realize the estimated benefits in the Alternative Scenario requires wider deployment of emerging power technologies in Turkey. Similar to modernizing electricity economies worldwide, they are mostly in the clean energy domain such as solar PV, onshore and offshore wind, other renewables, distributed low carbon generation, electrification of mobility, advanced grids and energy storage. These technologies will change conventional forms of the power business, significantly reduce dependence on imported fossil fuels and weaken the linkage between input commodity costs and electricity prices. They will also bring additional challenges and opportunities for the electricity market to create value for all its stakeholders and the wider ecosystem.

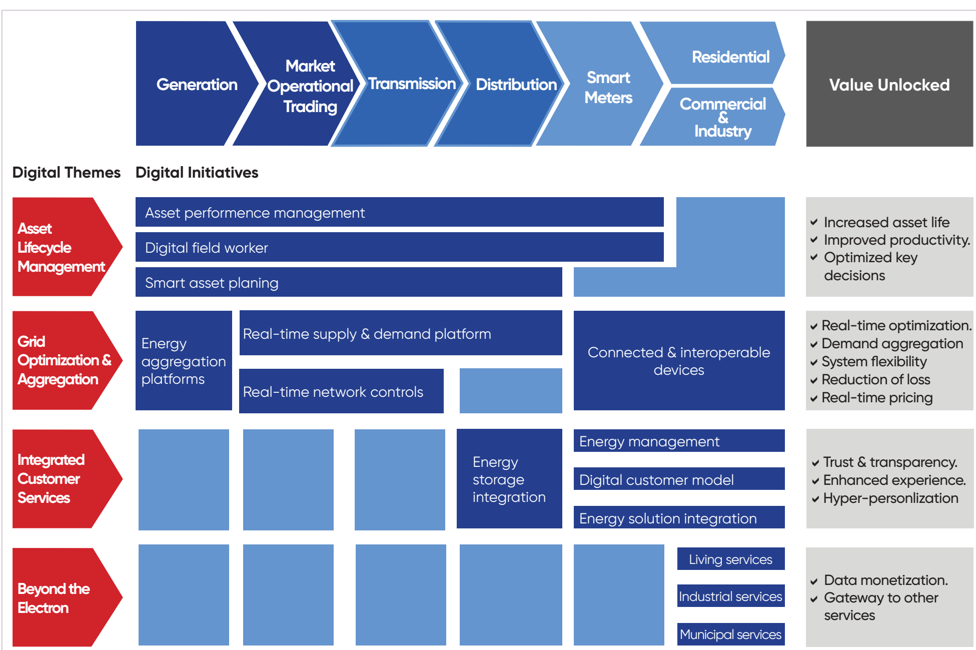
Globally, the electric utilities have traditionally grown in an environment of continuously increasing demand for electricity with industry capitalization reflecting a single business model: producing and selling electricity. In this asset based business model, profitability has been largely dependent on cost of commodities at the buy side, the cost and productivity of electricity-generating capital and the price of electricity at the sell side. Steady demand growth was a given considering the long history of electricity growth tied to economic growth and regulatory environments that tended to smooth out the consequences of business cycles for power companies. Excess production capacity was typically rolled into rate bases in return for reliable electricity services and no electricity shortages. More recent changes are being caused by decoupling electricity demand growth from economic growth, dispatching higher levels of renewable electricity with much lower marginal costs, innovations and the introduction of new technologies, including grid, generation and consumption. These factors required changes to past industry structure and have created many more opportunities for business innovation and investment. New market structures and changing technologies have increased opportunities for information based business models.

The classical structure of the electricity business is likely to merge with data driven networks, or urban and transportation services involving different business models. In addition to the flow of electrons, data and information will become tangible assets in the new value streams. Digital technologies will become widely developed for smart appliances and energy management systems in residential and other buildings, 3D printing and advanced robotics across manufacturing industries and electrified and connected mobility technologies. Digitalization would be at the epicenter of power sector transformation and a key enabler for a more efficient and sustainable electricity future for Turkey. Digitalization holds the potential to build new architectures of interconnected energy systems by breaking down traditional boundaries between demand and supply (Figure 1.31).

Given that policy makers, business executives and other stakeholders have been increasingly facing much more complex decisions, often under a number of uncertainties amplified by incomplete or imperfect information, digitalization could be instrumental to plan forward steps for an increasingly dynamic energy system. Digitalized energy systems would be instrumental in identify needs of consumers by delivering energy at the right place and time at competitive and affordable conditions.

As power market players generate data, several technologies will be instrumental in delivering value. Machine learning, Internet of Things (IoT), cloud computing and blockchain are among the prominent technologies increasingly deployed by utilities world-wide. These technologies would represent important future development avenues for an increasingly electrified and digitalized energy economy of Turkey. Investing in digital technologies by power market players would bring further productivity and efficiency gains in an increasingly competitive market framework. Remaining competitive will necessitate wider use of data analytics processing information from a variety of devices including electric meters, smart home systems, and other smart devices, electric vehicles, grid management systems and demand side management systems.

Figure 1.31 Digitalization Opportunities in the Electricity Value Chain



Source: WEF, 2016

It should be kept in mind that these opportunities also require simultaneous development and implementation of cyber security as all of these innovations create new opportunities, in addition to the already substantial risks, for cyber-attacks. The cyber risk in the power sector, and devices that are connected to the power network are especially dangerous as they could result in widespread and long-lasting blackouts, especially if critical infrastructure, such as transformers, are damaged. The extreme fragility and interdependence of the electric supply system has been demonstrated worldwide with many black outs that are typically repaired in fairly short order. However, disruptions that are caused by hostile actors could be specifically targeted to make quick restoration difficult or impossible without taking cyber-security precautions beforehand. Consequently, the risk is great. To address existing and future threats, increased emphasis must focus on worst case scenarios to protect critical assets that cannot be easily replaced and consider whether an emergency inventory of such equipment is needed. A system-wide architecture is necessary to maintain resilience and protect critical power infrastructure. Sufficient authority and resources are needed to ensure implementation of cyber security at all points of vulnerability despite the fact that these points are owned or controlled by a large number of private companies and government agencies.

Despite these risks, the digital future is unavoidable and will be the engine of worldwide economic growth. Electric distribution networks will require particular attention to keep them up to date with rapidly advancing digital technologies. Fortunately, Turkey has prepared a road map for future deployment of smart grids with concrete targets. The essence of the smart networks lies in their ability in monitoring power flows for adjusting to supply and demand variations. Smart metering systems enable data flows about real-time consumption patterns. Smart grids will be facilitating wider penetration of renewables, decentralized generation, improved energy management and efficiency.

The Smart Grid Road Map that outlines the actions and benefits until 2035 will be one of the central elements of the upcoming regulatory period for distribution activities in 2021-2025. The Road Map targets an extensive smart meter roll-out program. It anticipates that 80% of 50 million likely 2035 subscribers will have access to smart grids and related infrastructure. Road Map targets include:

- greater remote control and self-healing functionality in grid infrastructures,
- active and optimized implementation of integrated flexibility management solutions,
- implementation of large capacity flexibility resources,
- a 20% improvement in capacity utilization rates of current grid assets
- a 20% efficiency improvement in operational activities,
- grid resilience measures,
- data analytics based operations,
- full compliance with international smart grid communication and information standards and protocols,
- lifting service quality to that of the OECD average, and
- localization of smart meter production.

Communication, control and information technologies involving big data and the IoT will transform the distribution infrastructure into more efficient and secure form. This transformation will naturally create innovative and higher value-added business opportunities for power distribution players. Demand side participation is also addressed in the Smart Grid Road Map to involve 10 GW of load involving large power customers.

Demand side management and participation has become one of the most important global energy trends. It is mainly an optimization effort to manage demand, both in magnitude and by profile, based on several internal and external parameters such as the consumption levels, time profile of consumption, contractual conditions about supply, grid related constraints and market conditions. Demand side management achieves a more efficient demand profile to better match power dispatch and to reduce the need for additional generation capacity. Demand side management can also make power users a market player giving them more of a role in pricing and strategies to reduce energy costs.

Turkey is currently developing the regulatory framework to establish rules and practices for launching the first demand side management platforms. The first arrangements are set to be made by the regulator through voluntary tenders aimed at large consumers connected to the transmission network within the scope of the ancillary services market. The demand side assets can be a broad set of smart buildings, residential and commercial complexes, industrial sites, data centers and campuses either on a micro grid or integrated to the distribution network. Electric vehicle charging networks would also participate. Large industrial sites are expected to be the early adopters but their role should not be limited to load leveling in later stages for enabling active demand side participation in Turkey's power market.

Adoption of energy management becomes more necessary with increased uptake of variable renewables and other factors that contribute to mismatches between generation and demand. An effective program requires incentivized energy management systems and an increasingly wider integration of demand side resources. A natural expansion of energy management services includes smart building solutions for residential, commercial and industrial sites and campuses. As discussed earlier, digitalization plays a key role in all demand side management services (security and surveillance, smart heating and cooling, healthcare and assisted living, smart appliances and devices, electric mobility and home entertainment). These services will create a new flux of information and energy exchange and would also support energy efficiency opportunities.

The vast penetration of smart phone use is also showing how smart home devices can be a natural extension of the smart phone experience. Consumers can easily download apps to their phones or tablets that connect to their home devices including appliances, security and heating systems, or assisted living devices, give commands, check the status or get feedback. These technological opportunities will define a new and growing market to manage energy use, not only for traditional players but also for new and agile technology companies. This new market would be led by smart and connected technologies with a focus on consumer data and insights and matching solutions.

Energy storage management will also become a more distributed activity. In addition to storage at the grid and power generator level, the increasing use of rooftop PV systems should be accompanied by associated battery storage systems at the local level. In the past, storage to accommodate rooftop solar PV was often discouraged by "netback metering" in which utilities would be required to pay for excess electricity generated by rooftop PV at retail prices. This was an uneconomic solution as the utility often had no need for this power and especially had no need to receive any power at these particular points in the distribution network. The usual economic consequence was an additional subsidy to owners of rooftop solar units. Other customers would pay slightly higher electricity bills to pay for these netback purchases. After these cross-subsidies became apparent, a number of consumer groups expressed concern that low income consumers were being forced to subsidize electricity systems that were typically owned by higher income consumers. With more advanced and economic battery systems becoming available, storage can be more economically distributed among the grid and distribution network including the sites of rooftop solar PVs. These opportunities should influence the regulatory framework that is currently being shaped in Turkey.

Increasing electrification of transport brings new solution and service needs for urban battery charging to manage increased loads on some populated urban networks and substation capacities with changing load curves. New urban infrastructures and progressive planning with electric distribution companies, municipalities, public and private parking spaces, workplaces and residential areas will be required. The electricity demands created by BEVs will be either distributed among residences that can accommodate home-chargers or concentrated at charging stations. It was announced that 250 thousand charging points will be established to serve the EV demand. As autonomous and electric mobility technologies continue to evolve, new consumer behaviors along with new urban mobility solutions will be emerging. Electric mobility with smart and connected vehicles could have a potential to redesign the value streams for the automotive and transportation industries. The TOGG Project will also complement other localization programs in clean power generation technologies, particularly with YEKA model, and smart grids backed by localized meters and a national SCADA system.

1.3.10 Power Sector Emissions

The power sector is one of the largest contributors to energy related emissions in Turkey. According to the latest inventory of emissions, power sector GHG emissions[12] account for 40% of total energy related CO_2-eq emissions with 149 million tons. The power sector has an important share in the total inventory of air pollutants as well.

Neither TEO Scenario assumes that the Government will impose a CO_2 emissions target although significant emission reductions per capita and per kWh are achieved in the Reference Scenario and an absolute reduction of CO_2 emissions is achieved in the Alternative Scenario.

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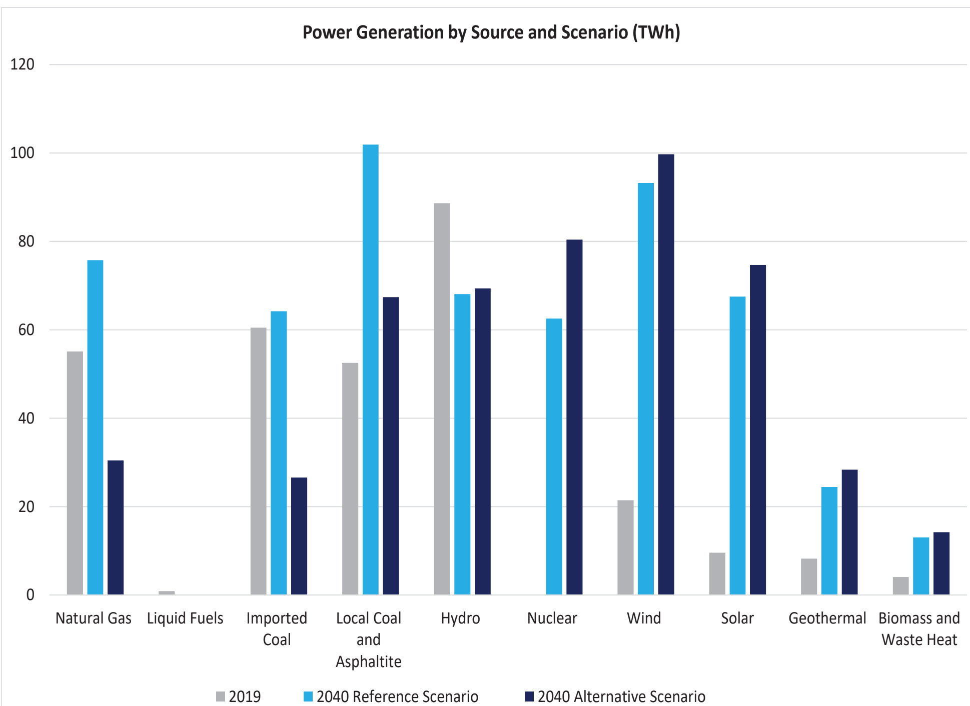
[12] Including heating purposes

Reduced emissions per kWh are due to multiple factors but increased use of renewable energy and nuclear power are particularly important as well as reduced grid losses. Reduced per capita CO_2 emissions also benefit from improved energy end use efficiency allowing the same energy services to be performed with less electricity consumption. The technology-driven transformation of the electricity sector allows more efficient management of supply and demand allowing more dispatch from low-emission sources.

The Alternative Scenario shows significant differences in the generation mix compared to the Reference Scenario that largely accounts for the fact that the Alternative Scenario projects absolute reductions of CO_2 emissions in 2040 despite the much larger population, personal welfare and higher GDP Turkey will enjoy in 2040 compared to today. Fossil fuel generation decreases, compared to the Reference Scenario, while nuclear generation increases by 18 TWh and renewables by 20 TWh (Figure 1.32).

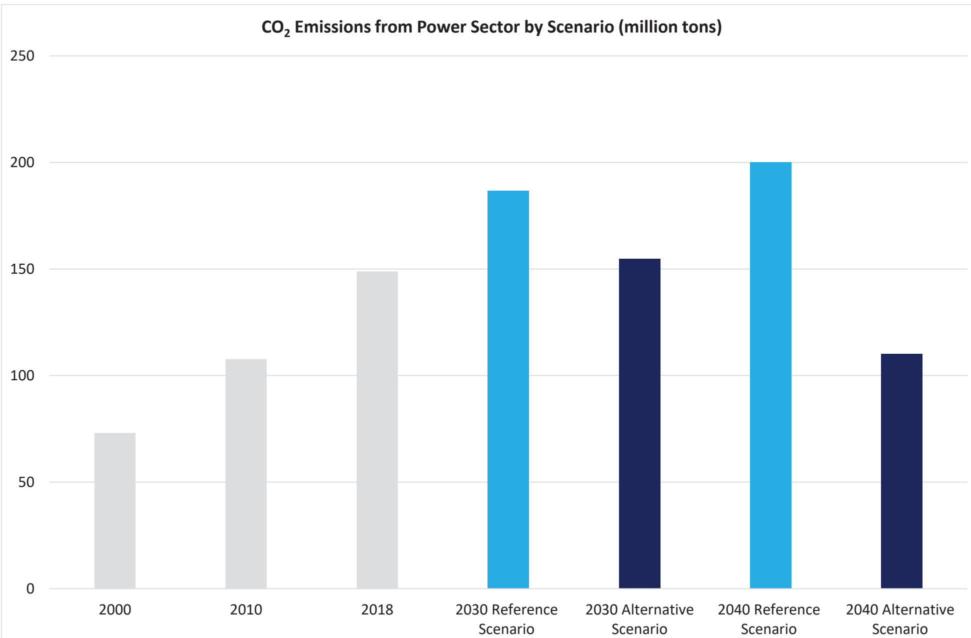
Figure 1.32 Power Generation by Source and Scenario (TWh)



In the Reference Scenario, where the combined share of fossil fuels in electricity production falls from 56% to 42% in 2040, CO_2 emissions continue to increase, but at a rate that slows down considerably reflecting a decrease in CO_2 emissions per kWh. In the period 2020-2040, the cumulative increase in CO_2 emissions from the electricity sector is 35%, compared to over 100% for the previous two decades.

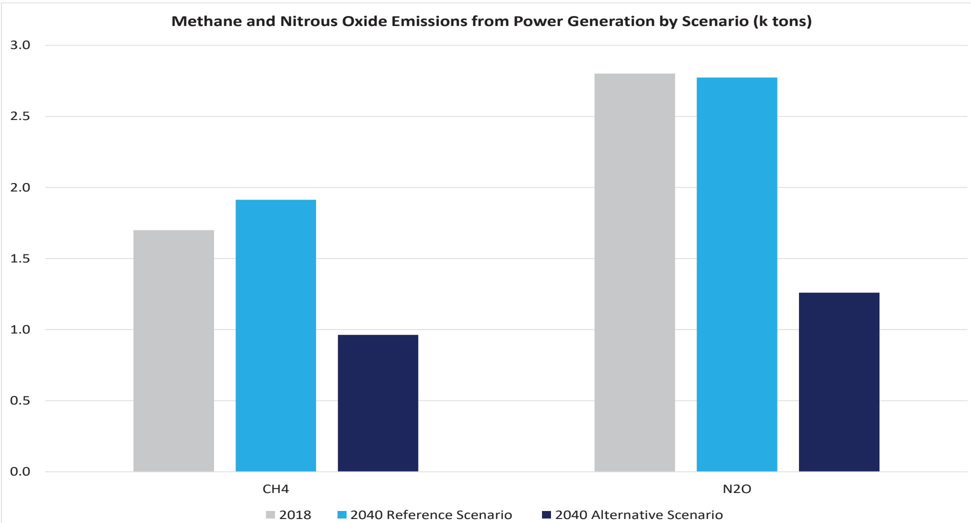
In the Alternative Scenario, where more challenging energy policies are achieved, generation from clean power reaches 56% by 2030 and 75% by 2040 (Figure 1.33). In this Scenario, CO_2 emissions peak soon after 2030 and then decline towards 2040. In 2040, power sector CO_2 emissions are 25% below 2018 CO_2 emissions despite serving a much higher national demand for electricity services (Figure 1.33).

Figure 1.33 CO_2 Emissions from Power Sector by Scenario (million tons)



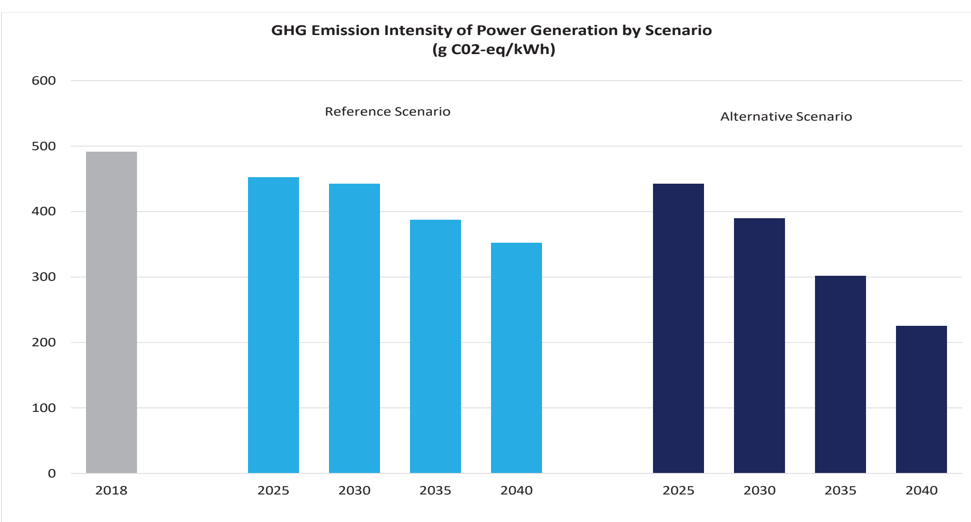
These projected reductions of CO_2 emissions in both TEO Scenarios follow Turkey's past pattern but at an accelerated rate. CO_2 emissions per kWh have been mostly on a declining trajectory since 2000 as a result of significant capacity increases in natural gas, sustained generation from hydro, recent growth by other renewable energy sources and generation efficiency improvements. The current CO2 emissions intensity of the power sector including heating is just below 500 g/kWh, a figure close to the global average (476 g/kWh in 2018). In the Reference Scenario, the carbon intensity of power generation drops to 440 g/kWh in 2030 and 350 g/kWh in 2040. These figures drop much further in the Alternative Scenario to below 400 g/kWh by 2030 and below 230 g/kWh by 2040. The Alternative Scenario also shows significant reductions in other GHG emissions. Methane (CH_4) emissions are lowered by half and nitrous oxide (N_2O) emissions are cut by 54% over the Reference Scenario until 2040 (Figure 1.34).

Figure 1.34 Methane and Nitrous Oxide Emissions from Power Generation by Scenario (k tons)



The Alternative Scenario results in 54% less CO_2-eq intensity by 2040 compared to 2018 (Figure 1.35). The level of emission intensity reductions achieved in the Alternative Scenario would set the stage for more radical reductions after 2040. Technological developments will provide economically sustainable opportunities to achieve net-zero emissions. These technologies and opportunities discussed in Chapter 6 (The Energy Transition) will be necessary to achieve lower GHG reductions beyond 2040.

Figure 1.35 GHG Emission Intensity of Power Generation by Scenario (g CO_2 -eq/KWh)



1.4. IICEC Policy Recommendations

- **Overview**

Turkey is a developing power economy with per capita consumption at about half of the EU average. Increasing population with a median age of 32 years, ongoing urbanization, electric mobility initiatives and industrial energy use are among the strong drivers for growth in power demand. Although the Turkish power market is currently oversupplied, the socio-economic drivers will necessitate a persisting investment cycle from now to 2040 across the electricity value chain. Turkey's recent steps in increasing the utilization of renewable energy resources, introduction of nuclear power, sustaining grid investments, improving energy efficiency in the power sector itself and at power demanding end-use sectors, and developing regulatory framework for newly establishing business models such as demand side management and battery storage are all positive to transform the Turkish power economy into a more sustainable structure. In particular, Turkey would become one of the leaders in renewable energy development and deployment, including enhanced technology localization, in Europe and an export outlet for these clean power technologies to other demanding markets in the region. Data analytics and digitalization related business models also stand as a value-added vector with multiple benefits for the electricity stakeholders as a whole.

In order for Turkey to achieve the benefits for a more localized, efficient and technology oriented power sector, ensuring a financially sustainable and competitive market is a key. Therefore, efforts for a more predictable and transparent power market with competitive forces that fully reflects supply and demand fundamentals and commodity costs should continue. This is essential to efficiently allocate investments and private capital into the power sector. Throughout the next two decades, IICEC expects a significant shift in cumulative investment needs from power generation to other segments of the value chain including distribution grids, flexibility solutions and consumers and a greater interrelation among these segments. A system level approach could act as the best solution to comprehensively address changing dynamics of the power sector and maximize the social, economic and environmental benefits to all stakeholders. A more localized, competitive and efficient power sector will reduce the energy related trade deficit, improve the environmental performance of the energy economy, and create more synergies with other key sectors such as transport, buildings and industry.

- **Enabling a More Dynamic and Competitive Power Market**

Turkey has achieved notable progress in expansion of the power infrastructure with significant supply security, reliability and quality gains in recent years. A number of achievements has also been made in the market framework. These will enable the market to move into a more competitive stage during this decade. However, a number of challenges still remain. Similar to other advanced power economies, a more predictable power market backed by clear policy direction and a supportive regulatory framework is the key to supply security, service quality and overall system flexibility. This is a complex task stretching across power generation, grid design and development, end users features, and encompassing the entire power system as an integrated entity. None of this can be accomplished without sufficient capital allocation, a challenge made more difficult by the evolving dynamic and shifting roles of generation, storage, grid services, distribution and a more active consumer role. The Government's role also needs to adjust in this changing dynamic, not by becoming less important, but by continuing to provide appropriate incentives and regulations that are consistent with and promote the changes that the power market itself must undertake.

A key element to this changing dynamic is fostering a stronger private sector role. Not only is this in line with past progress, as the choices become more multidimensional and inter-related, the advantage of private sector allocation and accountability become increasingly important. Such a trend also contributes to the three pillars of Turkish energy policy: security of supply, localization, and predictability in the markets. Enhanced predictability and financial sustainability along the entire power value chain is an essential factor that would contribute to private sector success and should be a top priority for government policies as they evolve to build Turkey's 21st Century power system.

Notable achievements in the short term markets include the Balancing Power Market, Day Ahead Market and Intra Day Market. These need to be complemented by advancing medium term markets with more predictability, transparency and enhanced risk management instruments, both for suppliers and consumers. These developments will enable price discovery over a longer time horizon and reflect supply and demand dynamics as well as a dynamic cost base that is linked to commodity and technology costs. The launch of an organized futures market with physical deliveries will constitute an important step to achieve a more efficient, transparent and competitive power market. Developments in the natural gas market will also be important for a better functioning power market since flexible natural gas fueled power plants are expected to continue their price setting role during peak demand periods.

Building upon recent moves to decrease the regulated portion of the end user market, another benefit can be realized in future tariff structures towards a fully cost-reflective scheme and by eliminating all regulated retail tariffs. This transition would be realized by implementing accommodations for certain consumer groups to meet social obligations and address energy poverty. Turkey's recent steps by introducing the LRT scheme and a social support for low income consumers are positive developments as cost-based pricing and tariffs will be instrumental in achieving the optimal utilization of energy resources and technologies with efficiency gains relying on market forces functioning through short and medium term market structures. Engaging the demand side into market design and operation would enable further benefits from an increasingly competitive power market. Although long term arrangements would continue to be instrumental in securing finance for certain technologies (for example, nuclear power), merchant mechanisms should become a more important aspect of Turkey's competitive generation market.

- **Sustained Growth in Renewables and Other Clean Power Generation Technologies**

Turkey's power sector policies favor actions for a cleaner electricity future. Objectives for expansion and further diversification in power supply, largely through low carbon generation options, mainly by renewables and nuclear power, will foster sustainability of Turkey's growing electricity economy.

One particular achievement towards a more secure and sustainable growth of the electricity system has been in renewables based capacity where Turkey has become one of the world leaders. It has accomplished this by increasingly utilizing its favorable resource potential using feed-in tariff incentives with hard currency denominated long term purchase agreements, the YEKDEM model. The YEKA model, used for large projects, include local content requirements for capital investment. YEKA has already produced a notable tendered capacity with hard currency denominated long term purchase contracts (PPA) and a new YEKA tender with PPA model was announced for 2020 in TL terms. The YEKA model is expected to be the prime growth avenue for large scale renewable investments, mainly solar PV and wind. However, a number of uncertainties still remain for sustaining and increasing growth from renewables based generation. The current YEKDEM regime will end for renewable investments commissioned after the first half of 2021. Terms and duration of PPAs including support price figures and currency choices are important considerations in design and post-2020 implementation of the YEKA and YEKDEM models as well as any other support scheme devoted to renewables. An attractive investment framework is required to secure finance to match Turkey's renewable resource base and achieve economic and environmental sustainability. As the actual realization rates of tendered capacities remained low over the past decade, an impact assessment would be timely to increasingly transform the tendered capacities into operational assets.

With global and national technology advancements, the best economic and environmental pathway will remain with renewables. Turkey would become one of the European leaders in renewables-based asset portfolio while progressively lowering the emission intensity from its growing power sector. Turkey's localization efforts would also create opportunities to become a renewable energy technology exporter to the regions with renewable energy growth potential such as MENA and the South East Europe (SEE).

The recent initiatives introducing Green Electricity Supply Agreements in the form of market based PPAs and a voluntary green tariff are both positive steps to advance renewable energy growth in an increasingly competitive power market with demand side (customer) engagement. In the longer run, market driven approaches would permit less reliance on government tenders when electricity prices reflect full costs and overall economic parameters improve. However, even when merchant power companies are selling into a competitive market and can secure financing without government guarantees, a government role still persists to ensure that energy security, localization and environmental objectives are met.

Nuclear power introduces a complementary asset to renewables in reducing fossil fuel imports, increasing security of supply and lowering carbon emissions when backed by an established safety culture and human resource development. Large nuclear power plants in Turkey, as in the rest of the world, will likely remain the purview of government for a variety of reasons. These include the large financial risks involved. A typical power plant project costs in excess of $10 billion, has uncertain construction times and uncertain ultimate financing costs. Costs and project timetables are also affected by government regulations. A number of other national security issues are also associated with nuclear power, including the management of the fuel cycle. It is possible that small modular nuclear reactors (SMRs) could change this picture somewhat. They would offer power in much smaller chunks, greatly reducing investment costs. The financial risk would also be greatly reduced by purchasing a manufactured reactor that is installed rather than built. Lastly, SMRs are likely to offer increased passive safety features. It is too early to say whether an SMR industry will develop. To be broadly successful, SMRs must provide electricity at a reasonable LCOE to avoid being consigned to niche applications where high cost is acceptable. This may or may not happen during the TEO projection period. However, there is a reasonable chance that SMR technology could be available to supplement or replace some of the expected large-scale conventional nuclear plants anticipated in the Reference and Alternative Scenarios.

- **Achieving a More Efficient, Flexible, Technology Driven and Localized Power System**

Turkey is one of the most dynamic power economies stimulated by strong socio-economic fundamentals and much lower per capita electricity consumption compared to European peers. While presenting solid growth opportunities for power supply, transformation of the power sector towards a more secure and sustainable future should also prioritize a more efficient development pathway for the whole electricity economy. Efficiency actions, when backed by policy instruments and increasingly competitive market forces, bring many advantages. Efficiency improvements in demand services will reduce the total investment requirement on the supply side and along with sustainable expansion of the power generation portfolio will reduce dependency on imported fuels while significantly improving environmental performance. Success in efficiency related objectives are strongly tied to policy tools and market forces.

Strategies in the National Energy Efficiency Action Plan provide a strong base for efficiency improvements in power generation, grid and consumption. On supply side, a more competitive generation and supply market is key for more efficient resource utilization. The regulatory framework for distribution is moving towards more efficiency in grid operations and services. Advancing energy efficiency and management in demand sectors, particularly in buildings and industries, will provide a more efficient growth pathway for Turkey's electricity demand services. Energy efficiency actions would be further strengthened by market and technology oriented solutions in an extensive roll-out of smart grids and demand side management. Distribution companies would play a more central role in improving power sector efficiency with hardware solutions.

Wider use of data analytics and digitalization will be one of the key enablers in more efficient and sustainable growth of the Turkish power sector. Several tools and technologies such as AI and machine learning have already demonstrated benefits and will be delivering value for market operations and investment actions supported by a vast set of data generated in the power sector. Digitalization presents a strong potential for optimizing power consumption across demand sectors. Increased connectivity opportunities by digital technologies would further allow for increased efficiency at the system level by matching evolving patterns in supply and demand. The benefits to the overall system will be multi-fold including optimized investments in generation and grid due to demand side flexibility, reduced unplanned outages, improved electricity quality and reliability, and integration of distributed generation and prosumers.

Evolving into a more efficiency and technology oriented structure, the grids will remain the backbone of the Turkish power system. Transmission and distribution networks will further increase their role as more variable and distributed supply and demand units penetrate the system. The electricity system will transform into a more decentralized structure mainly driven by rooftop PV developments supported by global technological advances, Turkey's favorable solar irradiation characteristics and Turkey's supporting policies.

Urbanization and road electrification are key drivers for power demand growth and necessitate sustained investments in expanding the distribution grids as well as enhanced collaboration and coordination among the distribution companies, municipalities and the electric mobility ecosystem. An effective regulatory investment framework should persist in order to advance the distribution grid to satisfy quality and reliability needs in modernizing electricity services. Future regulatory frameworks for distribution networks should continue to encompass a progressive technology perspective that incentivize increased efficiency actions and innovative business models while the grid infrastructure advances into a more mature level. In managing the grid, battery storage solutions would become a more feasible solution during this decade, first at grid scale and then via increased deployments at behind-the-meter. All these developments would be supportive for modernization of the Turkish energy economy by increased electrification and decentralization.

Adding to security and reliability objectives, power system flexibility will become a major issue for the Turkish electricity economy with strong uptake in intermittent generation capacities and increasingly variable demand services. Effective utilization of existing peaker natural gas units would be the most effective option based on economic and technical merits. A suite of other solutions including pumped storage hydro plants and battery storage will also be needed to manage generation and loads in a more flexible system structure. Smart grids and demand side platforms also provide value in expanding flexibility resources for improved load balancing. In an increasingly sophisticated generation and grid architecture, a system level perspective should be pursued to sustain power security and reliability while awarding value propositions from flexible supply and demand technologies.

Localization of the power sector is another important policy objective for Turkey to become an industrial participant in several global technology developments. Achievements in equipment manufacturing in solar PV, wind and other renewables have been important steps to develop technologies instead of a being largely dependent on imported technologies. These localization perspectives are reflected in current power generation strategies but need to be complemented by actions to secure external financing. Turkey also aims to develop local capabilities in various power technology areas beyond generation such as power storage. Launch of a national SCADA system for the whole electricity system is another technology localization effort to serve reliable and quality operation of Turkey's rapidly expanding power infrastructure. As discussed above, data and digitalization oriented innovation and business models offer multiple benefits for the electricity system as a whole and could be an important part of a wider power technology and innovation agenda. Industry and university collaboration programs could help identify the best power technology areas for Turkey to become a competitive global player. It should be noted that these growth and development pathways, outlined for Turkey, are not different than global trends and developments. Because of this, global technology developments will continue to reduce costs and endorse these approaches as the most likely to succeed. While Turkey will be following a pathway of ensuring technology localization, global cooperation is likely to remain a key feature and asset.

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CHAPTER 2:
TRANSPORT

Summary

- The transport sector represents one quarter of Turkey's final energy demand. While this is lower than industry (33%) and buildings (30%), transportation is 99% reliant on oil and accounts for almost 80% of Turkey's total oil consumption for energy.
- There are strong headwinds against rapid reduction of transport oil use. Turkish passenger car ownership is the lowest across Europe and socioeconomic factors will drive higher auto ownership per capita. This should not be avoided and, given the importance of the automobile industry in Turkey, is something to be encouraged as the economy matures from one with an export focus to a domestic focus. Therefore, minimizing and stabilizing Turkey's oil demand growth is a challenging goal.
- Timely policy and technology directions are needed for achieving a reduced share of road passenger and freight transport, improving the energy efficiency in all transport modes and advancing electrified vehicles to the maximum extent practicable.
- Fuel economy for new light duty vehicles (LDVs) is among the highest compared to peer economies due to tax policies supporting purchase of low engine sized vehicles. Fuel economy should continue to improve in line with developments in engine technologies.
- IICEC projects that the fuel composition of LDVs will change out to 2040 with a larger share of gasoline and aggressive uptake of electric vehicles. The truck fleet is large and old, necessitating an effective replacement program.
- While both TEO scenarios show fuel economy improvements, modal shifts and uptake of new technologies, the pace of progress is much greater in the Alternative Scenario. The Alternative Scenario includes stronger policies to amplify fleet fuel economy gains (through purchase of the best available technologies and faster retirement of older high-polluting vehicles, in particular the inefficient trucks), improving rail and marine services, and support for new vehicle and fuel technologies. As a result, the Alternative Scenario provides increased energy security, lower trade imbalances, greater economic growth and a cleaner environment. It has 13% less transport energy demand and 15% less CO_2-eq emissions compared to the Reference Scenario by 2040.
- Turkey's refinery balances are long on gasoline and short on diesel fuel. This requires export of gasoline and import of diesel fuel. The net cost to Turkey of these trades is high and constitutes a high share of Turkey's fuel import bill as discussed in Chapter 3 (Oil). Consequently, an increasing share of gasoline light-duty vehicles helps to reduce these import costs. Besides considering the national payments benefits from rebalancing Turkey's product slate demand to better match what Turkish refineries produce, a more neutral tax policy between diesel fuel and gasoline might better accommodate trends in vehicle technologies, especially gasoline lean burn and hybrid vehicles.
- Despite strong population and economic growth, diesel fuel demand increases by only 8% in the Alternative Scenario compared to 37% in the Reference Scenario. The reduction in diesel demand growth by the Alternative Scenario over the Reference Scenario is

significant (30% of current diesel demand) based on larger fuel economy improvements and achieving more challenging modal shifts in both urban and freight transport.

- The share of total transport energy demand met by non-oil based fuels increases from about 1% at present to 2.4% in the Reference Scenario and further to 6.5% in the Alternative Scenario by 2040. Electricity represents 4% of total transport demand in the Alternative Scenario compared to 2% in the Reference Scenario from a marginal contribution of less than 0.5% in 2018. While these are still small percentages, they can become more important on a pathway to a net-zero carbon economy (Chapter 6). In the Alternative Scenario, the contribution of natural gas also almost doubles from about 1% to 2% due to a more rapidly expanding CNG and LNG fleet in heavy duty vehicles (HDVs), primarily the buses and also in trucks. This growth can have particular air pollution benefits in local areas.

- Passenger transport energy intensity is reduced in both scenarios, 25% lower in the Reference Scenario and 32% lower in the Alternative Scenario from 2018 to 2040 (measured in terms of toe/Pkm). In freight transport, the Alternative Scenario results in 31% reduction compared to 14% in the Reference Scenario during the same period (measured in terms of toe/Tkm) driven by higher fuel economy improvements in trucks and further modal shifts to electrified rail. The improvements in freight energy intensity in the Alternative Scenario are particularly challenging and require integrated policy planning and implementation.

- GHG emissions intensity, measured in terms of travel activity, of the Alternative Scenario by 2040 is 35% lower for passengers (gCO_2-eq/Pkm) and 32% lower for freight (gCO_2-eq/Tkm) compared to 2018.

- How quickly older vehicles are retired is important for reducing Turkey's oil consumption. Diesel remains the logical fuel choice for trucks and buses over long distances. The most effective measure to retire old vehicles is to establish pollution standards that all vehicles must meet. These measures could be phased in to gradually force the retirement of older cars and trucks to move Turkey's vehicle fleet fuel economy to be more in line with its new vehicle fuel economy and provide significant air quality benefits. While this approach requires a careful implementation to maintain public acceptance, there would also be benefits to Turkey's economy from the domestic motor vehicle industry. More sustainable solutions could also be developed around increased utilization of CNG and LNG supported by the positive developments in the natural gas sector (Chapter 4). Hydrogen-powered trucks may be a long-term answer but they cannot be expected to be important until after 2040 (the TEO Scenario time horizon).

- Public transport will be enhanced in both scenarios to achieve modal shifts from road to rail in intra-city travel. IICEC recommends that, all urban areas should be given the resources and the methodologies to conduct a uniform, comprehensive and detailed travel survey, supported by the Government. New urban transportation planning centers would utilize this data to conduct analyses and establish long term plans using a process that includes effective public input. Capital outlays for public transportation and other investments to reduce traffic congestion and air pollution would need to be in line with these plans. The success of this initiative will be to convince commuters and other urban travelers that attractive public transportation services are preferable despite the fact that private auto ownership is likely to be increasing. These planning efforts could provide new tools to promote other elements of Turkey's transport policies such as providing privileged access for battery electric vehicles (BEVs) which would be a powerful incentive to encourage their purchase.

- Policies to develop a less-oil dependent transport sector is also consistent with Turkey's energy localization efforts. Government policy and industry support are expected to produce a strong increase in electric vehicle sales and use. Local production of BEVs as well as Turkey's charging infrastructure will grow Turkey's economy. An advanced and extensive recharging network is necessary to enable consumer use of BEVs and plug-in hybrid electric vehicles (PHEVs).
- Even compared to other TEO sector Scenarios, IICEC's Transport Scenarios highlight important opportunities for Turkey to become a stronger global technology player in addition to providing improved fuel efficiency, greater use of energy efficient modes of travel, reduced urban traffic congestion and an improved environment.

2.1 Global Developments

2.1.1 Introduction

Throughout human history transport has been a vital activity for economic and social development. Innovations beginning with the domestication of oxen and horses along with wheeled carts have charted economic development over the millennia including, in ancient times, building roadways and watercraft powered by human or wind energy. By the beginning of the 19th century, the first practical steam engine enabled the railroad and steamships. This was followed a century later by the internal combustion engine that enabled motor vehicles and aircraft.

Despite the progress provided by these innovations, the physical laws pertaining to the conversion of available energy into useful work have not changed and we are still constrained by fundamental thermodynamic and mechanical limitations as we seek to keep the benefits of our well-developed transport technologies while avoiding their harmful consequences including air pollution and increased atmospheric concentrations of greenhouse gases.

Transport is essential for trade and travel and has always been a supporting pillar for socio- economic development that led to global economic activity and our modern world. The rapid growth of the transport sector since the dawn of the 20th century was driven by a number of mega trends such as urbanization, connectivity, increased incomes and consumption. These all required more freight transportation, business travel and individual mobility. Without well-functioning transport systems, our modern economy would not be possible. Sustainable growth and a prospering global economy depend on finding ways to grow transport services while diminishing their adverse side effects.

Transport activity can be divided into two broad categories; passenger and freight. The means to provide each type of service diverge widely and are regarded as different modes of transport. The most suitable mode for each type of activity hinges on a variety of factors, including speed, cost, pricing, capacity and convenience of access. Transport modes for both passengers and goods include road, rail, marine and aviation. Each mode of transport offers unique advantages and each has its own infrastructure, vehicle technologies, operational dynamics and regulatory frameworks.

Policy priorities and technology efforts mainly focus on three key actions: increasing fuel efficiency; shifts from higher energy and emission intensity modes to less energy intensive and lower emission modes and wider use of lower-emission fuels and technologies in the existing modes of travel.

2.1.2 Key Trends in Passenger Travel

According to the International Transport Forum (OECD, 2019), passenger travel is expected to grow from 44 trillion passenger-kilometers (Pkm) from 2015 to 122 trillion Pkm by 2050. Besides the light-duty road vehicle, this travel is mainly served by intercity rail and buses, commercial aviation and urban public transportation.

Intercity Rail: Intercity rail services accounted for 87% of total passenger rail activity (measured by Pkm) by the end of 2017 (IEA, 2019a). In 2018, 75% of passenger rail transport activity took place on electric trains, representing a 60% increase from 2000, with the rest served by trains using diesel fuel. The electrified rail routes also have higher utilization rates carrying five-times more passengers per km than diesel lines (IEA, 2019a and UIC, 2019). Intercity rail is expected to grow fast, particularly in China, Japan and some European countries with geographic advantages and budget support. This is a turnaround from its long-term decline, first losing its near monopoly on intercity travel with the introduction of the motor car and modern highways and then, later, facing significant competition from commercial aviation, especially after the introduction of the jet airliner in the 1960s. In many markets, rail passenger travel was essentially replaced by air travel.

A turnaround began with the development of the high speed train (HSR), first pioneered in Europe and Japan. With improved track and new rail technology, the HSR provided an attractive alternative to air travel for cities that were not very distant from each other as was common in both Europe and Japan. Travel times became very competitive as much less time is spent at terminals and the rail terminals are typically located much more favorably within city centers, also contributing to faster origin to destination times for most passengers.

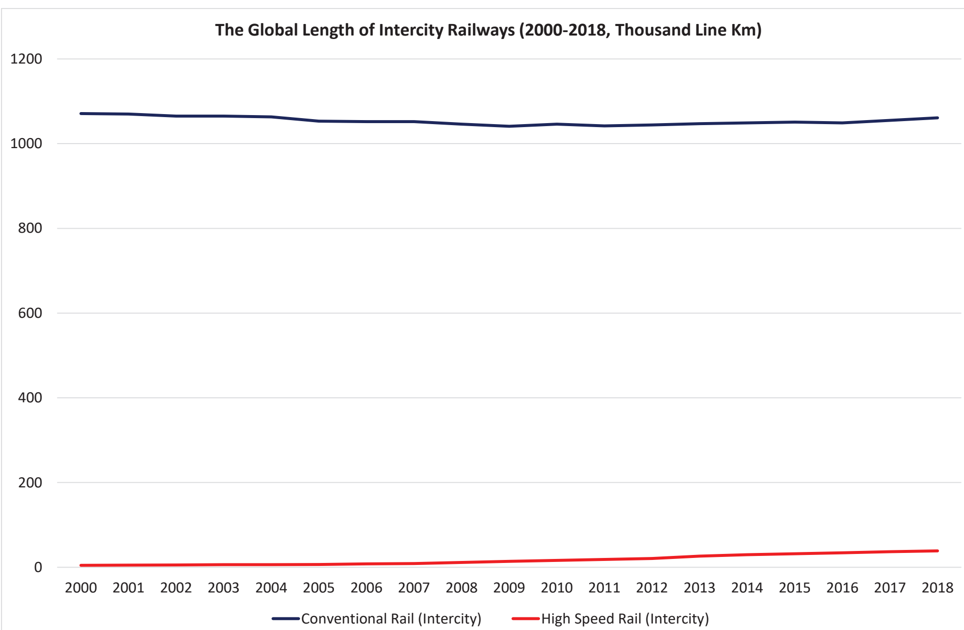
However, in countries with large distances among cities, the uptake of HSR is more challenging. Still, there are many markets in which relatively attractive HSR opportunities exist and investment is now occurring in many more countries. Only 600 billion Pkm out of 3,100 billion Pkm are served by high-speed rail (including urban rail) as of 2018. Today, China has the largest HSR infrastructure with over 41,000 km. It has been estimated that 17% of passenger flights could be served by rail, flights less than 1,200 km representing 5% of total aviation Pkm (UIC, 2018). Nonetheless, very large upfront investments would be required to accomplish this and not all routes, especially those that travel through heavily populated areas such as the U.S. East Coast can be serviced by HSR.[13]

For the last two decades, HSR system increased steadily from 4.6 thousand line kilometers in 2000 to 38.7 thousand line kilometers in 2018. On the other hand, conventional passenger rail services remained largely unchanged in this period, declining slightly from 1,071 thousand line kilometers to 1,061 between 2000 and 2018 (Figure 2.1). Despite the significant growth in HSR, the rail share in global passenger transport remained relatively constant. The main reason as to why the share remained unchanged was because intercity rail investments were realized during a decade of unprecedented increase in motorized mobility.

[13] For example, in the case of the U.S. East Coast, the percentage of travel distance between Boston and Washington DC during which a high speed train would have to slow down for safety reasons is very high and would significantly reduce average speed even if the investments to upgrade the rail line were carried out.

Urban Public Transportation: The share of intra-city road travel is also expected to decrease by improving public transportation services. In particular, more underground heavy rail systems (metros) are needed. These have enjoyed a renaissance that is expected to continue. Many cities that grew up without underground transit came to realize that it was needed to accommodate growth, reduce traffic congestion and lower pollutant emissions. With large expansions of high density office and residential real-estate development in many cities, efficient underground metros have become necessary to ensure connectivity for home-to-work commuting and other travel needs. In many situations, there is simply not enough real-estate available to expand roads and parking to accommodate the requirements of private auto travel. While buses can also be an alternative to private automobile use, traffic congestion often makes this mode of travel relatively unattractive and, in many markets, primarily serves customers that do not have access to private autos.[14]

Figure 2.1 The Global Length of Intercity Railways (2000-2018, Thousand Line km)

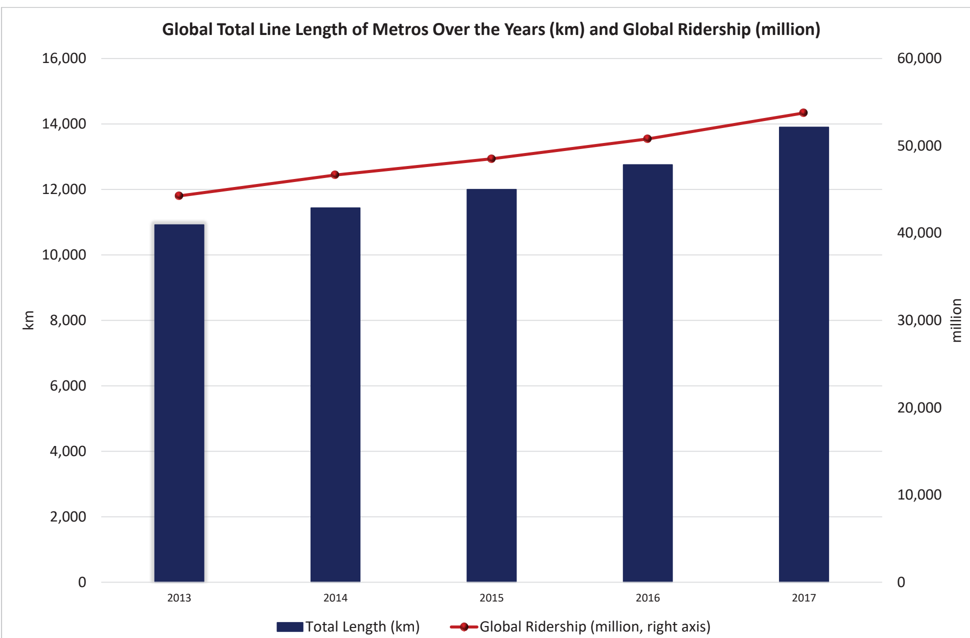


Source: IEA, 2020

[14] Bus rapid transit in which buses operate much like rail systems on their own right of way do provide service that is more comparable to Metro systems at a lower cost.

Since 2000, a total of 75 metros were opened globally. By the end of 2017, 56 countries had metros, serving 168 million passengers daily. Worldwide, 200 cities have metro systems with a length of 32 000 km. Over the last decade, the length of urban rail lines including both metro and light rail expanded 4% per year. Global metro ridership and investment to infrastructure has increased significantly and is projected to grow further in the developing world. The most robust growth in ridership between 2013 and 2017 occurred in the MENA region and Asia with 58% and 28% growth rate, respectively. In these regions, the significant increase in total line length of metros from 2013 to 2017 was largely due to China and India. At the end of 2017, metro infrastructure accounted for a total length of 13,903 km and total annual ridership grew to 54 trillion passengers up from 44 trillion in 2013 (Figure 2.2).

Figure 2.2 Global Total Line Length of Metros Over the Years (km) and Global Ridership (million)

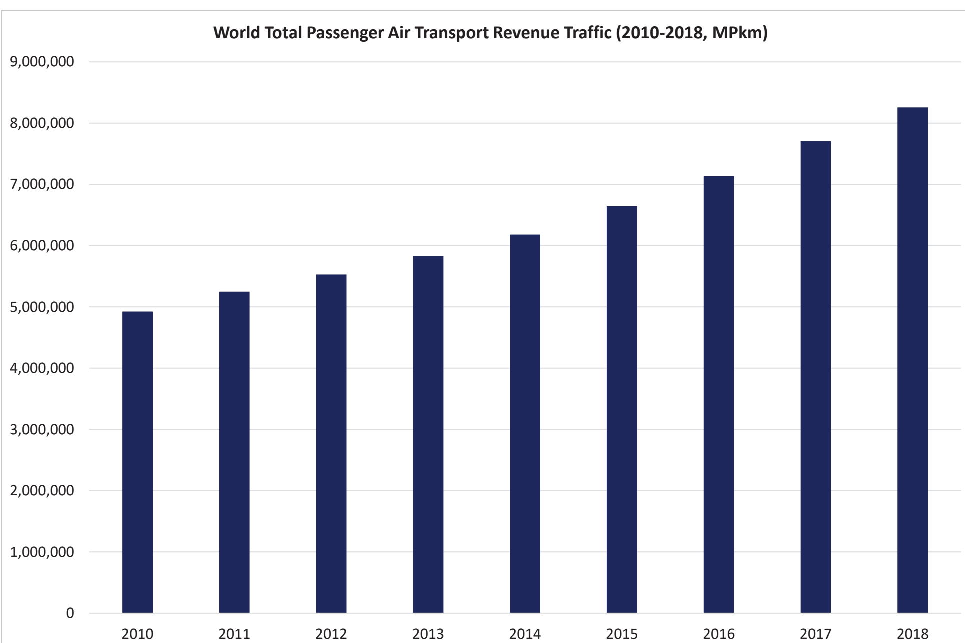


Source: UITP, 2018

Aviation: The demand for aviation transport increased more than two-fold since 2000. Total passenger activity surged by 6.1%/yr. to 8.2 trillion revenue passenger kilometers (RPK) by the end of 2018 (ICAO, 2019). Air transport has a relatively high fuel consumption per Pkm and fuel accounts for 20% to 30% of airlines' operating costs. By the end of 2018, airlines provided service to 22,000 city pairs. The total number of departures accounted for 37.8 million in 2018 and total passenger trips served were 4.3 billion (IATA, 2019). Strong air passenger demand is mainly underpinned by a solid global economic growth achieved over the last decade and gained further weight with robust financial outcomes. From 2010 to 2018, industry wide RPK increased by 68% (Figure 2.3). Continual improvements both in connectivity and in costs since 2010 have been instrumental in distributing benefits for consumers, suppliers as well as economies.

The aviation industry continues to emphasize more efficient engines and better aerodynamics in developing new models. Energy efficiency improvements have long been pursued to improve profitability given the high operating cost share represented by jet fuel. The aviation sector achieved substantial energy efficiency improvements per year by 2.9% from 2000 to 2016, an effort that needs to be sustained for better fuel economy (IEA, 2019b). These fuel intensity improvements of new commercial jet aircrafts are as a result of fleet renewal, as the industry continuously acquires newer and more efficient aircrafts. Additionally, the rise of low-cost airlines has led to lower energy use per passenger (ICAO, 2019). Increased aircraft utilization is one of the reasons for improved energy efficiency.

Figure 2.3 World Total Passenger Air Transport Revenue Traffic (2010-2018, MPkm)



Source: ICAO, 2018

Aviation is the second-largest transport sector GHG emitter after road transportation. From 2013 to 2018, CO_2 emissions from aviation have grown by 32%. CO_2 emissions from commercial passenger and freight operations totaled 918 million tons in 2018 representing 2.5% of global energy-related CO_2 emissions (ICCT, 2019).

Private Cars: Despite the potential for the growing share of high-occupancy alternatives, the private car is the leading mode of passenger travel and may remain so for the foreseeable future. After 8 years in a row, continuous growth achieved in global auto production reached at a record level of 96 million vehicles by the end of 2018 (OICA, 2019). Demand for motor vehicles from both business and individual consumer markets is expected to be further stimulated due to higher disposable incomes particularly in developing economies. However, demand growth in many mature economies is expected to remain low due to high ownership rates per population that have already been achieved.

Compared to urban public transportation or intercity rail, passenger cars consume a high amount of fuel per passenger kilometer. Growing environmental concerns are forcing the auto industry to modify their product portfolios and business models. Consequently, manufacturers are using more advanced fuel efficiency technologies that are required by stricter national regulations and responding to consumer demand for more sustainable auto technologies.

While major automakers are introducing new electric car models at a regular pace, there has been growing interest for Sport Utility Vehicles (SUVs) in recent years. The share of SUVs in total car sales have been on the rise and the growth trend of SUV's has become universal. In 2019, 50% of the cars sold in the United States and 36% of the cars sold in Europe were SUVs. In China, SUV sales have increased from 14% to 44% and also surged in India from 11% to 34% from 2010 to 2019 (IEA, 2019d, 2020). The global market share of SUVs increased to 41% in 2019. Consequently, after the power sector, SUVs alone has become the second-largest contributor to the increase in global CO_2 emissions given that average fuel consumption of a small SUV is 15% higher in comparison to a medium size car (IEA, 2019d & 2020).

Road electrification is another major trend and automakers are increasingly favor electric-powered vehicles in many regions, particularly in Europe, the U. S., and China. As government programs continue to gain momentum in promoting a move away from fossil fuels, these policy measures and incentives can further support the development of electrified vehicles also supported by a growing ecosystem around electrification including energy players, utilities, charging infrastructure and consumers. Innovations in the passenger vehicle manufacturing industry target increased navigation capabilities, internet connectivity and advancement in safety features. Likewise, semiautonomous and other related technological progresses are becoming staples of automobiles worldwide. The continued penetration via technological advances into new markets is likely to propel revenue. These will provide the base for future evolution of the global automobile manufacturing industry.

2.1.3 Key Trends in Freight Transport

Road transport remains by far the dominant means of freight travel. Freight travel within urban areas is exclusively provided by trucks while rail, marine and aviation modes are also important for shipments outside of urban areas. Freight activity depends on the underlying industrial and commercial structure that determine the types of commodities or manufactured products that need transport. The mode choice then depends on cost competitiveness and customer requirements. It is expected that freight transportation will be a more important factor that drives the future of global energy consumption. Emissions from the transport sector have been steadily rising and remain a major challenge. Due to heavy reliance on oil products that cannot be easily substituted with current technology, transport sector emissions are projected to increase at a faster rate than from any other sector, posing a challenge to the efforts to lower transport's carbon footprint. From 2000 to 2018, transport emissions grew by 38% and accounted for over 22% of global CO_2 emissions in 2018 (Figure 2.4). Transport energy consumption is projected to grow in both developed and developing countries. A strong increase in CO_2 emissions mainly stem from road vehicles, which accounted for 72% of global transport emissions. Mitigating truck emissions remains a major environmental challenge as trucks produce 36% of total transport CO_2 emissions while rail and maritime shipping combined only produce 2% of total transport CO_2 emissions. The continuing dependence on truck freight may make it more difficult to significantly reduce world oil consumption and associated CO_2 emissions (IEA, 2019b).

Figure 2.4 Energy Related CO_2 Emissions in the Transport Sector & Other Sectors (2000-2018, GT)

Source: ICAO, 2018

Marine shipments account for 11 billion tons/yr. and are growing at 2.6%/yr. while consuming 7% of transport energy (IEA, 2019b). Asia is the most important source of marine shipments accounting for 41% of loaded goods and 61% of unloaded goods[15] (UNCTAD, 2019). The marine fleet consists of over 95 thousand ships or 2 billion dead-weight tons of capacity. Bulk carrier vessels are 43% of the marine fleet and oil tankers 29%. Oil trade is particularly important with over 1.9 billion tons shipped per year until the Covid-19 pandemic. The pattern of oil trade has shifted away from Mid-East exports to Europe and the United States and these oil exports are now mainly headed to Asia. Asia's rapidly growing economies over the last decades, fuel efficiency gains and stagnating auto ownership in the West all contributed to this change in oil export patterns even before the more recent surge in U.S. oil production.

Besides the rapid growth of oil trade that began in the 1970s, the fast growing economies of the developing world have led to surges in shipping traffic. These motivated significant shipping investments on expectations of continued growth. With over a decade of slower world economic growth, the shipping industry has experienced chronic oversupply in most segments, causing freight rates to be highly competitive. Due to depressed market conditions and poor financial returns, many container shipping companies have adopted coping strategies through mergers and acquisitions, consolidation, vertical integration and changes in deployment patterns. Even prior to Covid-19, oil tanker traffic declined by 1% over the prior year by the beginning of 2019. Besides rapidly declining oil imports into the U.S., part of the reason is that there have been more petrochemical investments by oil-producing countries shifting some oil shipments to chemical tankers which were growing at 4%/yr. LNG shipments have also experienced high growth as new liquefaction capacity has come online, in particular in Australia and the United States, and was growing faster than 7%/yr.

The maritime transport landscape is changing and shifting with the rollout of a new set of rules and conditions. As of 1 January 2020 a new International Maritime Organization (IMO) regulation lowered the sulfur cap for diesel fuel or fuel oil used in ships from 3.5% to 0.5%. This regulation, causing somewhat higher fuel costs, or requiring investments for sulfur scrubbers (to allow the old fuel to still be used), will have an economic impact on maritime transport. However, even before the Covid-19 pandemic, the initial impact on fuel prices turned out to be relatively modest and much lower than many analysts were anticipating. While most maritime shipping involves large container ships serving international commerce, in some countries coastal and inland waterways can provide an energy-efficient alternative to truck shipping. Therefore, short sea shipping is an opportunity for states having a widespread coastline (OECD, 2019).

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[15] Seaborne trade is measured by the volumes, in metric tons, of goods loaded and unloaded. Goods loaded for international shipment are assumed to be exports, while goods unloaded from ships are assumed to be imports. In 2018, developing countries continued to account for most global maritime trade flows, both in terms of exports (goods loaded) and imports (goods unloaded), that is, who generates the trade and where it goes (UNCTAD, 2019).

Rail freight is projected to develop less than shipping and road freight transport in the coming decades (IEA, 2019a). The modal share of rail in surface freight is expected to decline from 28% in 2017 to 23% by 2050. The improvement in road infrastructure over the years and logistical advantages of road freight shipments are some of the reasons why road freight transport is expected to gain relative to rail freight. As of 2017, rail accounted for 7% of global freight activity, and this figure is projected to shrink to 5% in 2050. Rail freight is estimated to account for 21 trillion Tkm in 2050, the majority of which occurring in China, Russia and the United States (IEA, 2019a).

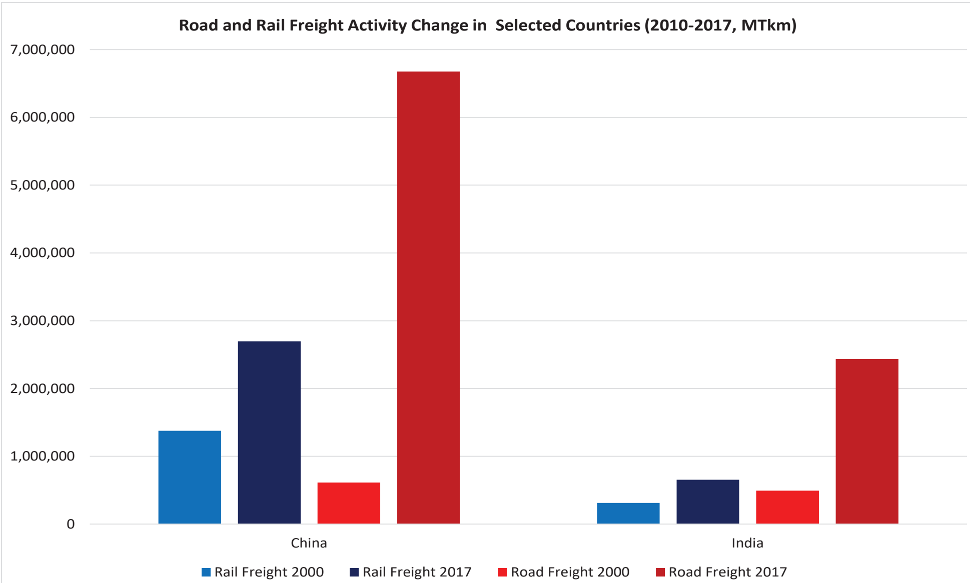
2.1.4 Mode Shifts

Modal shift is a key energy policy objective in the transport sector as it allows more freight or passengers to be carried by the most efficient modes. There are many factors influencing the choice of transport modes and many reasons these choices are sometimes difficult to change. Key determinants for moving urban passengers to high occupancy modes include urban density, the availability, convenience and desirability of public transit alternatives, journey characteristics, car ownership and traffic congestion. Modal shift is usually easier to achieve in urban travel than intercity travel. For example, offering travel alternatives that avoid traffic congestion and faster travel can motivate mode change. In addition, use of private car is often impractical or expensive due to limited parking. Consequently, there are many measures that can increase high occupancy modes employing new infrastructure, shared mobility and restrictions on vehicle access or parking.

Shifting passengers away from intercity road travel can sometimes be more difficult especially when families are traveling together as private automobile is often the least expensive and convenient option. As discussed above, the expansion of HSR services can attract travelers away from road and shorter aviation routes. With sufficient government support, expanding HSR can move intercity travelers to the most energy efficient and cleanest mode of travel.

Road Freight to Rail Freight: Balancing modes in freight is more challenging than passenger transport. Shifting from trucks to rail has been a long sought-after policy, first to reduce national oil use and then to reduce CO_2 emissions. Nonetheless, as commerce has trended from commodities to manufactured products and a premium is placed on fast delivery times, rail freight has struggled to maintain its market share. The majority of rail freight activity is concentrated in a few countries, mainly in the U.S., China and India (IEA, 2019a). Rail freight in China and India doubled from 2000 to 2017 increasing by 96% and 109%, respectively. However, as large as these increases in rail freight were, during same time period, the road freight activity surged by ten-fold in China and four-fold in India (Figure 2.5). The activity growth in these countries is broadly linked to the strong export-oriented nature of their economic growth which will continue to influence future demand for road freight.

Figure 2.5 Road and Rail Freight Activity Change in Selected Countries (2010-2017, MTKm)

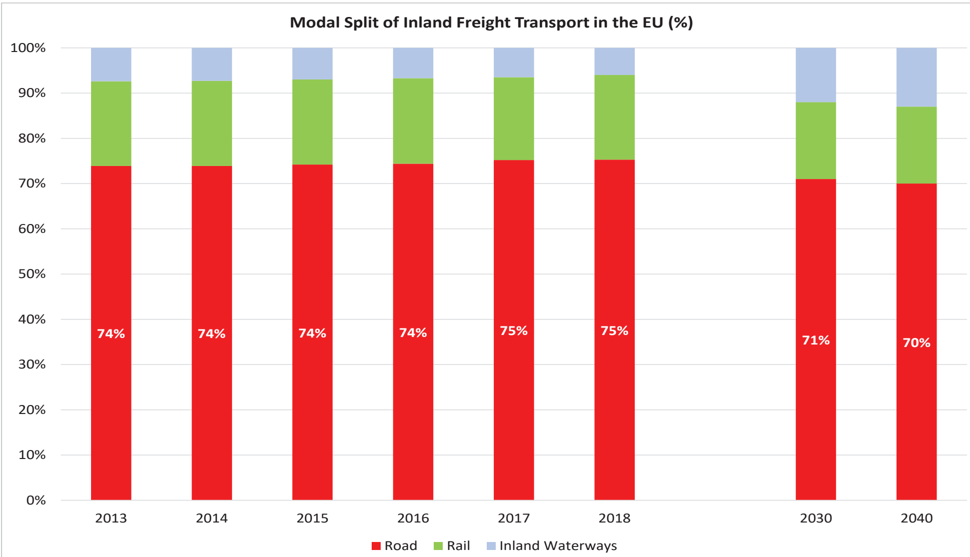


Source: OECD, 2020

The EU is another example of road to rail competition in freight. Road transport has the largest share of EU freight and accounts for three-quarters of the total inland freight transport, followed by rail at 19% and inland waterways at 6% of Tkm (Figure 2.6). From 2013 and 2018, the share of rail in inland transport remained largely stable while the share of inland waterways in EU freight declined from 7% to 6% (Figure 2.6). There is a vast difference among the Member States in terms of modal splits. For example, the share of rail freight is 74% in Latvia, 68% in Lithuania and 45% in Estonia while only 5% in Spain, 6% in the Netherlands and 2% in Greece (Eurostat, 2019).

Although mode shifts to rail freight saves energy and reduces the emission footprint, change is difficult for a variety of reasons, including the front-loaded capital expenses to build rail infrastructure, the shipping flexibility offered of trucks, the decreased share of bulk commodity shipments that railroads best serve and the increased need of fast deliveries. As these trends are likely to continue, the reliance on trucks is set to increase. Efforts to increase rail's share could cause energy efficiency and emission benefits but money for long term investments is difficult to justify in terms of economic returns especially considering competition from trucking companies that already enjoy an established road network.

Figure 2.6 Modal Split of Inland Freight Transport in the EU (%)



Source: Eurostat, 2020

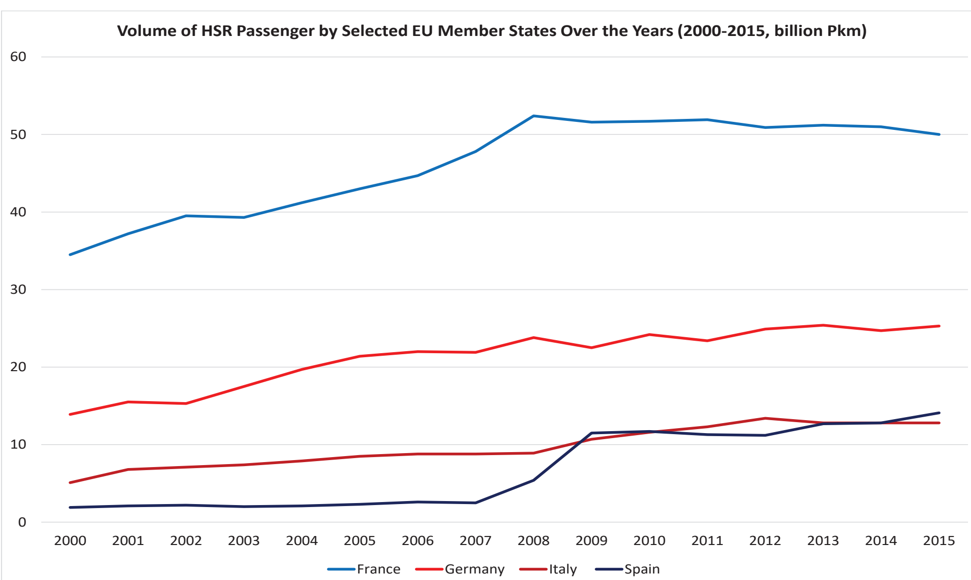
Intermodal Shifts to Passenger Rail: Expanding infrastructure provides an opportunity to attract passengers to fast and comfortable rail services. In some regions, railways are in competition with aviation based on travel costs, time and comfort levels. High speed rail (HSR) is the main way railways can offer more attractive service than aviation for many of the closer city pairs. Nonetheless, rail investments take time and require high capital spending which is often magnified by the complexity of the route's geography. In highly dense population areas, the speed advantages of HSRs can be lost due to safety considerations.

HSR in Europe: The EU is one example of an ambitious HSR expansion programs that has led to increasing HSR use (Figure 2.7). The share of EU rail passengers traveling on HSR's increased from 18% in 2000 to 28% in 2015. This was a result of large investments, particularly in France, Spain, Germany and Italy. The share of HSR passengers in total rail traffic in France and Spain accounted for 56% and 54% respectively. In Germany and Italy, the HSR passengers represented 28% and 24% of total rail passengers, respectively (ECA, 2018). Despite these HSR developments, it is worth noting that the rail density and overall geographical distribution of the rail infrastructure in each of these countries do not alone account for HSR's success. Also important are frequency of service, population density, household composition, destination distance, travel time and costs, traveler's income levels, share of business travel and competition.

Since 2000, the EU has been investing €23.7 billion into HSR infrastructure. The most extensive networks are in Spain and France, followed by Germany and Italy. While the world's first HSR rail line was built in 1964 in Japan, the world's second HSR line opened in Italy between Rome and Florence in 1977. Italy now has two lines: one connecting Turin and Venice and the second linking Milan to Salerno (Table 2.1). France built the world's third HSR system. Referred to as TGV (Train à Grande Vitesse) with the first line opening in 1981, between Paris and Lyon. Encouraged by HSR in France and Italy, German leaders made high-speed rail a national priority. As a result of political demands and a denser population, Germany's HSR service has been developed to connect many hubs.

The EU's recent policy targets are to triple the length of its HSR network by 2030 and have a 100% HSR network by 2050 (EU Commission, 2011). Moving forward towards these ambitious targets, the EU introduced another in 2013, the Connecting Europe Facility, as an instrument to remove the bottlenecks through enhancing rail interoperability, bridging missing links and improving cross-border sections connecting countries (EU Council, 2013). However, HSR investment depends on public subsidies and will continue to be controversial due to its high construction and operational costs and avoiding unaffordable ticket prices for many potential users. Consequently, higher operating subsidies to keep ticket prices affordable and competitive could be required to maintain the necessary occupancy levels. The construction cost of a HSR project is influenced by line design speed, topography, land acquisition costs, use of viaducts, and the construction of major bridges and terminals. Despite the costs and challenges, the motivation remains that HSRs can provide more convenient, faster and cleaner travel than other transport modes among a wide variety of city pairs that still do not have HSR services.

Figure 2.7 Volume of HSR Passengers by Selected EU Member States over the Years (2000-2015, billion Pkm)

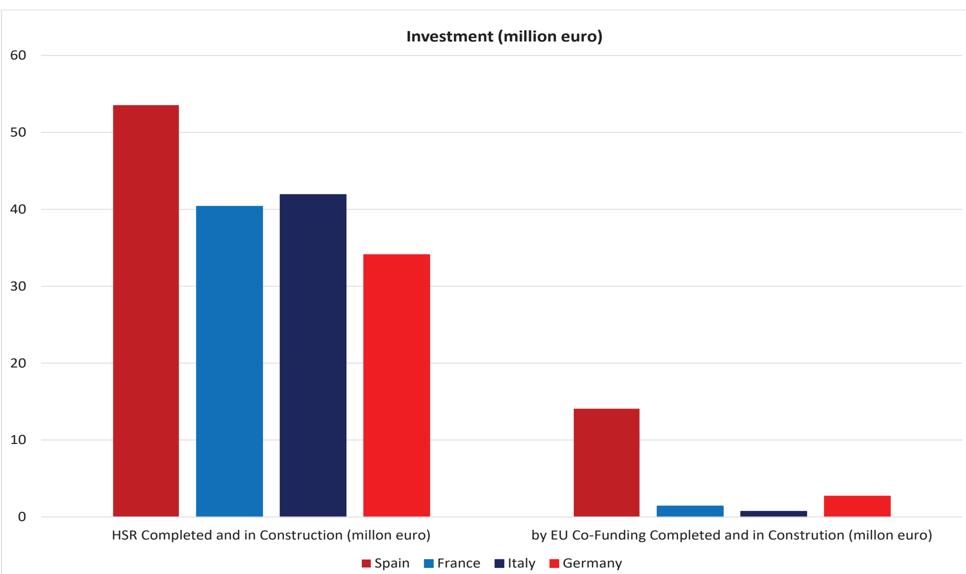


Source: OECD, 2020

The EU is also finding it difficult to transform national rail monopolies into a market in which operators compete across borders. On the contrary, national rail firms prefer to collaborate rather than to compete. To rally for political support for the national rail operators for privatization is surely not an easy option[16] especially since HSRs are subsidized including not only capital investments but also operating expenses. In addition, competition from other modes of transport has been rising as low-cost airlines are expanding and the market for long-distance coaches are being liberalized[17].

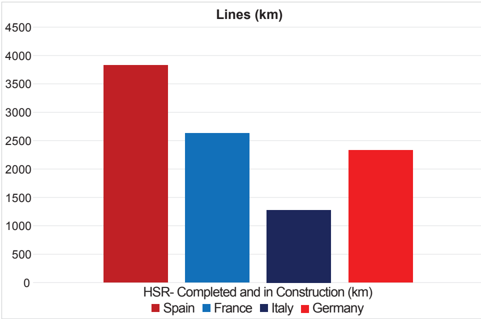
National investment data for HSR networks in Spain, France, Italy and Germany are presented in Table 2.1. National networks have different characteristics but a typical cost is over € 10 million/km (Figure 2.8). EU co-funding provided for up to a quarter of total construction cost in Spain and about 10% in Germany. The lines constructed before 1990, when land prices were lower, had lower construction costs. Generally, Spain's and France's construction costs are lower than Germany's or Italy's. This is a result of the hub and spoke network and the earlier construction dates. It is not a coincidence that the two most fiscally successful lines, Madrid-Galicia and Barcelona, have the two lowest construction costs per km (Table 2.1). Typically, the first high-speed rail line a country builds makes the most economic sense. Providing an HSR system, however, requires that other city pairs are served even though their cost and revenue parameters are not as attractive.

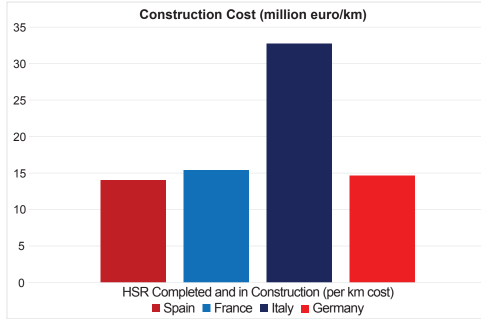
Figure 2.8 The HSR Investment Figures in Some European Countries



16 While Italy is considering at least a part-privatization of Italian state-owned railways, in France privatization so far has not been an option at all. In Germany, privatization idea is quietly shelved without realization. While high-speed rail largely stays under the control of state monopolies, its chances of becoming a successful and competitive private business looks sluggish so far.

17 Germany opened up its coach market in 2013. A similar liberalization is being proposed in France





Source: ECA 2018 [18]

Data on the cost per km for particular high speed lines and ticket prices for those lines is shown in Table 2.1. Airfares for the same roundtrips can either be higher or lower showing no particular pattern. Data is not available on rail operating subsidies for these lines, adding to the difficulty to determine whether HSR is cost competitive with air travel based on the available information. In any case, HSR is well established in Europe providing high quality and sustainable transportation between many city pairs.

Table 2.1 Investment Costs, EU Funding and Ticket Costs on Selected High Speed Lines

Line	Total Length (km)	Total Cost (billion euro)	Final Completion Cost per km (million euro)	EU Funding (million euro)	Price of HSR Round Trip (euro)	Price of Plane Round Trip (euro)
Berlin-Munich (Germany)	671	14.7	21.9	734	257	214
Stuttgart-Munich (Germany)	267	4.9	49.7	288	84	210
Rhin-Rhone (France)	138	2.6	18.8	207	93	N/A
LGV Est Europeenne (France)	406	6.7	16.5	331	152	285
Madrid-Barcelona (Spain)	797	12.1	15.2	3553	239	164
Eje Atlantico (Spain)	165	2.6	15.7	418	37	N/A
Madrid-Leon (Spain)	345	5.4	15.7	2118	77	N/A
Madrid-Galicia (Spain)	549	5.7	13.7	440	130	154
Turin-Salerno (Italy)	1007	32.2	31.9	530	212	95
Milan-Venice (Italy)	273	11.9	43.4	178	96	195

Source: EC, ECA, Rail Europe

[18] In its Special Report No 19/2018, the Court of Auditors of the EU suggested that there is a high risk of ineffective spending of EU co-funding on HSRs.

Outside of Europe, China is planning to develop the largest HSR network in the world. China's rationale is that HSR will relieve the pressure of passenger demand on its overcrowded existing rail system, improve transportation connections between the country's different regions and promote the economies of less developed regions. Currently, China is upgrading existing lines and building new dedicated electrified lines. Many other countries are also developing HSRs or expanding their existing HSR networks.

HSR could deliver further modal shift in specific transport demand segments, but at the cost of large investments. Compared to conventional lines, totally new dedicated HSR lines require infrastructure with specific characteristics and technical requirements, such as heavier superstructures, more resistant catenary system for electricity supply and an advanced on-board signaling system to ensure adequate headway and safety levels. HSR design constraints together with the characteristics of the territory crossed may, and more often than in the case of conventional lines, need viaducts, bridges and tunnels, therefore leading to a higher cost per kilometer of infrastructure built. The construction cost of totally new infrastructure can be significantly higher compared to upgrading a conventional line (EP, 2018).

In general, HSRs provide consumers an attractive mode choice especially for intercity travel up to 600 km compared to traveling by air. In particular, high speed services over those distances may divert a significant share of passengers traveling by air. Nevertheless, the development of HSR alone does not seem to be sufficient to shift significant volumes and passengers from road to rail where the costs of a high occupancy car per passenger are low. Due to the high costs of HSR investments, they should be carefully evaluated to avoid particularly expensive new HSR expansions. That might favor upgrading selected existing rail networks, where the potential to improve service at a reasonable cost is greater.

Modal Shifts in Urban Passenger Transport: As cities expand and traffic congestion soars, governments and municipalities are increasingly seeking alternatives to encourage public transport. Light rail, tram and metro systems are the most widely implemented alternatives to urban individual transport. Although they provide benefits to lower congestion, air and noise pollution and a cheap alternative per mileage compared to private cars, behavioral decisions of commuters would be a limiting factor for their expanded use absent any incentives. Therefore, many countries have started to introduce programs to support wider use of public transport including rail transit, high occupancy road and marine[19].

Securing a successful urban transport system in any city is a multifaceted task that requires a clear vision, sound policies, specific plans, and effective institutions. A precondition for substantial use of public transport is to provide accessible, comfortable, fast and high

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[19] For example, Luxembourg has become the first country to make all public transport free as of March 2020 driven by congestion and pollution related challenges. Fares on trains, trams and buses lifted. This is one step forward from the introduction of free transport for commuters under the age of 20 starting from 2018. Free use of public transportation covers both residents and non-residents over the whole country. France is another example introducing a sustainable mobility package in 2019 to assign the employers to cover the travel costs of employees who choose to commute to work either with bike or with car pool. The policy measures also support the use of self-service vehicles, for example scooters, motorcycles and cars.

quality connections from door to door. Knowledge and expertise are required on all aspects of local public transport ranging from market analysis to planning and implementing network and infrastructure as well as clean fleets, financing, operation and management. In most cases, cities are held responsible for local infrastructure for all types of public transport systems. A high quality public transport system requires reliable, frequent and fast passenger service and the ability to serve both the elderly and passengers with disabilities.

Metro vs. Buses: A number of technologies can help make public transport more sustainable. A choice between bus and underground systems is a complicated task and several variables should be taken into consideration while choosing the most plausible option. While buses have a high degree of flexibility in the routes they serve, they have a limited carrying capacity and their performance is often undermined by traffic congestion. Underground metro systems have a relatively high carrying capacity but no flexibility with respect to the routes they serve. They also cost considerably more than bus systems. A choice between these options is often challenging. Cities that have linear and long travel distances, with limited alternative roads, have often found metro rail systems to be attractive additions to bus services. Cities with difficult terrain and severe gradients have often found metro rail systems more difficult to build. Sprawling cities that need a spread out and diffuse public transport network often find that bus-based systems are the only practical alternative. In cities with tall building bylines and narrow streets, underground metro systems are needed to carry a high share of passenger travel (UITP, 2018).

Reducing Auto Travel: The biggest challenge in urban public transportation is to lure passengers out of their private cars. In cities, fast and reliable public transport options like tramways and metro lines are an attractive alternative to travel by car. It is also important to consider the total trip rather than the characteristics of one modal leg. That's often where coaxing drivers out of their cars becomes the most difficult. Commuters and other travelers want to travel seamlessly between transport modes for an efficient journey that takes no more time than by traveling by car. In many cities, the main purpose of public transportation is to provide mobility to people who do not have access to cars. While that is a social obligation, overcoming that image is a key challenge to diverting drivers to public transportation especially when public transportation services are of a poor quality, partly because they serve a captive ridership.

The growth of cities is making the public transportation question more urgent in many more places than before. Fewer and fewer cities can get by simply by expanding roadways to accommodate urban and suburban developments. High traffic congestion results causing the performance of private auto transport to severely deteriorate. In addition, air quality often gets worse as more cars attempt to use limited road space and take much more time to go from point a to point b. Even without considering increased GHG emissions, the public typically demands urban public transportation solutions, however difficult they may be to bring about, especially as public opposition and costs mount against the old solutions to construct newroads.

It becomes clear that improved bus service and the expansion of light rail, metro and suburban rail are, in some combination, necessary (EP, 2018). Metro systems generate high ridership and are popular although high capital and operating costs as well as long construction times are barriers to their expansion

During the 1990s, public transport projects that were less capital-intensive, such as light rail transit (LRT), were planned and constructed in different regions, namely Europe, North America and Japan. The LRT systems worked well in some regions where land use and transport planning were often well connected (IPCC, 2020). Around the world, the concept of bus rapid transit (BRT) is gaining much attention as a substitute for LRT and as an enhancement of conventional bus service. BRT is a mass transit system using exclusive right of way lanes that mimic the rapidity and performance of metro systems but utilizes much less expensive buses and bus right of ways. The BRT systems can be seen as an enhanced bus service and an intermediate mode between conventional bus service and heavy rail systems. Most BRT systems today are being delivered in the range of $1–15 million/km, depending upon the capacity requirements and complexity of the project. By contrast, elevated rail systems and underground metro systems cost from $50 million to over $200 million/km (IPCC, 2020).

Much less expensive opportunities also exist to improve public transportation. For example, the Panjin Municipality in China replaced all of their diesel buses with 60 natural gas and 80 electric-hybrid buses causing reduced air pollution and lower GHG emissions. Improved bus performance measures resulted in a 30% increase in passengers (150 thousand people) improving revenue as well as the bus company's finances (WB & ESMAP, 2014).

Singapore provides a good example of effective urban transportation planning. Singapore manages its transport problems in a holistic way with high quality public transport, effective integration of land-use and development and execution of long-term transport plans. Land-use and transport planning have been connected effectively through a participatory process of developing a long-term concept plan for the city with shorter term investment plans. Easy access to mass transit is available. Fare card systems have provided integration between modes and transfers in a convenient way. There are stringent restraints on the ownership and use of personal cars. Ownership is constrained by strict requirements. To buy a car one needs to first acquire a Certificate of Entitlement through an auction process which often results in additional costs equal to the price of a car. The imposition of stringent demand-restraint measures has been in use for many years as Singapore was one of the first cities in the world to employ them many decades ago. Under their pioneering system, road users are charged at a varying degree between peak and off-peak times (WB & ESMAP, 2014). Clearly, not all of Singapore's solutions are applicable more broadly as Singapore is geographically unique and the population is much more inclined to support the restrictions on automobile use than would likely be found in most other cities. However, it is worth noting that variable road user fees that reflect traffic congestion is beginning to take hold in other cities. However, regardless of the particular solutions employed in Singapore, the holistic planning process is a good model for all.

2.1.5 Improving Motor Vehicle Fuel Economy

Improving motor vehicle fuel economy has been a public policy focus for 50 years along with reducing the urban air pollution associated with motor vehicle use. However, in many countries, passenger vehicles have become larger and more powerful. SUV and light truck sales have also increased. Consequently, vehicle fuel efficiency has experienced two opposing forces. Fuel economy technology has significantly improved over the years. This would have had a larger effect to improve overall vehicle fuel efficiency had it not been for the sales trends toward these larger more powerful vehicles that have "used up" the benefits of fuel economy technologies. This dilemma can partly be explained by unfortunate timing. Policies to improve fuel efficiency were introduced by several countries during the 1970s to increase national oil security and to reduce growing oil import expenses. The global automobile industry then made great strides to introduce fuel efficiency technologies, some of which were enabled by the digital technologies needed to meet new pollution standards that were being introduced during the same period. However, as these technologies began to become more advanced and commercially available during the 1980s, oil prices collapsed. The drive to improve fuel efficiency then stalled. In particular, fuel efficiency requirements were not updated during this decade to reflect the rapidly growing technological opportunities to improve fuel efficiency. This explains why, in many countries, technological advances were "spent" on larger and more powerful vehicles instead of more fuel-efficient ones.

More recently, fuel efficiency policies have been reinstated or strengthened. Countries with effective regulations along with efficiency-based fiscal incentives have improved overall fuel efficiency 60% earlier when compared with countries without such policies (IEA, 2019e). Fuel efficiency is greatly affected by the types of vehicles that are typically purchased in different countries. Many countries have a tradition of using smaller compact vehicles and this leads to a more efficient vehicle fleet, particularly in most of Europe, Japan and South Korea. However, despite the major improvement attained in recent years in fuel consumption within each vehicle classification (subcompact, compact, etc.), the growing market share of more energy intensive SUVs and pick-ups are increasingly taking place at the expense of the smaller, more fuel-efficient passenger cars. The rapid drop of diesel sales in European markets is also impeding progress until more efficient gasoline or gasoline hybrid models are available (IEA, 2019b).

Fuel efficiency/carbon regulations not only promote more fuel-efficient internal combustion vehicles but are often set at levels that cannot realistically be met only with fuel efficiency gains. These standards also require that manufacturers sell battery electric vehicles (BEVs) which earn credits that can be counted towards fuel efficiency/carbon compliance. Fuel efficiency standards that provide incentives for BEVs are now in place in the United States and the EU. The EU Clean Vehicles Directive also sets requirements for electric vehicle charging infrastructure. Other initiatives such as the EU's Clean Mobility Package show a commitment to limit the market share of petroleum vehicles in Europe. India announced an electric vehicle policy, reducing the purchase price of both hybrid and electric vehicles. Korea is using BEV subsidies, rebates, public procurements and reduced highway tolls for BEVs. China and Japan use a variety of mechanisms including standards and financial incentives to purchase BEVs, plug-in hybrid electric vehicles (PHEVs) and hydrogen fuel cell vehicles (HFCVs). While these efforts are important for improving oil use and combating climate change, they are likely to have a relatively limited impact on the fastest growing source of transport oil consumption; trucks.

As a key enabler of global economic activity, the road freight vehicles play an essential role in delivering all types of goods or commodities from their points of production to their final points of use. There is a large variety of road freight vehicles that serve very different purposes. Road freight vehicles account for around one-fifth of global oil demand. Depending on their load characteristics, trucks vary both in size and weight. While many different types of road vehicles transport goods, two-thirds of road freight is served by heavy trucks. Over the past two decades both medium freight trucks (MTFs) and heavy freight trucks (HTFs) have grown at a rapid pace in Africa, China, India, Latin America and the Middle East, as the economies in these countries and regions have risen. The rise was more significant for MFTs in China, ASEAN member countries, and in Africa. In some regions, individual truck fleets are small and the markets are fragmented. In Asia, the trucking sector is essentially unconsolidated where 90% of trucks are owned by their drivers while only 0.1% are owned by companies (IEA, 2017).

As the global economy expands, trucking activity and oil use are also increased. In comparison with passenger vehicles, policies and standards for improving energy efficiency and the emissions intensity of road freight vehicles have not yet been broadly implemented. In contrast, fuel efficiency and environmental standards apply to 80% of the sales of global passenger vehicles. Policy coverage for heavy-duty vehicles (HDVs) still lags behind that of light-duty vehicles (LDVs). With the adoption of a new set of policies in India in 2018, and in the EU in 2019, over 50% of HDVs sold worldwide will be covered by fuel economy and CO_2 emissions standards. These substantial regulatory opportunities adopted in different parts of the world aim at decreasing energy use and air pollution from trucks both in developing and developed energy economies. While regulating the efficiency of road freight vehicles has been more challenging, and has taken longer, it should have an important impact on fuel use, CO_2 emissions and local air pollution (IEA, 2017).

Efforts to make trucks more efficient are worthwhile but may be limited by the fact that a good share of the world fleet has already achieved efficiency improvements due to their good payback, particularly in developed economies and in more integrated truck fleets. Truck characteristics are already well suited to their tasks and fuel efficiency has often already been exploited as a way of increasing profits for the truck industry. Therefore, there is less scope for regulatory action to improve fuel efficiency in many advanced economies. Consequently, deeper energy and CO_2 emissions savings in truck freight will likely have to come from a switch to non-petroleum fuels and engines.

Heavy trucks will continue to remain a key segment of global oil demand growth. Vehicle types, length and weight limitations, types of cargo as well as driving conditions and necessary fueling infrastructure are all influenced by policy instruments and customer preferences. In spite of recent efficiency improvements, optimization of road freight vehicle operations, tightening fuel economy standards, and advancement of digital technologies and their applications in supply chain and fleet management, increased heavy truck fuel consumption will continue to drive global oil demand growth. Nonetheless, continued emphasis on technological developments and policy actions are necessary to produce incremental fuel savings. These are important to at least limit the growth of transport oil demand.

2.1.6 Electric and Hydrogen Vehicles

As mentioned above, revised standards to improve motor vehicle fuel efficiency are also providing an incentive for manufacturers to market BEVs, PHEVs and HFCVs as they provide credits that can be applied towards compliance with fuel economy or CO_2 emission standards. A large number of other incentives are also in place or being introduced to subsidize vehicle purchase costs, support for recharging and refueling infrastructure and other incentives, for example, access to "fast" lanes that are reserved for high occupancy vehicles or reduced charges on toll roads.

Thus far, the most important developments in alternative fueled vehicles are BEVs, PHEVs and HFCVs.[20] The penetration of BEVs and PHEVs is on the rise all around the world with the total fleet of BEVs and PHEVs of 5.1 million reflecting a strong expansion (doubled in one year) due to government policies and interest from many consumers. While HFCVs have only been sold in much smaller numbers, for a variety of reasons discussed below, they are expected to also play a large longer-term role in reducing the transport sectors high dependence on petroleum fuels.

BEVs/PHEVs: Electric vehicle sales have been concentrated in China, the United States, Europe and Japan. Within these four regions that represent 97% of total sales, core growth markets are still concentrated within a number of cities with 25 EV capitals representing 44% worldwide EV sales. The leading EV capitals possess a set of 'carrots' and 'sticks' policies. These include not only Federal carbon regulations and fiscal incentives but local benefits such as free parking, unrestricted access to high-occupancy lanes or tollways and the unmeasurable but tangible ways to show users' commitment to a clean environment by driving a BEV. Nonetheless, BEV uptake so far represents a very small percentage of all vehicle sales (less than 1% in 2018) (IEA, 2019c). It is yet to be seen how deep the consumer acceptance of BEVs will be. Factors affecting consumer acceptance are typical driving patterns, the ability to provide home recharging, the recharging infrastructure that exists in the areas that are typically driven and the value that the average consumer will place on purchasing vehicles that have a low carbon footprint. Consumer acceptance can be greatly stimulated by government's fiscal policies, especially in countries that have high excise taxes on motor vehicles.

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[20] Biofuels have also made high penetrations into important fuel markets, notably the United States and Brazil, but this topic is discussed in Chapter 3 (Oil) because almost biofuels used today are blended into petroleum motor fuels and used by conventional vehicles.

Despite a promising outlook for strong growth in the next few decades, there are four major challenges that stand against the wider deployment of electric vehicles: the lack of charging stations, high up-front costs, long re-charging times and consumers' "range anxiety". Charging stations are not only very few and often far between, lack of standardized charging and payment systems are issues that need to be resolved. Due to the high battery costs which can take up as much as 50% of the total vehicle cost, high up-front costs make electrical vehicles still less attractive when compared with traditional internal combustion engine cars. Despite cost of ownership benefits offered by less expensive electricity costs compared to diesel or gasoline per kilometer travelled, achieving better performance and lower battery costs require introduction of more efficient battery technologies at reduced costs on a continuous basis. From 2010 to 2018, battery demand increased by 30% annually at a global level and reached 180 GWh in 2018. Global battery demand is expected to grow by 25% annually, reaching at 2,600 GWh in 2030. A large majority of battery production serves the auto industry. The future growth of BEVs will strongly dependent on achievements in battery technologies. Batteries can play a significant role in future transportation provided that further technical improvements and cost reductions are realized backed by Government and private R&D and innovation efforts.

While electric light-duty road vehicles have been the major driver of innovation in battery technology, the benefits can be applied to other transport sectors. In the marine sector, batteries can expand efficiency and diminish the environmental impact of all vessel types, including ferries. As a result, battery-powered marine vessels and surface transport could challenge those powered mainly by diesel, even in the rail sector with the advantage that they do not entail the installation of overhead cables or electrified tracks.

New battery technologies are expected to reach market maturity as early as 2030, for instance solid-state batteries. Increasing attention is being given particularly to solid state batteries that will induce the continued cost cuts by capitalizing on innovative design architecture. Even though Li-ion will be the main battery type used in the years to come, chemistry variations would affect the business case of recyclers, for this reason, new types of battery flexibility and chemistries must be explored.

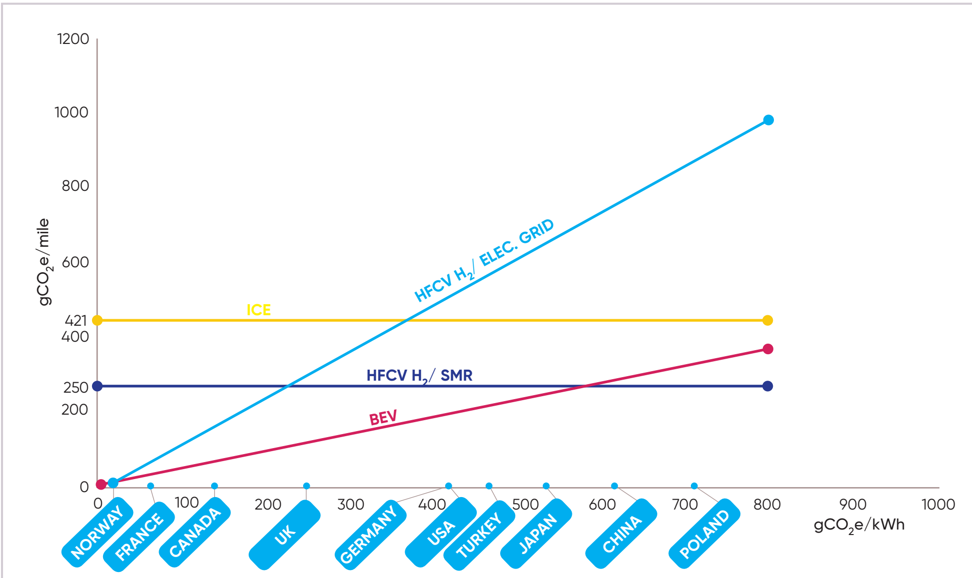
Despite the substantial expansion of the battery value chain, there comes a wide array of challenges. Mines-to-wheel analysis that parallels the more well-developed well-to-wheel emissions analyses is essential to fully understand the environmental and supply chain consequences of BEVs. Over the next decade, the overall increase in raw material production for batteries will come at an unprecedented pace. Consequently, considerable expansion of raw material demand on cobalt, nickel and lithium will cause social, environmental and energy security risks as we use more and more electric vehicles. Lithium-ion batteries are expected to dominate the market in the near term as they currently deliver the best energy density at the lowest cost. As most li-ion batteries utilize substantial amounts of expensive metals, predominantly cobalt, there will be an effort to replace cobalt with less expensive substitutes such as manganese and nickel. Another factor that is likely to gain increased policy attention is the energy security of the mines-to-wheel supply chain with concerns that a single country could control a large share of the necessary raw materials. This should cause an increase R&D focus on alternative materials and recycling.

Charging availability varies for BEVs. The issue of BEV charging has been a major question mark for consumers over many years. Home charging, roadside charging, parking lot charging, battery replacement and fast charging stations are all current options. The successful penetration of greater numbers of BEVs will only be strengthened with advanced planning of charging networks. Unless charging options are expanded, confidence in using BEVs will remain low globally, and would hamper demand. Consequently, adequate charging capacity is a precondition to cope with increased BEVs penetration into the market. In addition, even with available charging stations, the long time that it takes to recharge a BEV compared to refueling a conventional vehicle can weigh against consumer acceptance.

HFCVs: Compared to BEVs, hydrogen fuel cell vehicles (HFCVs) provide a refueling experience that is much closer to a conventional (ICE) vehicle with a refueling time of 3-5 minutes instead of one-half hour depending on vehicle characteristics and desired ranges. Consequently, if hydrogen refueling were widely available the “range anxiety” of a BEV would not exist for HFCVs. These characteristics would make the HFCV a more natural consumer choice to replace the ICE vehicle for long-distance travel. Still, widespread hydrogen refueling is not available and there are significant challenges to providing it. One of the reasons the BEV has experienced such rapid uptake is that electricity is a ubiquitous commodity with widespread availability almost anywhere in the world. Installation of recharging equipment is therefore a relatively simple and inexpensive proposition, even in one’s home if it has a garage. In contrast, HFCV use is limited to areas where hydrogen refueling infrastructure is being installed as a consequence of government demonstration projects, especially in Japan, California and Germany. These and other demonstration projects have the potential to bring about widespread HFCV use and hydrogen refueling. However, considering the substantial investments required from a variety of industries that have little likelihood of an economic return without government subsidies, the pathway to widespread hydrogen use will take some time. Thus far, the number of HFCVs are counted in the thousands while there are millions of electric vehicles, so whether hydrogen transportation will accelerate quickly enough to have a mid-term effect on transport sector greenhouse gas emissions remains to be seen. The global HFCV car stock reached 11,200 units in 2018. The United States accounts for about half of the global HFCVs in circulation, followed by Japan with about a quarter. Japan is followed by Korea, Germany, and France. There are only a limited number of HFCVs models for sale mainly in the compact car class and they are currently quite expensive. Hydrogen fuel is also expensive, unlike electricity that makes the per km cost of driving a BEV a bargain without even considering the fact that, until now, electricity has not typically been taxed as a road fuel (IICEC, 2019).

Hydrogen also is not an unambiguous way to reduce greenhouse gas emissions as, for example, claimed by a California State government website promoting HFCV use which says: “Since fuel cells are so much more efficient than gasoline powered engines, the overall greenhouse gas emissions are much lower (at least half) no matter which hydrogen production method is used.” Actually, depending on how and where hydrogen is produced, as shown as in Figure 2.9, HFCVs can produce more carbon dioxide emissions than a conventional vehicle.

Figure 2.9 HFCV & BEV Full Fuel Cycle GHG Emissions vs. the GHG Emissions of the Electric Grid (Assuming Distributed Generation of Hydrogen from Electricity for HFCVs)



Source: IICEC chart based on 2017 U.S. DOE Argonne GREET Model and IEA data

As shown, for Germany and the United States, an HFCV that is refueled from a service station using electrolysis to produce hydrogen (a common method used in various hydrogen demonstration programs), produces significantly more gCO_2e/mile than a conventional internal combustion engine (ICE) vehicle. Service stations can also reform natural gas to produce hydrogen. HFCVs using hydrogen produced from natural gas reforming do achieve emissions reductions compared to gasoline-fueled vehicles but the reduction is about the same as is achieved by a typical plug-in hybrid electric vehicle. For example, a plug-in electric hybrid vehicle operating in Germany or the United States produces about 245-281 gCO_2-eq/mile (152-177 gCO_2-eq/km), a range surrounding the gCO_2-eq estimated for a HFCV using natural gas derived H2 (155 gCO_2-eq/km). Since the plug-in hybrid is much less expensive, has a much lower fuel cost, requires no new infrastructure investments and provides a similar driving experience with no range anxiety, it would appear to be a more practical approach to achieve similar emission reductions.

The lesson from Figure 2.9 is that the source of hydrogen refueling greatly affects the environmental benefits of HFCVs. Except for countries that have very low electric grid CO_2 emissions due to large shares of low carbon power generation (for example, Norway or France), large emission reductions will require that merchant plants produce hydrogen from low emission sources and ship the hydrogen to service stations that install large hydrogen fuel storage tanks. Various reports have suggested that excess renewable electricity production could be used as a method to reduce the cost of hydrogen to match the currently standard methods of producing hydrogen with steam methane reforming of fossil fuels. Besides solar and wind, nuclear power plants could also be sources of low-priced low-carbon electricity as, in many markets, they often dispatch power at low prices. Whether this would actually significantly reduce hydrogen costs is a much more complicated calculation than these reports typically provide. For example, the lower capacity factors at the merchant plant because it is only producing hydrogen when electricity is cheap is often not considered. There are also other low-carbon options to produce hydrogen using standard chemical reforming methods if carbon capture is applied (often referred to as "blue hydrogen"). It is far too early to estimate how a merchant hydrogen production industry for the transport sector would evolve especially as transport and distribution problems need to be solved and that these issues are intertwined with economies of scale, the location of hydrogen merchant plants, their supply chains and distances to retail markets. For now, the early expansion of hydrogen refueling will likely depend on electrolyzes or steam methane reformers at retail outlets (IICEC, 2019).

While the widespread development of hydrogen production, transportation, distribution and vehicle infrastructure is challenging, it will likely be necessary to significantly cut distillate use in road freight. Battery technology is not likely to serve the heavy truck sector very well except in shorter urban applications such as trash trucks or buses. As discussed in Chapter 3 (Oil), sufficiently large biofuel supplies are not likely or, even if they were, biofuels would not necessarily produce the required greenhouse gas savings. Consequently, despite the challenges, hydrogen technology needs to be pursued in the transport sector. Considering the wide variation of greenhouse gas savings produced by different hydrogen scenarios, policies should emphasize development pathways that produce greenhouse gas reductions. This could be achieved with low-emission production at merchant plants or using electrolyzes at service stations if the national grid has achieved very low greenhouse gas emissions, much lower than needed by BEVs to be an effective measure to reduce greenhouse gas emissions. Nonetheless, for both transport technologies, HFCVs and BEVs, a national energy and greenhouse gas strategy needs to be holistic, in this case, linking the transport and power sectors to achieve a common objective.

2.1.7 Innovation and Game Changers

Achieving low greenhouse gas emissions in transport goes beyond focusing on more efficient vehicles and vehicles that use low greenhouse gas fuels. Communication investments and development of smart cities is also an important factor. Attention must be paid to the ongoing urbanization that leads to a fast-growing building stock. These trigger needs for transportation. Meeting this new transportation service demand can be achieved in a more or less sustainable way depending on urban planning and other methods. These could lead to dramatically different future looks for private and commercial transport. These also change consumer expectations. While there will continue to be a demand for individual mobility, the way it can be satisfied can change. New technologies and business models such as increasing utilization of autonomy and the greater use of data and connectivity are key opportunities for what the future transport system might look like. Advanced technologies such as autonomous vehicles would offer a number of new options.

Private vehicles are widely expected to remain the preferred mode of personal travel. For urban travel, public transport and shared mobility may become more important as a consequence of increased traffic congestion. In addition, artificial intelligence and other advanced technologies may cause new forms of urban travel to emerge – personal public transportation – that may offer the appeal of private automobile travel while serving many more trips with less congestion. Another factor to consider is that city size tends to be constrained when traffic congestion reaches certain levels. This can restrict the growth of the largest cities by encouraging businesses and their employees to move to smaller cities with less congestion. This is a major reason why the growth of urban population in many countries is greatest in the newer smaller cities while the older mega cities are often losing population or growing more slowly.

Personal public transportation is an option that could be a huge game changer and could change whether people will continue to purchase as many private vehicles. Under this scenario, mass transportation could change to individual personal public transportation, a service that could have widespread consumer appeal to all income groups. Likewise, technology has already revolutionized the retail industry and it is likely that the current trends away from "brick and mortar" shopping to on-line deliveries is likely to continue. We may see increased automation and efficiency in package delivery lead the way to advances that can be applied to automated passenger vehicles that operate in a variety of business models. The Covid-19 pandemic has caused the more innovative business models to thrive amongst a collapse of the general economy and is likely to accelerate change in these directions.

2.2 Turkey's Transport Policies

The key policy documents considered in the TEO include the 11th Development Plan issued by the Presidency of Turkey in July 2019 and the Strategic Plans of the Ministry of Energy and Natural Resources and the Ministry of Transport and Infrastructure. Each of these documents focuses on plans and goals towards 2023. The National Energy Efficiency Action Plan also defines strategies for a more efficient transport sector. TEO scenarios also take into consideration key legislation in place or under consideration.

- Modal shifts

One of the long-lasting policy efforts of Turkey is to reduce the road share of Turkey's passenger and freight travel. The policies aim to reduce passenger travel from 90% road to 72% and freight travel from 90% road to 60%, both as early as by 2023. Turkey aims to increase the share of rail in passenger transportation to over 10% (from less than 2% in intercity passenger travel) and in freight transportation to 15% (from approximately 5%) by 2023. These are challenging goals. For example, a one-third reduction in road's contribution to freight implies, in addition to tripling the share of rail, a significant increase in the share of marine (from 6% to 20%) by 2023. Turkey's aspirations for a more balanced and sustainable transport structure are also reflected in more ambitious longer-term targets, in particular further enhancing rail's share in freight and passenger, to 20% and 15% respectively, by 2035. Achieving inter-modal shifts requires connecting load centers and key industrial zones, mainly to rail and port infrastructures. These policies acknowledge the large investment needs and interrelations with developments in the logistics industry.

- Fuel economy

Improving road vehicle fuel economy is an essential part of Turkey's energy policies. Turkey's current tax structure favors small efficient diesel engines, hybrids, and BEVs. These fiscal incentives have led to a very efficient light duty vehicle fleet, at least for the newer vehicles. In order to remove the older vehicles, rebates were used to scrap aged vehicles. However, it is estimated that the number of scrapped vehicles fell well below the targets by the time the program ended at the beginning of 2020. In 2019 Turkey also adopted stricter fuel economy and emission standards for motor vehicles in line with the corresponding EU standards. Turkey is also considering tax regimes that explicitly consider fuel efficiency performance as measured by CO_2/km instead of taxes based on the type and size of engine.

- New vehicle technologies

Research and development is a key aspect of transport-oriented energy policies in Turkey, similar to global trends for achieving a more sustainable transport economy. Development of R&D programs for road vehicles with alternative fuels and rail system technologies are priority goals. Turkey also emphasizes the near-term uptake of BEVs and, for the longer-term horizon, investigating HFCVs to see how they would fit into a Turkey hydrogen roadmap. In particular, Turkey's Automobile Initiative Group (TOGG) introduced the first prescreening BEV of Turkey in 2019 and production is set for as early as 2022 with five different models. The project is expected to trigger a wider electrification of Turkey's road transport supported by greatly increased availability of BEV recharging stations. Another significant electrification is targeted in railways where Turkey aims to increase the share of electrified lines from less than a half to over three-quarters by 2023. Turkey announced a new Railway Transport Technologies Institute to work on innovation and R&D efforts that would enable further development and localization of railway technologies.

- Urban Planning and Public Transportation

Turkey has been undergoing a strong urbanization trend backed by its young population and growing social, economic, and demand centers. Therefore, urban transport has become more important and necessitates a suite of integrated solutions to meet rising mobility needs of Turkey's growing cities. Expanding the use of urban public transport is the major policy being adopted by Turkey, particularly in its larger cities. Pursuing investments in metro lines is a favored strategy to reduce passenger car travel and urban congestion. These policies are supplemented by initiatives to integrate other modes (bus, bus-on-exclusive-right-of-way, mini-bus, taxi) and encourage wider use of efficient private cars with smaller engine sizes or electric/hybrid drive. Lower emission and less congested areas within urban centers are also being planned. Wider use of pedestrian right-of-way is also among the planned urban transport policies in order to avoid the intrusion of motor vehicle traffic and emissions. Technology is a consistent theme emphasizing smart transportation systems to manage and optimize activity in a more sustainable way.

- Data and Monitoring

Turkey is seeking a more systematic approach in data gathering and monitoring to achieve its energy and environmental policy objectives. An analytical framework is used to quantify passenger activity for multiple vehicle types in order to estimate the fuel and emission consequences of different strategies. The analytic approach also focuses on comparing urban transport energy data among all cities to gain further insights. The analytical aim remains to shift travel to high-occupancy modes of travel, support efficient alternative technologies in private vehicles and open up vehicle-free spaces for pedestrians. Each of the strategies can then be evaluated with energy and emissions benchmarks.

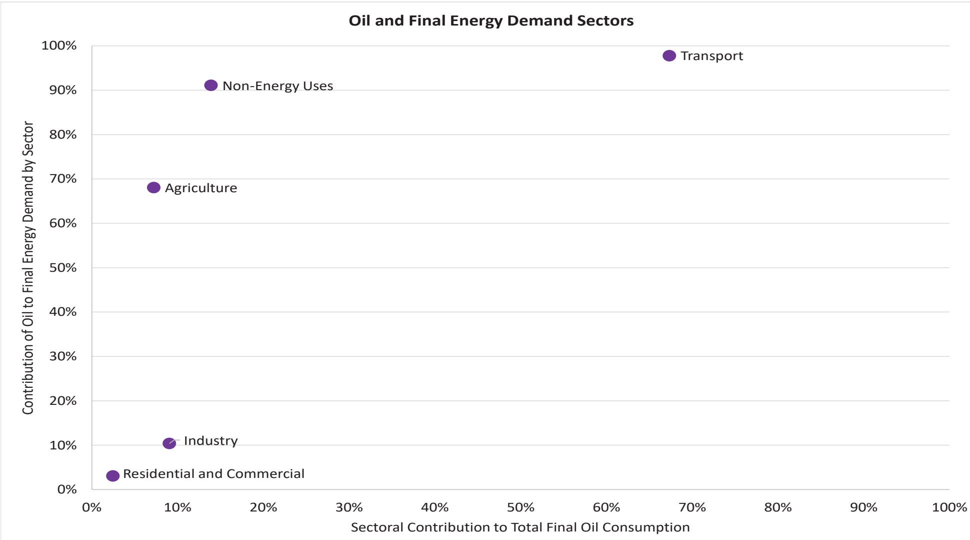
2.3 IICEC Overview, Scenarios and Analyses

2.3.1 Introduction

The transport sector represents one quarter of Turkey's final energy demand. While this is lower than the other two major sectors, industry (33%) and residential/services (30%), transport is almost completely reliant on oil. Oil fuels 99% of transport energy demand and transport accounts for two-third of Turkey's total oil consumption. After transport, non-energy uses follow at 13%, the industrial sector at 9%, followed closely by agriculture (7%) and further back by the residential/services sector at less than 3% (Figure 2.10). When non-energy uses such as petrochemical feedstocks are excluded, transport accounts for 78% of Turkey's total oil consumption and is the major driver behind crude oil and oil product imports.

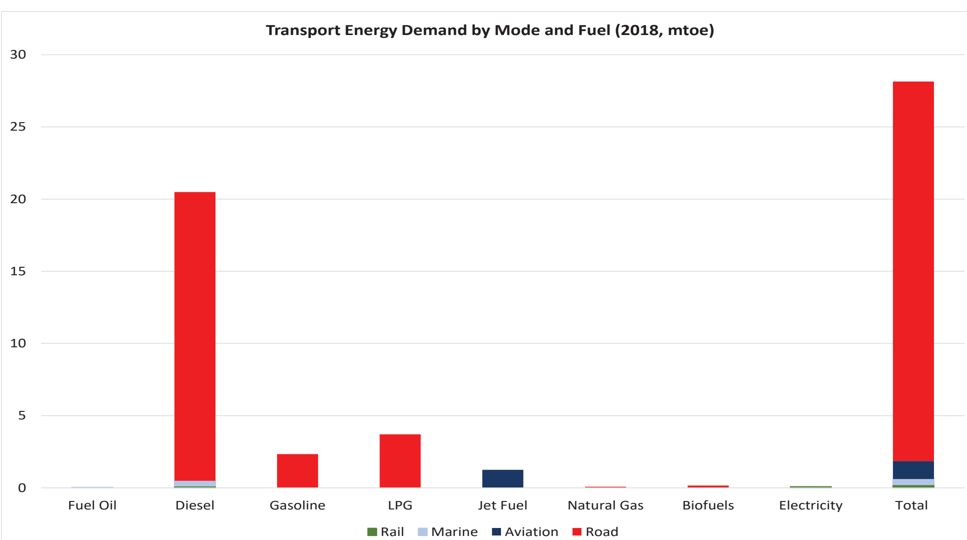
Like many other industrialized economies, especially geographically large countries in relation to its population, road transport is the dominant mode with a share of around 90% in both passenger and freight transport. Despite long lasting policy targets to foster shifts towards more fuel efficient modes, mainly rail and marine, the share of Turkey's road transport has remained stable over the past decade. Turkey is a large consumer, and a heavy importer of diesel fuel, largely stemming from the predominant road transport activity. As shown in Figure 2.11, over three-quarters of energy use in road transport and 72% of energy use in total transport is met by diesel fuel used in a fleet of heavy, medium and light duty commercial vehicles as well as passenger cars. Railroads and marine travel also consume diesel fuel. As Turkey's current diesel production capacity covers 40% of current diesel demand, policies affecting the share of diesel fuel and gasoline should be a factor in setting Turkey's transport sector policies and technology pathways. This topic is also taken up in Chapter 3 (Oil) as it can affect product import slates and Turkey's oil security.

Figure 2.10 Oil and Final Energy Demand Sectors



Transportation and associated services are fundamental factors of all economies underpinning economic, social and welfare development. Transportation is an important economic activity in its own right and has almost a linear relationship with all other sectors throughout the economy since each economic element requires transportation services. Transportation systems grow under a variety of dynamics with varying interrelations among transport modes and infrastructures reflecting the operational capacities of the transport system in relationship to the mobility needs of Turkish citizens, commerce and industry.

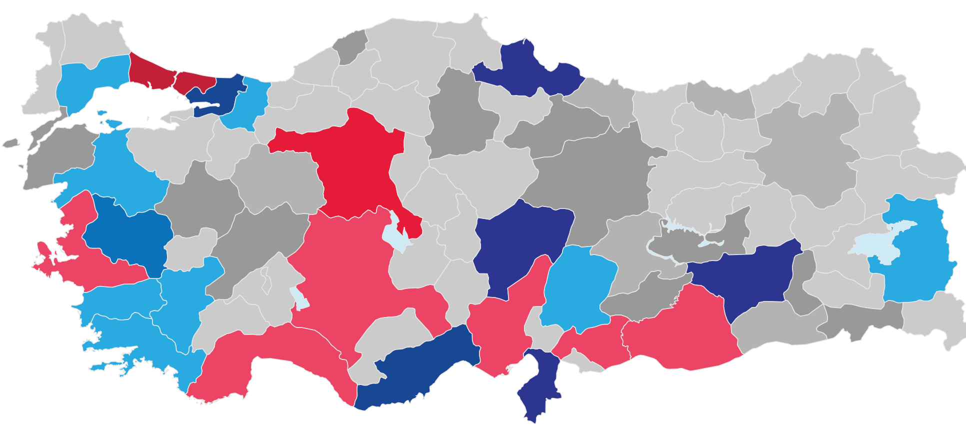
Figure 2.11 Transport Energy Demand by Mode and Fuel (2018, mtoe)



Turkey's ongoing urbanization and emergence of large urban centers will remain a key driving force for increasing transport activity. Turkey is continuously extending intercity roads and railways and expanding airports across the country. Developing modern urban transport systems, in particular light rail and metro, is still at the early stages of development except in the largest cities. Currently, 10 cities have a population over 2 million and 24 urban centers with a population of over a million (Figure 2.12).

Population density has increased from 96 persons/km^2 in 2010 to 108/km^2 in 2019. Although Turkey still has a relatively low population density compared to several EU peers (For example 205 in Italy, 122 in France and 113 in the Slovak Republic), Turkey's effective population density will increase with a growing and more urbanized population. Freight transport will also continue to grow with Turkey's growing economy and commerce. For example, new logistic centers along with intercity road expansions and an intensive rail investment program will be needed to efficiently serve growing surface freight needs. As Turkeys' transport infrastructure grows to meet its needs, policy choices are needed to ensure that it grows in such a way to serve the need for transport services while also taking account of Turkey's energy import bill, urban congestion, urban pollution and greenhouse gas emissions. There are several realistic transport policies that serve all of these objectives.

Figure 2.12 Turkey's Urban Centers (2019)



İstanbul	15.5 million	Balıkesir	1.2 million	Batman	0.6 million
Ankara	5.6 million	Aydın	1.1 million	Elazığ	0.6 million
İzmir	4.3 million	Kahramanmaraş	1.2 million	Kütahya	0.6 million
Bursa	3 million	Van	1.1 million	Sivas	0.6 million
Antalya	2.5 million	Denizli	1 million	Tokat	0.6 million
Adana	2.2 million	Muğla	1 million	Zonguldak	0.6 million
Konya	2.2 million	Sakarya	1 million	Ağrı	0.5 million
Şanlıurfa	2.1 million	Tekirdağ	1 million	Çanakkale	0.5 million
Gaziantep	2 million	Eskişehir	0.9 million	Çoorum	0.5 million
Kocaeli	1.9 million	Ordu	0.8 million	Osmaniye	0.5 million
Mersin	1.9 million	Trabzon	0.8 million	Şırnak	0.5 million
Diyarbakır	1.8 million	Erzurum	0.8 million		
Hatay	1.8 million	Malatya	0.8 million		
Kayseri	1.6 million	Mardin	0.8 million		
Manisa	1.4 million	Afyonkarahisar	0.7 million		
Samsun	1.4 million	Adıyaman	0.6 million		

Source: ISPAT, 2020

The TEO Reference and Alternative Scenarios both reflect strong growth in Turkey's transport activity driven by socio-economic fundamentals. However total energy use through consumption by alternative modes, fuels and technologies are estimated to be significantly different. Although neither of the Scenarios assume explicit climate policies, both demonstrate significant achievements in terms of CO_2-eq intensity of the transport sector.

The Reference Scenario reflects the current trends and progress reflecting a set of policy initiatives defined in the near-term targets provided by government documents. The Alternative Scenario adds more ambitious policy priorities that requires a variety of additional measures that amplify progress in fuel efficiency, high occupancy travel and advanced technologies. While each scenario shows fuel economy improvements, modal shifts and uptake of new technologies the pace of progress is much greater in the Alternative Scenario. The Alternative Scenario includes stronger policies to amplify fleet fuel economy gains (through purchase of the best available technologies and faster retirement of older high-polluting vehicles), improving rail and marine services, and support for new vehicle and fuel technologies. As a result, the Alternative Scenario provides increased energy security, lower trade imbalances, greater economic growth and a cleaner environment. It has 13% less transport energy demand and 15% less CO_2-eq emissions compared to the Reference Scenario by 2040. These percentage reductions are a bit misleading as the Alternative Scenario also sets Turkey on a faster downward emission trajectory that, after 2040, can also lead to a net-zero carbon future that is likely to be required on a world-wide basis (discussed in Chapter 6). Nonetheless, the economic benefits for the next two decades are also important, for example, despite strong population and economic growth, diesel fuel demand increases by only 8% compared to 37% in the Reference Scenario. The reduction in diesel demand growth by the Alternative Scenario over the Reference Scenario is significant (5.9 mtoe or 30% of current diesel demand) by realizing stronger fuel economy improvements and achieving more challenging modal shifts in both urban and freight transport. Judged from all these perspectives it is a more sustainable scenario. By increased uptake of global technology advancements and solid achievements in localization of emerging technologies (including BEVs) it would also contribute to wider gains for the economy.

In the Reference Scenario, transport energy demand increases by 1.7% per year, yielding 12.4 mtoe more demand in 2040 (44% cumulative growth) compared to 2018. The largest growth in absolute terms takes place in diesel with 7.6 mtoe (37%), mainly due to use in trucks (58% of the total increase). Diesel remains the dominant fuel in the transport energy mix but its share gradually declines from 73% in 2018 to 69% in 2040. Gasoline demand expands with the uptake of gasoline and hybrid LDVs benefitting from technology improvements, policy orientations and environmental gains. As a result, gasoline's share in transport energy use reaches to 14% by 2040 up from 8% in 2018. Aviation fuel is the fastest growing petroleum product with a 93% increase, supported by expanding activity and fleet development. It increases its share to 6% of transport energy by 2040 compared to 4% in 2018 (Figure 2.13).

The share of all non-petroleum fuels increases substantially, natural gas by 6.9 times and electricity by more than 8 times until 2040. Despite increasing uptake of these non-oil based technologies as a result of Reference Scenario policies, technological advancements and support from the energy and auto industries, the share of total transport energy demand met by non-oil based fuels still only grows to 3.9% by 2040 (Table 2.2).

Table 2.2 Summary of Transport Sector Energy Demand by Scenarios

Scenarios			Reference Scenario		Alternative Scenario	
mtoe	**2000**	**2018**	**2030**	**2040**	**2030**	**2040**
Transport Energy Demand	11.9	28.2	35.3	40.6	33.7	35.2
of which						
Diesel	5.5	20.5	25.6	28.1	23.4	22.2
Gasoline	3.6	2.3	3.7	5.6	4.0	5.8
Kerosene	0.7	1.2	1.8	2.4	1.7	2.1
LPG	1.4	3.7	3.5	3.0	3.5	2.7
Natural Gas	0.0	0.1	0.2	0.5	0.5	0.7
Electricity	0.0	0.1	0.3	0.9	0.5	1.4
Share of Road in Transport Energy Demand	88.0%	93.4%	92.2%	90.3%	92.0%	88.8%
Share of Fuels Other Than Oil in Transport Energy Demand	1.0%	1.2%	1.5%	3.9%	3.0%	6.5%

In the Alternative Scenario, transport energy demand increases by 25% from 2018 to 2040. The largest growth in absolute terms takes place in gasoline (3.5 mtoe), driven by further shifts away from diesel among light duty vehicles. Diesel fuel demand demonstrates the second largest growth in absolute terms (1.7 mtoe) but is 21% lower than in the Reference Scenario (Figure 2.13). In addition to lowered total energy demand by means of better fuel economy and wider modal shifts, fuel mix also develops towards a more diversified and environmentally sustainable structure compared to the Reference Scenario. The share of total transport energy demand met by non-oil based fuels increases from 3.9% in the Reference Scenario to 6.5% in the Alternative Scenario in 2040 (Figure, 2.14).

Figure 2.13 Transport Energy Use by Fuel (mtoe)

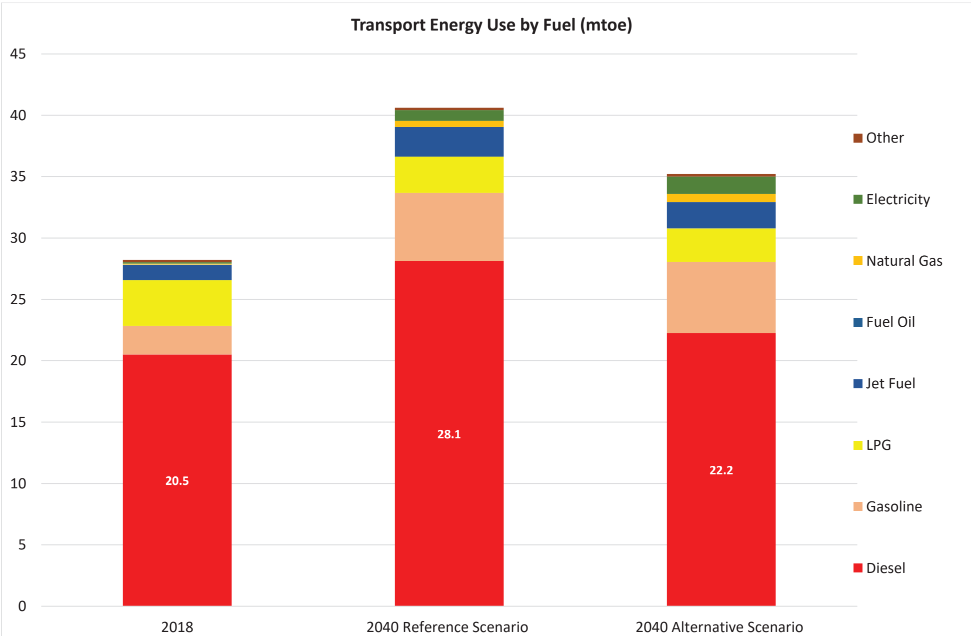
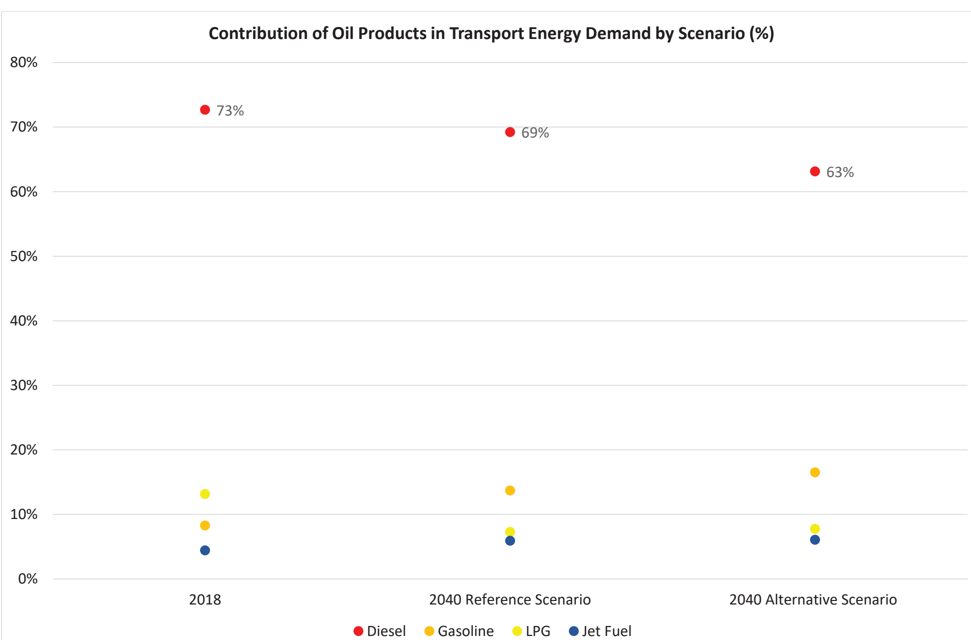
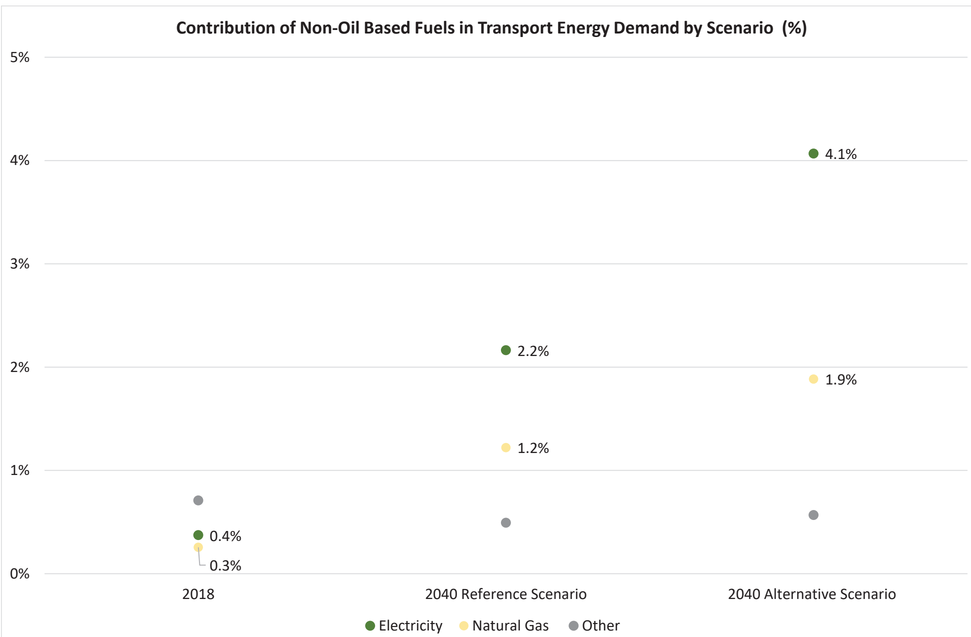


Figure 2.14 Contribution of Oil Products in Transport Energy Demand by Scenario (%)



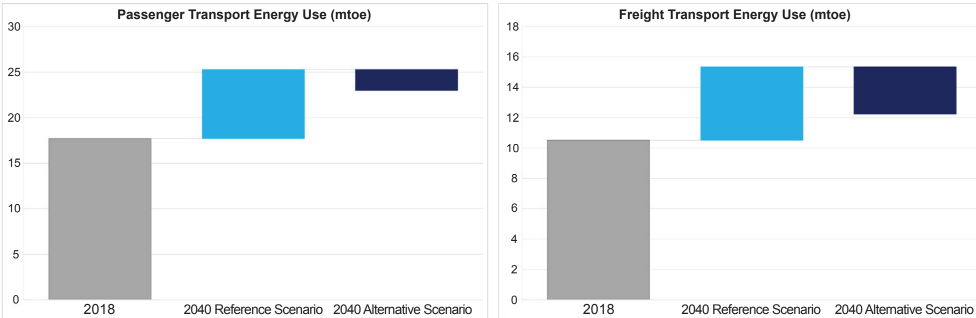
The Alternative Scenario reflects the strong role of energy efficiency in all transport modes and vehicle types. Electrification is more progressive as a result of policy support and industry achievements both in road and rail transport. Electricity represents 4% of total transport demand in the Alternative Scenario compared to 2% in the Reference Scenario from a marginal contribution of less than 0.5% in 2018 (Figure 2.15). While these are still small percentages, they can become more important on a pathway to a net-zero carbon economy beyond 2040 as discussed in Chapter 6 (The Energy Transition). The contribution of natural gas also almost doubles from 1% to 2% due to a more rapidly expanding CNG and LNG fleet in HDVs, primarily the buses and also in trucks. This can have particular air pollution benefits in local areas.

Figure 2.15 Contribution of Non-Oil Based Fuels in Transport Energy Demand by Scenario



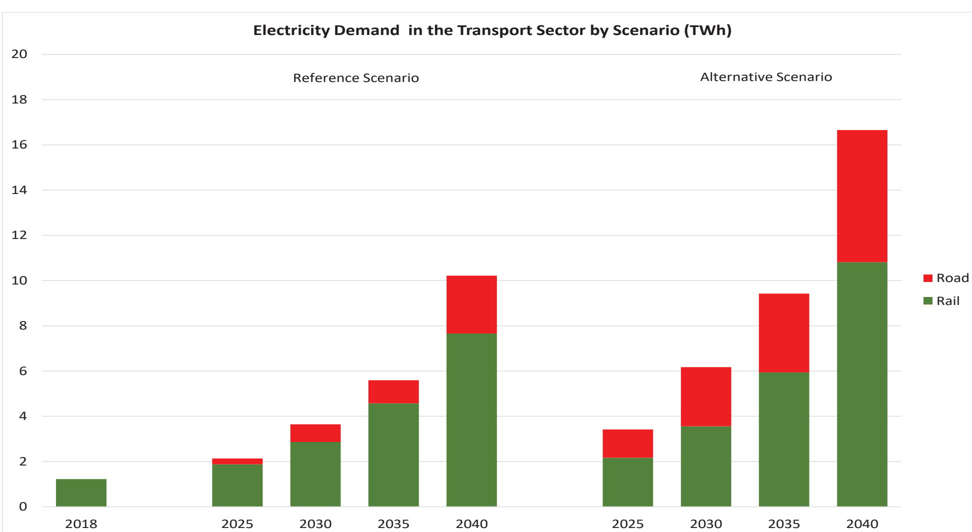
The Alternative Scenario shows how significant reductions in both passenger and freight transport energy use can be achieved compared to the Reference Scenario (Figure 2.16). The realized relative savings in freight driven energy use is more substantial compared to passenger transport energy use as a result of a greater effort to improve fuel economy across Turkey's large truck fleet and more aggressive modal shifts from road to rail (20% in freight vs. 9% in passenger). These are also the most challenging transport policy targets to achieve and require holistic and integrated approaches in energy and transport policy planning and coordination. In the Alternative Scenario, passenger transport represents about two-thirds of total energy demand compared to the current 63%, based on IICEC analyses reflecting a detailed representation of vehicle technologies and intercity and urban travel activity.

Figure 2.16 Passenger and Freight Transport Energy Demand (mtoe)



Modern EV uptake and strong rail electrification programs backed by localization targets yield 10.2 TWh and 26.2 TWh annual power demand by 2040 in the Reference Scenario and the Alternative Scenario, respectively (Figure 2.17). However, these absolute demand figures still remain low in terms of contribution to total power demand (less than 2% in the Alternative Scenario from 0.5% in 2018). BEVs and PHEVs represent a quarter of transport electricity demand in the Reference Scenario while their contribution is above one-third in the Alternative Scenario as a result of a more aggressive EV uptake program. Road electrification has a dispersed nature compared to electrifying a number of rails over distances. However, as discussed in Section 2.3.2, Turkey's promising BEV expansion outlook can be accommodated with convenient recharging stations supported by the modernizing power grid.

Figure 2.17 Electricity Demand in the Transport Sector by Scenario (TWh)

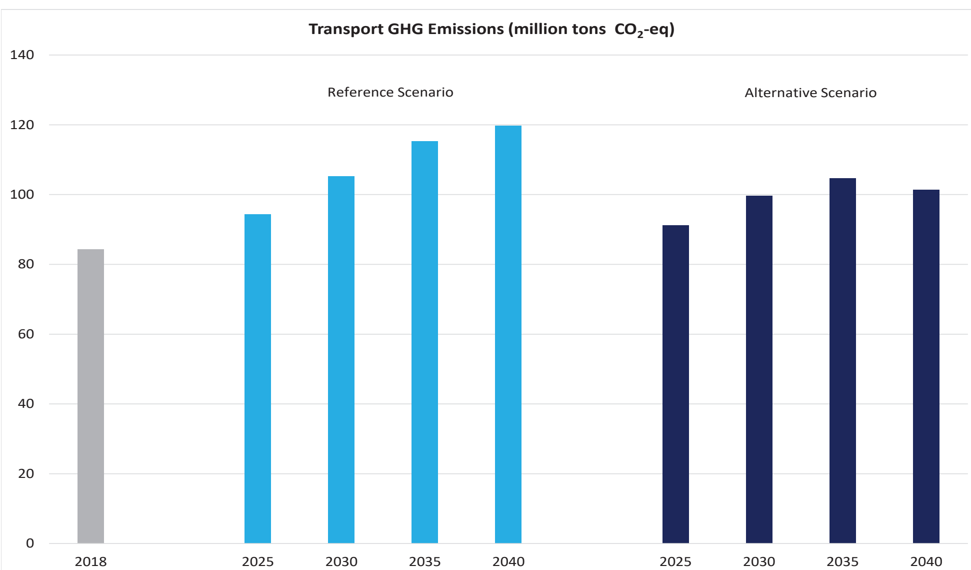


Note: Power demand in rail transport including urban light rail and metro lines

Transport energy intensity is reduced in both scenarios, 25% lower in the Reference Scenario and 32% lower in the Alternative Scenario from 2018 to 2040 (measured in terms of toe/Pkm). In freight transport, the Alternative Scenario results in 31% reduction compared to 14% in the Reference Scenario during the same period (measured in terms of Tkm) driven by higher fuel economy improvements in trucks and further modal shifts to electrified rail. The improvements in freight energy intensity in the Alternative Scenario are challenging and require integrated policy planning and implementation (discussed further in Sections 2.3.2 and 2.3.3).

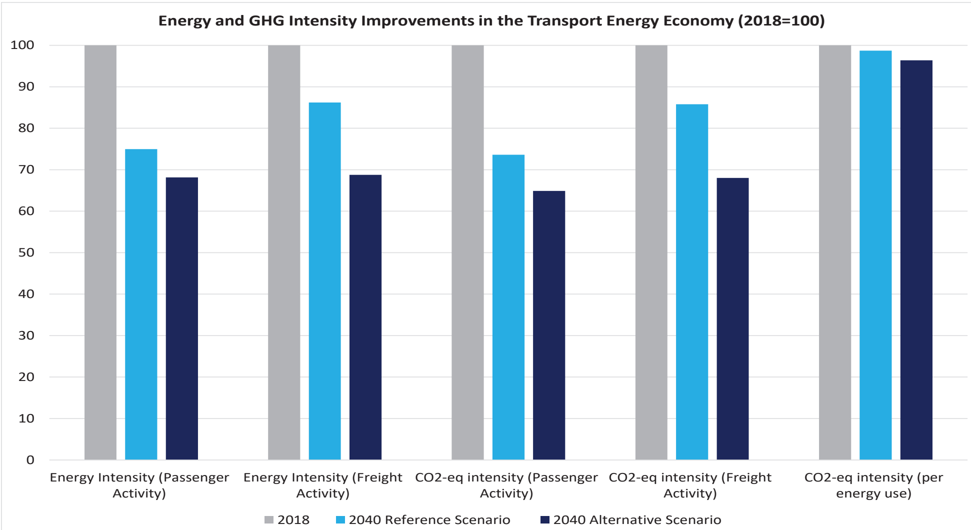
Energy intensity improvements and fuel mix shifts cause important benefits in transport carbon emissions compared to Turkey's emission future without them. CO_2-eq emissions from transport increase from 82.6 million tons in 2018 to 117.2 million tons in 2040 in the Reference Scenario. Although the growth rate slows down, particularly after 2030, emissions do not reach a peak until 2040 or later. The Alternative Scenario demonstrates CO_2-eq emissions peaking before 2040 resulting in emissions below 100 million tons by 2040, 20% higher than 2018 but much lower than the 42% increase in the Reference Scenario (Figure 2.18).

Figure 2.18 Transport GHG Emissions (million tons CO_2-eq)



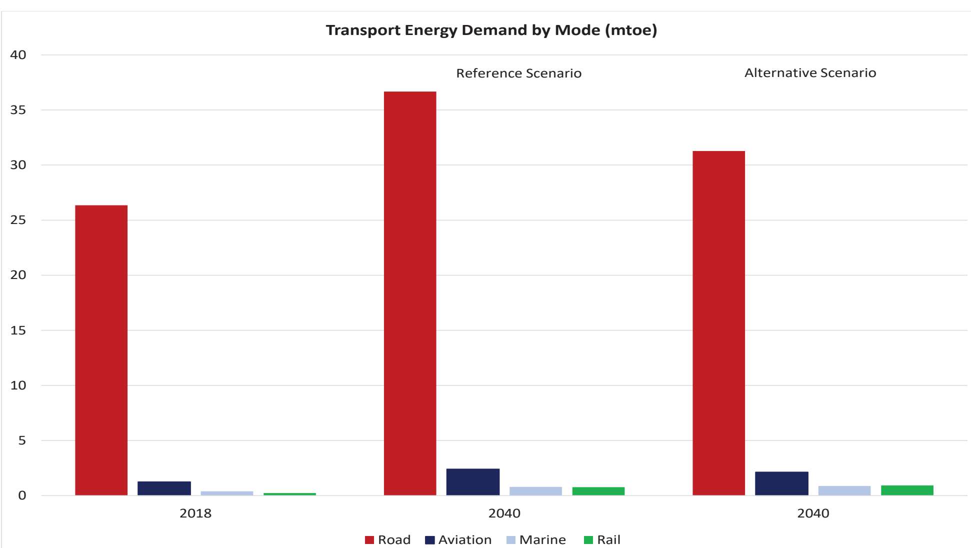
When measured in terms of travel activity, CO_2-eq intensity of the Alternative Scenario by 2040 is 35% lower for passengers (gCO_2-eq/Pkm) and 32% lower for freight (gCO_2-eq/Tkm) than in 2018 (Figure 2.19). Progress in these indicators represents a major improvement for a more sustainable transport energy economy backed by integrated policy measures and effective market forces in fuel economy, modal shifts as well as global and national technological progress.

Figure 2.19 Energy and GHG Intensity Improvements in the Transport Energy Economy (2018=100)



When looking at the balance of energy use by mode, changes in activity growth, modal shifts and fuel economy improvements tend to balance out leaving the energy use by mode relatively unchanged. Road remains by far the largest energy consuming mode representing 90% of total transport energy demand by 2040 in both scenarios compared to 93% in 2018. Aviation follows with 6% up from 4% in 2018 while rail and marine each contributes to 2%. (Figure 2.20).

Figure 2.20 Transport Energy Demand by Mode (mtoe)



The Alternative Scenario shows how a more efficient and sustainable development of the transport energy economy can bring significant fuel use and consecutive environmental benefits until 2040. Furthering this performance will be contingent upon longer term technology solutions, particularly for achieving stronger improvements in road transport energy and emission intensities. Key enablers that will enforce a lower carbon pathway can include stronger fuel economy improvements across all vehicle types and sizes, wider electrification of road transport including HDVs, and commercialization of green and blue hydrogen as a sustainable fuel for use in HFCVs. These technologies, among others, will be discussed in Chapter 6 (The Energy Transition). When assessing the transportation energy and greenhouse gas emissions progress cited above in the Reference and Alternative Scenarios, certain factors should be taken into account. The opportunities to improve fuel efficiency beyond levels that have already been achieved after 4 decades of technological progress face diminishing returns. Road transport for passengers and freight is difficult to shift to higher occupancy and more efficient modes and the policies already embodied in the Alternative Scenario are challenging. The challenges involved in shifting the vehicle fleet and supporting infrastructure to non-petroleum alternatives are considerable. Electric drive technologies have a limited applicability to road freight. Hydrogen vehicles can accelerate progress by providing consumers vehicles that are more similar in operation to conventional vehicles and the technology can well be applied to freight transport. Nonetheless, the infrastructure and related developments necessary for HFCVs to contribute greatly to Turkey's transport picture will likely only come into play near the end of the next two decades.

2.3.2 Road Transport

Road transportation is especially convenient since it provides uninterrupted service between the trip origin and destination. While it can also serve multi-modal travel, such as traveling to the airport, etc., most road travel involves no transfers. This also follows a history of roadway travel that has existed for millennia where, apart for sea travel, there were no other modes of travel. The convenience and privacy afforded by personal vehicle travel goes a long way to explaining why public transportation tends to be used an economic necessity, or because of traffic congestion or the unavailability of parking. Roadway travel is, and has always been, an essential aspect of social and economic life without which our economies and societies could not easily be imagined. Road investments have a significant impact on public, social, cultural, commercial, and economic aspects. They ensure that other economic sectors are productive. Whether though direct mechanisms to trust funds or the indirect funding of the national tax base, road users pay for roadway investments through different taxes. Nonetheless, roads have zero marginal cost to the user. Therefore, an excess of demand over supply is rationed by traffic congestion. This has led to road user tax systems in a variety of urban areas with mixed success as it is often discovered that the road charges have to be very high to achieve free-flowing roadways, a measure of how valuable road services are to the population that can afford to pay them. From a social policy point of view, it is difficult to endorse a traffic solution that may work for the most well off citizens while not benefitting lower income auto owners or actually making them worse off.

Turkey's geography creates advantages for road transport in intercity travel. Turkey's roadways have also a particular international significance as Anatolia is the natural bridge connecting Europe, the Middle East, the Caucasus, the Far East and the Mediterranean countries. Turkey thus provides one of the most important sections of the middle corridor. In order for Turkey to strengthen its global position by improving the quality of road transport, improvements in the quality of the roadway system will continue. In addition, over the past two decades, Turkey has implemented a strategy of achieving a better balance among the transportation modes. Its agenda relies on increased public investment, international cooperation, enactment of new regulations as well as introduction of public private ownership options. As a result of the Government's efforts to create multimodal transport opportunities, the rail network has grown, as well as the capacity of its ports and airports. With completed and planned transport infrastructure investments, Turkey is set to become a "logistics center" in its region. So, Turkey's hub strategy not only includes its roadways but development of all modes, including specialized investments such as natural gas and petroleum pipelines that are essential for the energy sector.

However, in spite of long lasting orientations to facilitate inter-modal shifts, road continues to keep its large share of transport with about 90% of both passenger and freight. Highways have been the most used alternative followed by railway and airline, and the least used option has been maritime option for many years. Passenger transport on highways and other intercity roads was equal to 182 thousand MPkm in 2005 growing to 227 thousand MPkm in 2010 and 340 thousand MPkm by 2018, a 50% growth in 9 years. Similarly, road freight activity has posed a rapid increase growing from 190 thousand MTkm in 2010 to 268 thousand MTkm, a 41% growth in the same period. IICEC estimates that 93% of Turkish passenger and 90% of freight travel is on roads when urban and intracity travel are aggregated across all modes.

Switching a significant portion of road freight to rail and marine is not an easy task when infrastructure requirements, load carriage characteristics, and growing new urban demand centers are all taken into account. Enabling a more balanced modal structure requires a long term and integrated planning perspective that especially takes into account the preferences of personal and business travelers and, for freight, shippers' requirements.

Road motor vehicles rose from numbering 8.3 million in 2000 to 15.1 million in 2010 and surged to 23.2 million in 2019. This represent a tripled motor vehicle stock in just two decades. During the same time period, motorized vehicles' energy consumption climbed from 10.5 mtoe in 2000 to 26.3 mtoe in 2018, a 2.5 times increase. Although these figures exhibit some efficiency improvement, Turkey will need to further improve fuel economy across all road vehicles for a more efficient and sustainable transport economy especially with regard to the less efficient older vehicles. Going forward, the growth of the vehicle stock, in scale and by fuel, will be key factors that shape energy use and road transport. In particular, road freight will have a major impact on energy and emission intensity of the transport sector and Turkey's oil import needs as a major consumer of diesel fuel.

Passenger Cars and Other LDVs: Despite strong growth in passenger car stock, from 5.8 million in 2005 to 7.5 million in 2010 and 12.5 million in 2019, Turkey's ownership rate of 150 passenger cars/1000 people (2019) remains the lowest in Europe (the EU average is 531/1000 in 2018). For example, several Eastern European countries have more than double Turkey's per capita auto ownership (369/100 in Latvia, 332/1000 in Romania and 373/1000 in Hungary). This suggests a strong growth potential that is highly linked to growing economic fundamentals. Net change of passenger car stock annually reached its highest at around 700,000 in 2013-2017 but then shrink substantially through 2018 and 2019 due to economic conditions. According to IICEC expectations, the ownership rate would reach 210/1000 by 2030 and 280/1000 by 2040 with the passenger car stock growing by 740,000 units/yr. until 2040 (compared to the average annual growth in the last two decades of 550,000 units/yr.). This auto uptake will be driven by growing incomes, urbanization and will be facilitated by Turkey's strong auto industry and integration with the global automobile market.

Over the past decade, fuel mix of the passenger car stock has changed. Since 2010, 68% of the net stock increase has been from purchases of diesel powered passenger cars. The share of diesel cars on the road has increased from 18% in 2010 to 38% by 2019. Over the same interval, the stock of gasoline cars dropped from 42% to 25%. The LPG stock remained largely unchanged (38% in 2010 and 37% in 2019). At 37%, Turkey has the highest share of LPG in passenger car fuel mix across Europe where the average figure is about 3%.

Electric vehicles including hybrids are still at the early stages of penetration, representing less than 1% of the total LDV stock. Efforts are underway to establish a modern electric vehicle ecosystem including localization targets. In recent years, there has been an upward trend in hybrid car sales reaching over 3% of total sales by 2019. Gasoline car sales outpaced diesel in 2020 after more than a decade representing about half of total passenger car sales in the first half of 2020. Despite all these recent trends, with the increasing share of diesel cars over the past decade Turkey's demands for refined petroleum products have increasingly turned to middle distillates and, as will be noted in Chapter 3 (Oil), has had an impact on Turkey's balance of trade due to the need to export gasoline and to import more diesel fuel. Managing future LDV stock development is an important opportunity to have a positive influence on Turkey's energy balances and oil product import bill.

Turkey's growth in light-duty diesel vehicles has followed a similar path with Europe. The diesel wave in Turkey began around 2005, about 6 years after Europe. This common trend was mainly driven by some significant advantages of diesel engines. Diesel cars could provide 20% to 40% better fuel economy compared to gasoline and this advantage is more notable in congested urban traffic. In addition, diesel engines produce better torque at low revolutions per minute giving diesel engines and advantage in hauling capacity.

In spite of these advantages, diesel emissions have become an increasing concern in Europe where the environmental community has turned strongly against them. Consequently, the European trend will likely reverse as gasoline vehicles become more popular and consumers purchase more BEVs and gasoline hybrids.

This trend is likely to continue for a couple of reasons. The fuel efficiency difference of gasoline vehicles and diesel vehicles is declining due to advances in gasoline technologies, especially lean burn. Gasoline hybrid vehicles also provide urban fuel efficiency performance that is superior to the diesel vehicle because of regenerative braking and other aspects of stop and go driving. Consequently, there will likely be an uptick in gasoline-hybrid purchases.

Moving to all-electric cars or BEVs is a mainstream policy direction in Europe and is also making inroads in China, the United States and other countries. Remarkably, many European cities have actually banned diesel vehicles. Like many policy changes, these are not necessarily based on a rigorous cost benefit analysis or fact based. Turkey's policies are likely to follow a more balanced direction that is more influenced by economic considerations. Nonetheless, the European trends could affect Turkey more directly by the types of cars Turkish auto factories produce in future years, as these cars are also exported to Europe. Consequently, future trends away from diesel vehicles towards gasoline vehicles, gasoline hybrid vehicles and electric vehicles may result simply from this factor.

The current vehicle tax system is the major determinant for all new car sales in Turkey. It favors low engine size with special consumption taxes. This helps explains why Turkish car sales with engines above 2 liters has been less than one-half percent in recent years. Ninety-five percent of total car sales in the first half of 2020 had engines below 1600cc. This impact is also quite visible in the rapidly growing hybrid sales. Ninety percent of 2019 gasoline hybrid sales were between 1600-1800cc with electric power exceeding 50 kW, thus enjoying the lowest special consumption tax category. Special consumption tax categories based on engine type and size strongly influence new car purchase decisions and contribute to increased passenger car fuel economy.

According to GFEI Data, Turkey is among the countries with the highest fuel economy in new LDV sales. The impact of this vehicle tax regime on fuel economy is also reflected in average emission figures. 40% of the new passenger cars sold in 2019 represent emission levels between 100-120 gCO_2/km. Half of the new passenger cars sold in 2019 emits less than 120 gCO_2. This figure increased to 59% in the first half of 2020. Currently, there is no binding legislation in Turkey for emissions from vehicles. The EU will start a compulsory regime for new passenger cars to be sold from 2021 to emit lower than 95 gCO_2/km. It would be anticipated that relevant EU mechanisms will transform into auto manufacturing and sales strategies in Turkey. Turkey also positively differentiates EVs in the current tax system imposing Special Consumption Tax (SCT) levels for them under three different tax rates of 3%, 7% and 15% while the lowest level of SCT for the gasoline and diesel cars is 45%.

Fuel taxes also play a key role in vehicle purchase preferences. Turkey uses motor fuel taxes to raise revenue. Fuel taxes are attractive since they are relatively difficult to evade compared with Turkey's income tax system. The current tax priority is to bias these revenues away from the commercial sector towards consumers that can afford them. Diesel prices have been lower at the pump due to Turkey's tax policies. Differentiating diesel and gasoline prices by means of tax adjustments could improve the trade balance of Turkey in oil products and bring environmental benefits. Evenly weighted gasoline and diesel fuel taxes would add burden on commercial diesel users such as the trucking industry and farmers (who consume diesel fuel in their tractors). Gasoline engines are often seen in the high performance and luxury class, already discouraged by high excise and annual vehicle taxes. So relatively higher fuel prices for these vehicles may appear to be in line with public policy. However, gasoline sales among ordinary cars is also increasing and are much greater in terms of numbers. If environmental, economic and technological trends turn away from diesels to gasoline and gasoline hybrid vehicles, then that increases a need to reassess these policies. Several factors could be considered. For example, Turkey's foreign account deficit could be reduced by lowering its diesel fuel imports as its exports of excess gasoline production do not offset the cost of replacing them with an equivalent energy volume of imported diesel fuel. A more neutral tax policy between diesel fuel and gasoline would help rebalance Turkey's refinery product slate with Turkish product demand. It should be possible to replace the lost gasoline tax revenue in other ways, especially with taxes that promote Turkey's clean energy economy.

Electrification of Road Transport: Achieving a strong uptake of BEVs and PHEVs is a major policy opportunity to improve the environmental performance of road transport and to reduce expenditures on Turkey's oil imports. Turkey is already taking strong actions to produce and promote BEVs for multiple reasons: reduced oil imports, localization of transport within the Turkish economy and improved emission performance. Wider penetration of BEVs and PHEVs, underpinned by Turkey's broader energy security and localization objectives, are also being supported by a developing ecosystem of auto manufacturers, energy and utility players and consumers. Currently the BEV/PHEV stock is limited to around 1000 cars out of the total stock of over 12.5 million passenger cars. Strong initiatives taken by the Government and several industrial players provide a promising outlook for increasing uptake of EVs starting from mid 2020s and triggered by the TOGG Project and local car development.

The Government targets that around 1 million electric vehicles will be on the road by 2030. Some experts estimate that the stock of electric vehicles would increase to over 2 million in 2030s. There are also some estimations that the total electric vehicle stock will be much lower than the 1 million units, targeted by the Government. This is perfectly natural since we are dealing with a number of uncertainties on both the supply and demand side of BEV uptake. IICEC analyses suggest that several factors will play a role including battery and vehicle costs, and especially the operating cost incentive that will be largely dependent on future government tax policies. The relative cost of petroleum fuels and electricity will be very important. Without considering taxes, electricity is already a less expensive fuel than gasoline or diesel fuel. However, consumer costs are largely determined by fuel taxes. Should electricity that is provided to BEVs be untaxed, or taxed lightly, the operating cost advantage of BEVs could be decisive in driving BEV uptake and meeting government targets. The EU and USA are using a different approach to stimulate BEVs (vehicle greenhouse gas standards that motivate manufacturers to sell BEVs) so the key policy tool Turkey is most likely to use will be vehicle and fuel taxes that make BEVs and PHEVs the most economic choice for consumers. In addition, the widespread uptake of

BEVs will require a vast expansion of charging stations, especially at locations where it is practical for the motorist to leave the vehicle for a more extended period of time than is required to refuel a conventional vehicle.

In order to encourage a greater uptake of electric vehicles, fast charging units need to be widely available and need an adequate level of power supply so as to cope with their high point consumption. Fast chargers can recharge a BEV between 15 to 30 minutes depending on how low the BEV battery was prior to recharging and whether an 80% charge would be sufficient (the last 20% of charging takes longer). This performance requires a high voltage line for the chargers. Widespread charging services, including fast charging stations, in parallel with the development and implementation of smart charging mechanisms for load management should not be any problem for the Turkish power grid or industry. Grid issues can easily be overestimated as region-specific measures to avoid overloading and voltage violations will be sufficient to avoid problems. Nonetheless, the expected uptake of BEVs should become a part of a wider power sector planning process to ensure that power distribution grids can accommodate their varying loads. What should be kept in mind is that, even with many more BEVs that can be reasonably expected over our forecast period, the electric consumption of BEVs will remain less than 2% of total annual power demand. The key take away here is that if BEVs retain a significant cost of driving advantage over conventional internal combustion vehicles, and the enabling policies described here are implemented, the prospects for significant BEV uptake in Turkey are good.

TOGG: Turkey's Automobile Initiative Group (TOGG) introduced the first prescreening car of Turkey on the 27th of December 2019 at the innovation Journey Meeting in the IT Valley of Gebze. Production may begin as early as towards the end of 2022. Established in 2018, TOGG reflects cooperation among the leading Turkish companies in their respective fields under the umbrella of the Union of Chambers and Commodity Exchanges of Turkey.

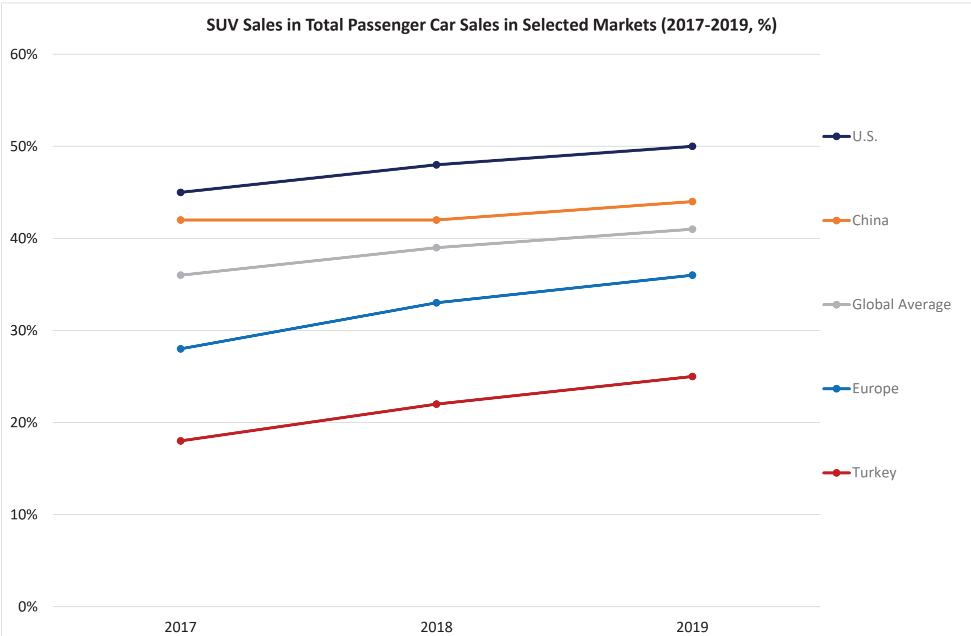
The factory construction started in July 2020 at the Gemlik district of Bursa, the heart of the Turkish Automotive Industry with fully owned intellectual property rights. Plans are to produce 5 different models, including sedans and SUVs, by 2030 using a common e-platform. The brand takes the ambitious approach of achieving technologic transformation to become a BEV manufacturer. Apart from Tesla, none of the other BEV developments appear to be taking this approach. The branding mechanism will address the requirements of both domestic and foreign markets. Along with the branding incentives, the automotive support program will take the technology and production capability into consideration particularly in the field of batteries, sensors and software. All aspects of the project are to be systematically researched and developed including technology development, marketing, and branding. TOGG is expected be competitive in the rapidly developing international BEV market. This is necessary for it to be successful in the Turkish market as well as the product must be on a par or better with the offerings for the many original equipment manufacturers that must initiate BEV production and sales to meet emission requirements in the USA, Europe and China. Battery investments will be further strengthened for electric automotive production. The establishment of an industrial platform which will provide the digital infrastructure and service center for the sector will be a critical element. To maintain the competitiveness of the Turkish automotive industry, and to meet with the changing customer expectations an infrastructure will be created for the new generation vehicles. Within this context, legislation on the collection, utilization and conversion of data from new-generation vehicles to value-added services will be developed and implemented.

Building a domestic hydrogen industry is also one of the recent policy ambitions of Turkey. It will begin with introducing hydrogen into the natural gas distribution system at the end of 2021. At first, this will be experimental with small injections but it will be part of an "all-of-the-above" approach to secure energy supply security with energy resources and carriers to replace oil and natural gas products. However, commercial hydrogen utilization as a transport fuel is not foreseen until near the end of the TEO horizon (out to 2040). Afterwards, it could become an integral part of Turkey's advancing transport economy. In other applications, however, progress could be more rapid, for example, in its ability to fuel high temperature processes in several industries. The technologies and policies that will facilitate an energy transition towards a net-zero carbon economy is discussed in Chapter 6 (The Energy Transition).

Another factor that could have an important role in Turkey's oil consumption and greenhouse gas emissions will be SUVs. As mentioned above, 50% of the new car sales in the United States and 44% of the sales in China were different classes of SUVs. Over two-thirds of passenger car sales in Europe is now occurring in SUVs. Globally, SUVs reached a market share of 41% in 2019 up from 17% in 2010 (IEA 2020). SUV sales are also increasing at a rapid rate in Turkey. One quarter of Turkish passenger car sales in 2019 were SUVs (Figure 2.21). However, 85% of SUV sales in 2019 occurred in B (entry) and C (compact) segments, both having smaller engine sizes compared to most of the SUVs sold in the United States and Europe. Therefore, if this trend continues, the impact of the increase in SUV sales on fuel consumption and emissions is expected to be less than in countries where larger engine sizes are the main choice. However, it is a possibility that this trend may reverse as the customer preferences opt for larger and luxury segments that are currently constrained by affordability and especially Turkish vehicle tax policies.

In both TEO Scenarios, Turkey's fleet of passenger diesel cars gradually decreases. For the Reference Scenario they decrease from 38% to 33% and this declines further to 25% in the Alternative Scenario. These reductions are a result of several factors. The primary driver is reformed tax policies that would remove the gasoline vehicle penalty in order to lower Turkey's imported fuel dependency and reduce foreign fuel costs. Therefore, there would be less of a gasoline/diesel imbalance in Turkey's refinery slates vs. domestic demand. However, other factors are estimated to be important. We expect technological progress in gasoline fuel economy and a larger uptake of gasoline hybrid vehicles. This can offset any fuel efficiency penalty from fewer diesel vehicle purchases. The trends in the European auto industry and their impact on Turkish auto production could also be a factor.

Figure 2.21 SUV Sales in Total Passenger Car Sales in Selected Markets (2017-2019, %)



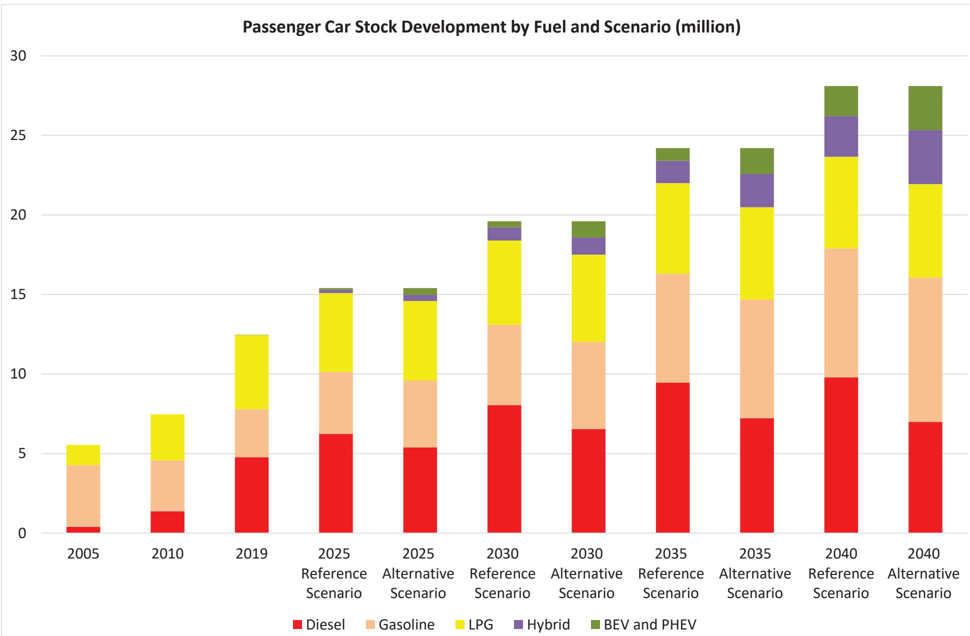
LPG is expected to remain a major fuel choice due to fuel economy and environmental benefits backed by Turkey's experience over the years with an expanded infrastructure. However, the LPG market share is expected to drop to 20% and 21% of total stock by 2040 in the Reference Scenario and Alternative Scenario respectively, down from 37%.

While the time scale for reducing oil consumption through the uptake of passenger BEVs and PHEVs is fairly long, Turkey is nonetheless expected to achieve a strong electric vehicle uptake supported by an extensive electric mobility ecosystem. As Turkey's passenger car stock grows to over 20 million after 2030 and 25 million after 2035, EVs become a more integral part of Turkey's LDV fleet. By 2030, the EV fleet will exceed 1 million vehicles in the Alternative Scenario, compared to 380 thousand in the Reference Scenario (5% and 2% of the fleet, respectively). About 10% of the fleet in the Alternative Scenario is EVs compared to less than 7% in the Reference Scenario by 2040. In 2040, 22% of the total fleet is estimated to be hybrids and EVs compared to 16% in the Reference Scenario up from below 1% in 2019 (Figure 2.22).

Plug-in hybrids can be almost as important in achieving emission and fuel savings benefits as full BEVs. They present no "range anxiety" because they can be refueled with gasoline on long trips but, for many consumers, the much lower cost of operating the PHEV on electricity will encourage the minimal use of gasoline especially in most urban driving where recharging opportunities will be widespread and convenient.

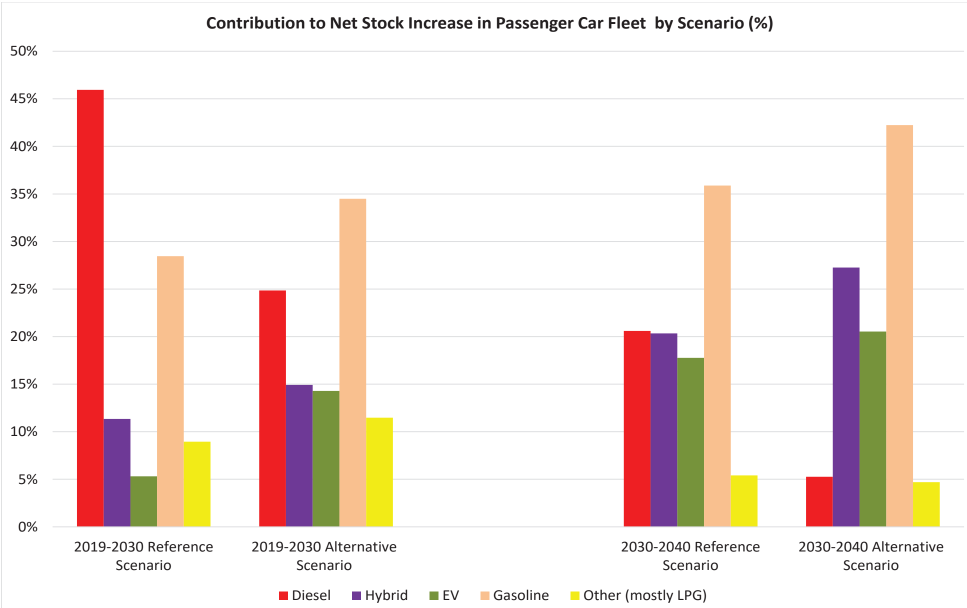
The full effect of BEV and PHEV purchases on reducing oil consumption will be seen after the TEO forecast horizon (2040). There is also the problem that electric drive uptake is not expected among most trucks. These will be challenges that are expected to be addressed towards the end of the TEO time horizon but, the EV investments will set the stage for rapidly reducing oil use in the longer term.

Figure 2.22 Passenger Car Stock Development by Fuel and Scenario (million)



In the Alternative Scenario, gasoline passenger cars represent almost 40% of the increased number of light duty vehicles until 2040, followed by gasoline hybrids, 22%, and BEVs/PHEVs at 18%. The changes in the fuel used by Turkish LDVs is accelerating in both scenarios especially after 2030. Diesel car growth slows after 2030 in both Scenarios. Also, between 2030 and 2040, one out of five passenger car sales is a BEV or PHEV (Alternative Scenario) compared to one out of seven cars prior to 2030. The pace of growth in gasoline-fueled cars also becomes greater after 2030. Gasoline hybrids also show a similar pace increasing their contribution to net stock increase from 15% (2020 to 2030) to over a quarter (2030 to 2040) (Figure 2.23). The Alternative Scenario assumes that Turkey will use tax policies to discourage the purchase of large, fuel inefficient, SUVs.

Figure 2.23 Contribution to Net Stock Increase in Passenger Car Fleet by Scenario (%)



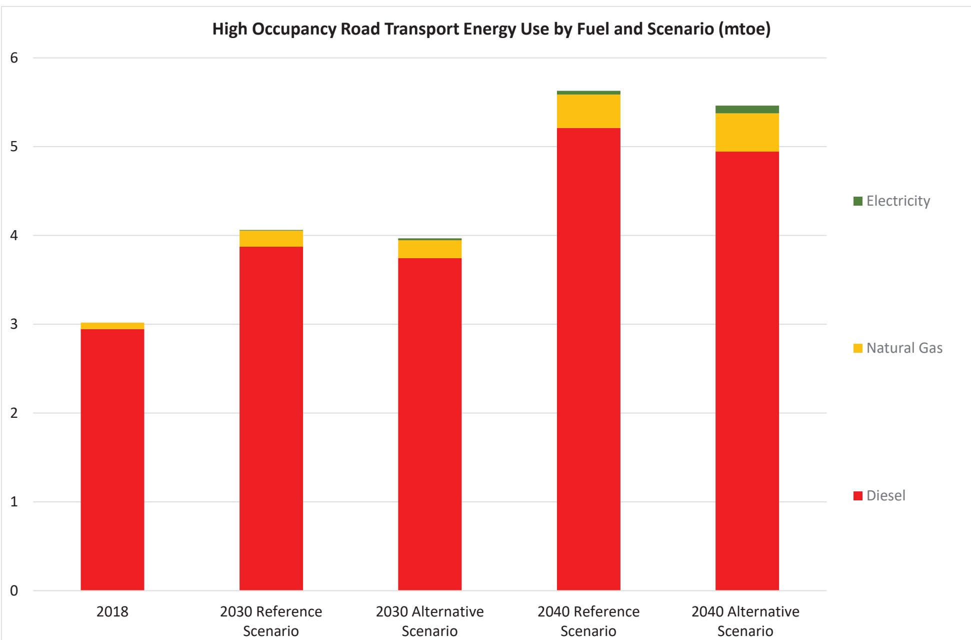
Although Turkey's current passenger car fuel economy figures are better than European and global averages, ongoing global progress in advancing internal combustion engine efficiency provide opportunities for Turkey, especially if supported by fleet renewals. As discussed below, the average Turkish passenger car is 12 years old and 45% are older than 15 years. Both scenarios realize efficiency improvements across the fleet but the gains in the Alternative Scenario are higher because of a faster uptake of new vehicles using vehicle retirement programs and stricter enforcement of pollution standards. Technology advancements in the auto industry are also more promising in the Alternative Scenario allowing for more efficient cars in the marketplace. As a result, the fleet in the Alternative Scenario is more than 10% more efficient than the Reference Scenario (for diesel 21% vs. 11%, gasoline 20% vs. 11%, and hybrids 20% vs. 13%)

Light duty vehicles other than passenger cars, currently representing 3.8 million vehicles (14% of total LDV stock), also expand at a slightly lower growth rate as passenger vehicles and show similar trends in terms of fuel type. As electrified models become more widely available for LDV trucks, the light commercial vehicle fleet also benefits from electrification opportunities, particularly after 2030, with additional oil and emission savings.

High occupancy road transport is widely used in Turkey. Buses and minibuses serve a high share of urban travel especially in the large cities and intercity buses also have a significant passenger share. IICEC estimates that currently 19% of passenger transport energy use takes place in these vehicles. These buses are almost all powered by diesel fuel although some CNG and electrified buses are beginning to be used in the large cities.

Both Scenarios realize a strong uptake of alternative fuel urban buses, backed by policy and investment strategies at the municipal level including the necessary refueling infrastructure. Together with fuel economy improvements in diesel-fueled high occupancy vehicles (14% in the Reference Scenario and 20% in the Alternative Scenario, 2020-2040). Over the same period, the share of high occupancy road travel is also estimated to increase by 7% in the Reference Scenario and 10% in the Alternative Scenario. CNG dominates non-diesel buses at 90% in the Reference Scenario and 83% in the Alternative Scenario where electric buses gain a higher share (Figure 2.24).

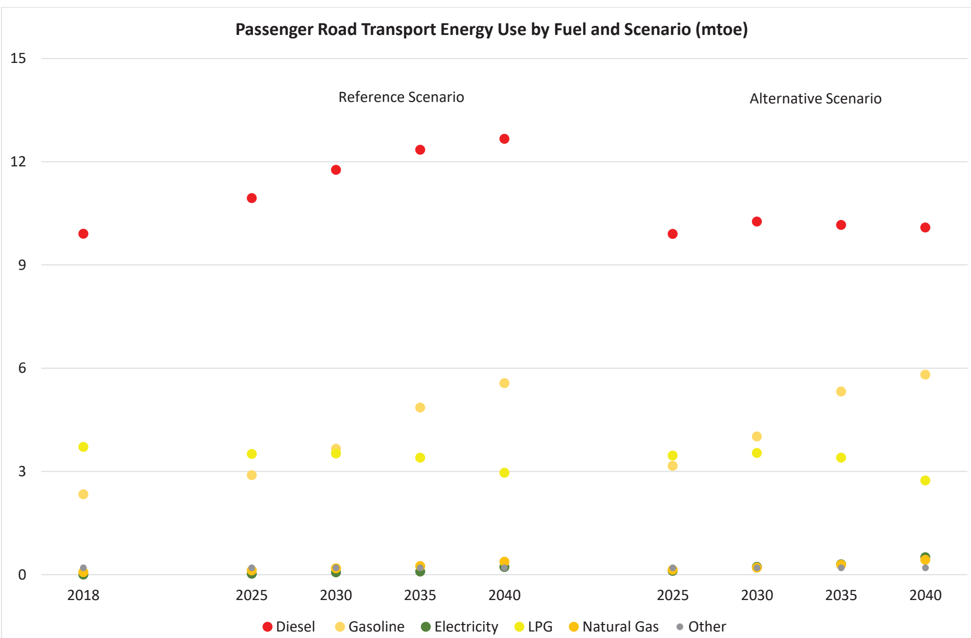
Figure 2.24 High Occupancy Road Transport Energy Use by Fuel and Scenario (mtoe)



Despite the importance of increasing fuel efficiency and high-occupancy modes, passenger travel energy use is expected to increase. In the Reference Scenario, it grows by 35% (to 22 mtoe) by 2040. The stronger Alternative Scenario policies limit this growth to 22% (20 mtoe). The distribution of energy use, however, shows more significant changes. The passenger energy savings achieved in the Alternative Scenario significantly reduce Turkey's consumption of diesel fuel while not greatly increasing energy use in the other fuels. In the Alternative Scenario, passenger road transport diesel use through 2040 stays relatively steady around 10 mtoe but increases to 13 mtoe in the Reference Scenario. Over the forecast horizon, through 2040, gasoline use in light duty vehicles increases from 2.3 mtoe to 5.6 mtoe in the Reference Scenario and 5.8 mtoe in the Alternative Scenario due to the estimated growth of gasoline and gasoline hybrid passenger cars.

LPG use for passenger vehicles begins to decline after 2030 in both Scenarios and results in 1.0 mtoe less demand in the Alternative Scenario. Near the bottom of passenger energy use, natural gas and electricity contribute to 0.9 mtoe by 2040 (4% of passenger road transport energy demand) in the Alternative Scenario (Figure 2.25). What should be kept in mind in considering these passenger energy use projections is the considerable growth of road passenger travel that is expected over the forecast period: 81% in the Reference Scenario and 78% in the Alternative Scenario. Consequently, the energy intensity of road passenger travel is expected to decrease by 25% in the Reference Scenario and 31% in the Alternative Scenario.

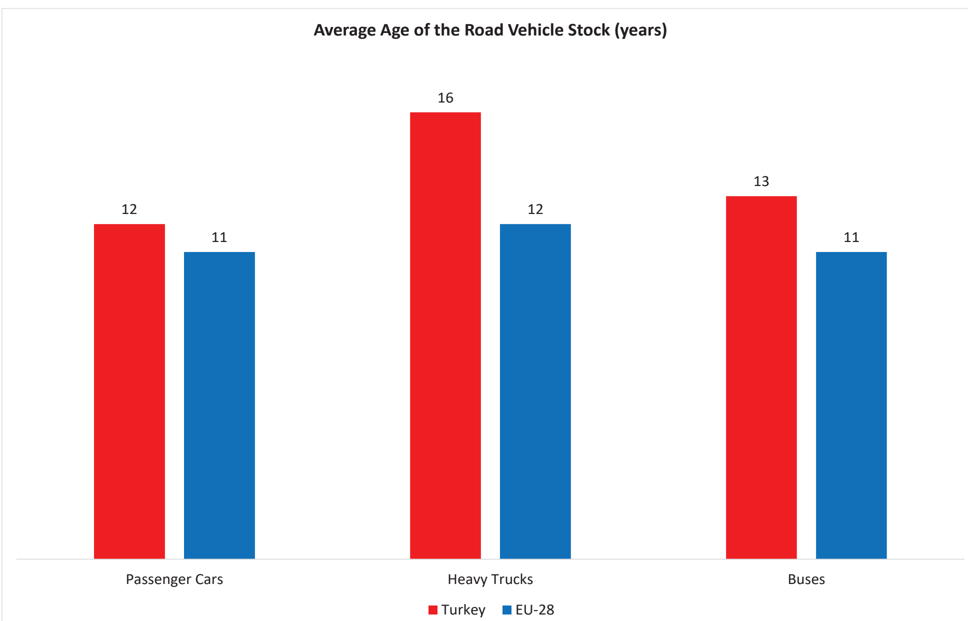
Figure 2.25 Passenger Road Transport Energy Use by Fuel and Scenario (mtoe)



Over 90% of freight activity is performed by medium and heavy duty trucks in Turkey. The truck fleet is also significantly older than the passenger car fleet. The average age of the Turkish heavy truck stock is 16 years, compared to 12 years in the EU (Figure 2.26). 45% of heavy trucks are older than 15 years and 15% of the heavy trucks on the road are over 30 years old (Figure 2.27). The age of the truck fleet is of vital importance for energy consumption. Trucks consume the majority of diesel fuel and are the greatest contributor to Turkey's high oil dependency. The aging heavy truck fleet points to an important opportunity for improving energy efficiency in the transport sector. While Turkey has benefitted from European fuel efficiency standards for light duty vehicles (as the passenger cars produced and sold in Turkey are all world-class vehicles), these benefits have not yet occurred for trucks.

In all countries, the fuel economy and emission standards for trucks have lagged behind light-duty vehicles, partly because they are much more difficult to quantify since truck chassis and engines are typically separate commodities (IEA, 2020). Still, some other countries have adopted fuel efficiency and environmental standards for truck engines but these have not automatically affected the Turkish fleet as the European car standards have[21]. Consequently, fuel efficiency and environmental policies for trucks present a strong improvement opportunity in Turkey. Diesel remains the logical fuel choice for trucks and buses. For heavier vehicles, diesel engines are far superior to gasoline engines. Electric drive is not practical for medium and heavy trucks. Also, hybrid systems do not offer the benefits they do for light-duty vehicles and provide no net benefit in intercity travel for trucks or cars. The future demand of diesel fuel in Turkey will be mainly driven by its use in trucks, similar to many countries and regions. Therefore, given the growing demand for road freight to accommodate a growing Turkish economy, and compounded but a relatively old fleet of trucks, the road freight sector presents an important challenge for Turkey to reduce its oil demand and GHG emissions as well as to improve air quality.

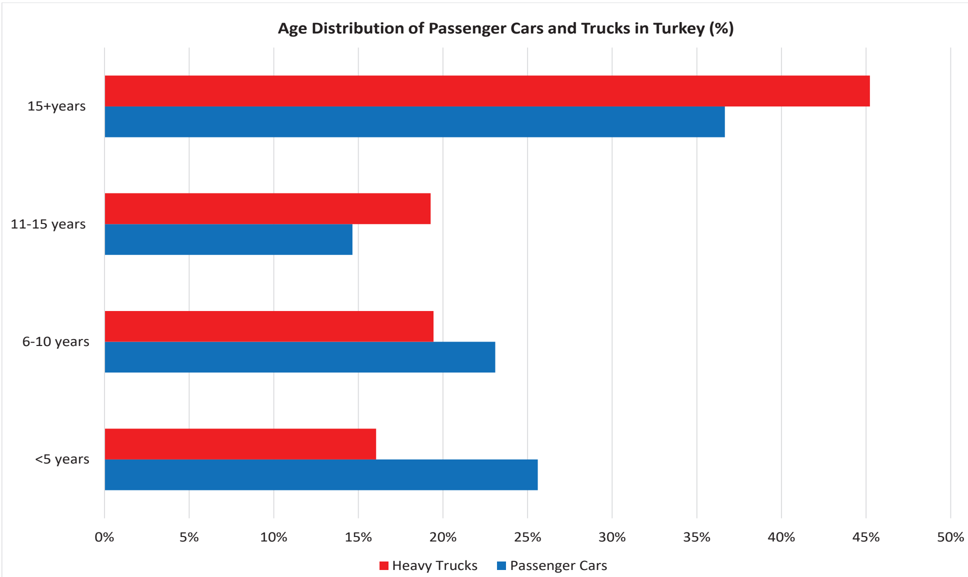
Figure 2.26 Average Age of the Road Vehicle Stock (years)



Source: Turkstat, 2020 and Eurostat, 2019

[21] 70% of HDVs sold globally were subject to vehicle efficiency regulations compared to about 85% of cars and other light commercial vehicles covered by fuel economy standards in 2019.

Figure 2.27 Age Distribution of Passenger Cars and Trucks in Turkey



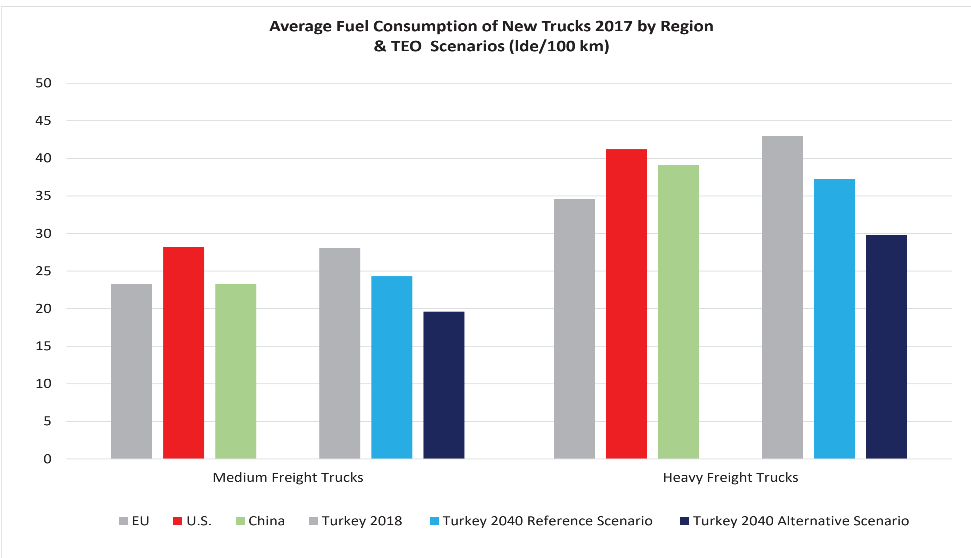
Source: Turkstat, 2020

Acknowledging the negative impact on fuel economy and environment of the aging fleet of cars and trucks, Turkey has introduced regulations and incentives to set aside old vehicles as scrap. The last of such regulations was the Special Consumption Tax (SCT) Discount. It provided an incentive to scrap vehicles older than 16 years. The SCT Discount expired after 2019. Intermittent and permanent scrappage incentives are hardly unique to Turkey and the typical experience is that they fall short of retiring as many vehicles as expected. Out of the 6 million vehicles that could be scrapped in response to Turkey's last SCT, it is likely that the actual number of scrapped vehicles was far smaller. Further to this, there is no clarity yet on the future of this replacement and fleet renewal policy after 2020. Part of the problem is that intermittent schemes are likely to be better than sustained policies as the sustained policy eliminates the urgency of people to respond by a certain deadline. So it is difficult to make scrappage schemes a regular feature of energy policy. Fortunately, other policies can cause the retirement of older trucks and cars, especially establishing and enforcing fleet wide tailpipe emission standards. This would also have a direct benefit on the health of Turkish citizens especially with regard to the exposure to polycyclic aromatic hydrocarbons. The Alternative Scenario assumes that such a policy will be pursued but in a realistic way to encourage a gradual change as opposed to sudden and unrealistic burdens on the trucking industry.

Given the age of the truck fleet and global progress in truck fuel economy, Turkey would gain concrete benefits by achieving a more efficient truck park until 2040. Truck fuel efficiency is a function of different factors such as engine size and power, average mission profiles and payloads.

The EU market demonstrates better fuel economy figures than the U.S. and China and stands as a proxy for Turkey as both markets are tied in terms of imports and exports of various models. New medium freight trucks (MFTs) consume 23.3 lde/100 km (liter diesel equivalent per 100 km) while heavy freight trucks (HFTs) 34.6 lde/100 km in the EU, while, according to IICEC estimates, the average fuel economy of the Turkish fleet of MFTs and HFTs is 28.1 lde/100 km and 43.0 lde/100 km, respectively. The Reference Scenario realizes a partial renewal of the aging fleet until 2040 resulting in improved fleet efficiency figures. The Alternative Scenario achieves a larger renewal of the truck fleet yielding in 19% savings per km for the entire fleet by 2040 compared to the Reference Scenario. Achieving these savings also reflects a 14% improvement of new MFT fuel economy and a 9% improvement of new HFT fuel economy (Figure 2.28). Realizing this untapped potential will not be achieved by scrapping schemes as a forced retirement of older high-polluting trucks will be required.

Figure 2.28 Average Fuel Consumption of New Trucks in 2017 by Region & TEO Scenarios (lde/100 km)

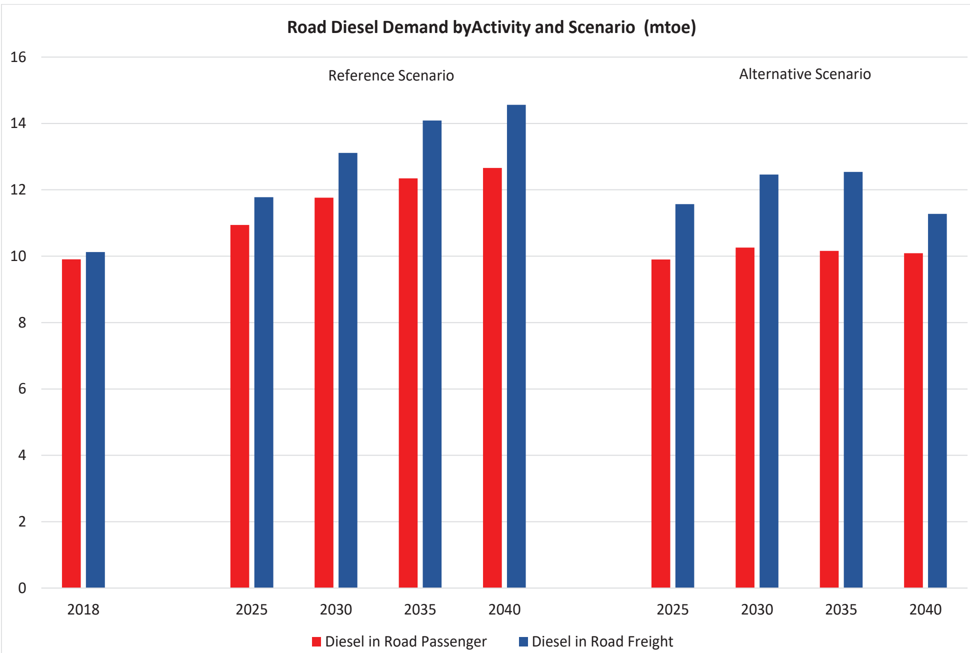


Note: lde is liter diesel-equivalent

IICEC Scenarios show a more efficient road vehicle fleet that is also more diversified in terms of non-oil based fuels. The expected alternative fuels are natural gas and electricity (Figure 2.24 and 2.25.). While biofuels are important in the United States and Brazil and encouraged in the EU, IICEC does not estimate that biofuels are a viable long term option for Turkey's road transport energy balances and concludes, based on the bulk of available evidence, that they are not sustainable policies to reduce Turkey's greenhouse gas emissions, noting that the policies in other countries are largely driven by agricultural interests rather than environmental concerns.

Considering the consequences of both passenger and freight vehicle policies, the Alternative Scenario achieves a low growth of diesel fuel out to 2040 while serving 81% more passenger km of travel and 59% more ton km of freight shipments compared to 2019. However, unlike the pattern of passenger diesel fuel consumption discussed above, truck diesel fuel use grows and then declines after 2035 (Figure 2.29).

Figure 2.29 Road Transport Diesel Demand by Activity and Scenario (mtoe)



Diesel demand in the Alternative Scenario is 14% and 21% less than in the Reference Scenario by 2030 and 2040, respectively and peaks around 2035 supported by improved fuel efficiency, increased use of other fuels and enhanced modal shifts. While there is some fuel switching from diesel to gasoline, compared to the Reference Scenario, road transport energy demand peaks before 2040 in the Alternative Scenario driven by higher reductions in petroleum fuel demand and greater modal shifts as discussed in Section 2.3.6 (Figure 2.30).

The policies, technological advances and measures defined by the Scenarios result in a progressive decline in energy intensity of Turkey's road travel. Energy intensity of road passenger travel (measured in lde/100 Pkm) decreases by 25% until 2040 in the Reference Scenario and 31% in the Alternative Scenario by 2040. Similarly, both scenarios indicate a strong achievement in freight travel energy intensity (measured in lde/100 Tkm) but the reductions by the Alternative Scenario are much stronger relative to the Reference Scenario (12% in the Reference Scenario vs. 28% in the Alternative Scenario). These gains require integrated policy measures including vehicle fuel economy, modal shifts and technology orientations (Figure 2.31).

Figure 2.30 Road Transport Diesel and Total Energy Demand by Scenario (mtoe)

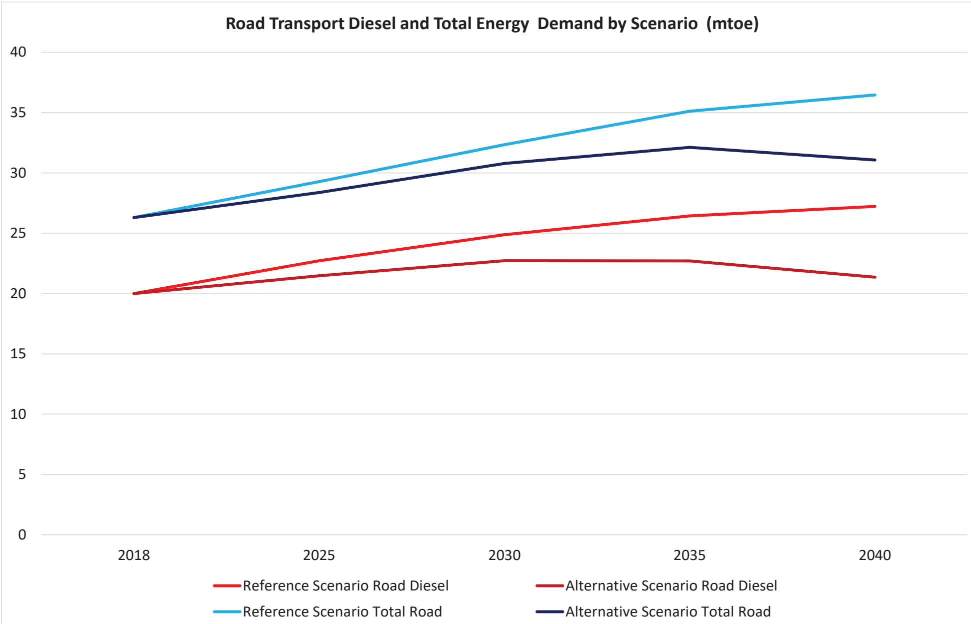
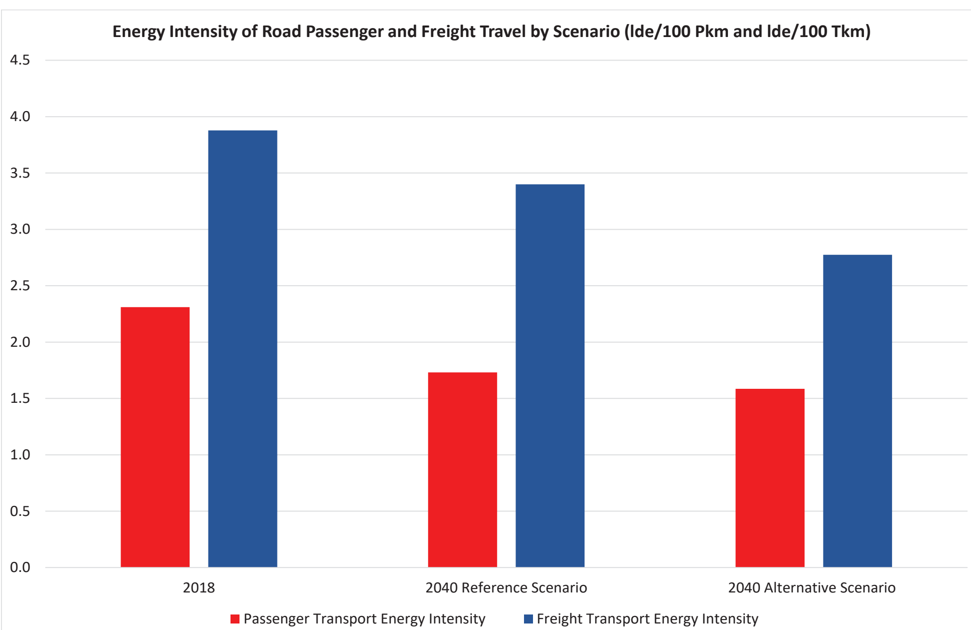


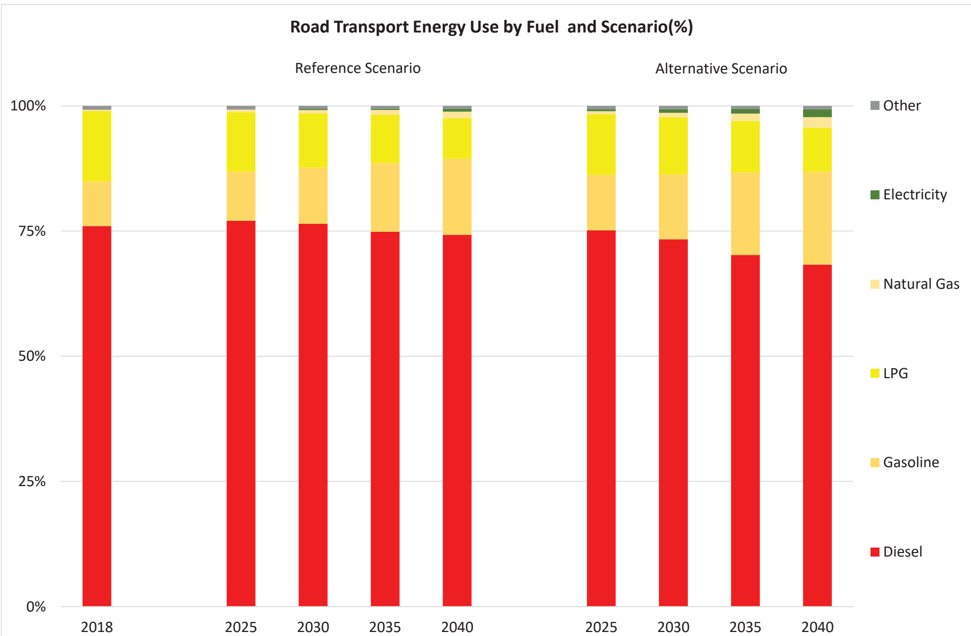
Figure 2.31 Energy Intensity of Road Passenger and Freight Travel by Scenario (lde/100 Pkm and lde/100 Tkm)



Note: lde is liter diesel-equivalent

The road transport energy economy develops into a more diversified fuel mix in both scenarios through 2040 (Figure 2.32). The share of oil used in road transport drops from 99% to 96% in the Alternative Scenario. For fossil fuels, the most notable changes take place in diesel (from 76% to 68%), gasoline (from 9% to 19%) and LPG (from 14% to 9%).

Figure 2.32 Road Transport Energy Use by Fuel and Scenario (%)



Turkey's Auto Industry: Turkey's auto industry will play a major role In driving the sector to be more efficient, technology driven, consumer focused and set on a sustainable pathway. Dating back before the 1960s, the industry began with assembly-based production growing to high value-added production capacity of over 1.5 million passenger automobiles and trucks per year. Thanks to the rapid progress, the automotive sector has transformed its work schedule from assembling automotive parts into a fully developed and well-integrated industry with significant RD&D and design capabilities. Since then it has become one of the main locomotives of the manufacturing sector in Turkey and one of the main sources of Turkish exports with a net positive trade balance and high employment. The auto industry led the Turkish exports in 2019 with over 30 billion TL and accounted for 18% of Turkey's exports. 77% of Turkey's auto production is exported to EU countries. There is also a recent increase of exports to emerging countries in Africa and the Middle East that have relatively low levels of vehicle ownership that, like Turkey's, are likely to increase.

The Turkish automobile industry has been one of the most resilient industrial sectors in the face of economic difficulties. Compared over the last several decades to other industries, the auto industry has done relatively well during times of economic bottlenecks. The Turkish auto industry has achieved productivity growth rates gaining competitive advantages in world-wide automotive markets and has become a major supplier of motor vehicles to Europe. The global auto industry has long ceased to be a collection of national enterprises. American autos are no longer exclusively made in America nor are Japanese cars exclusively made in Japan. In the United States for example, a Japanese-branded car may have more U.S. content than a U.S. branded car. The car logo and the source-country-content of the car no longer have much to do with each other. The major motor vehicle companies have a global reach locating production based on competitive factors and export market considerations.

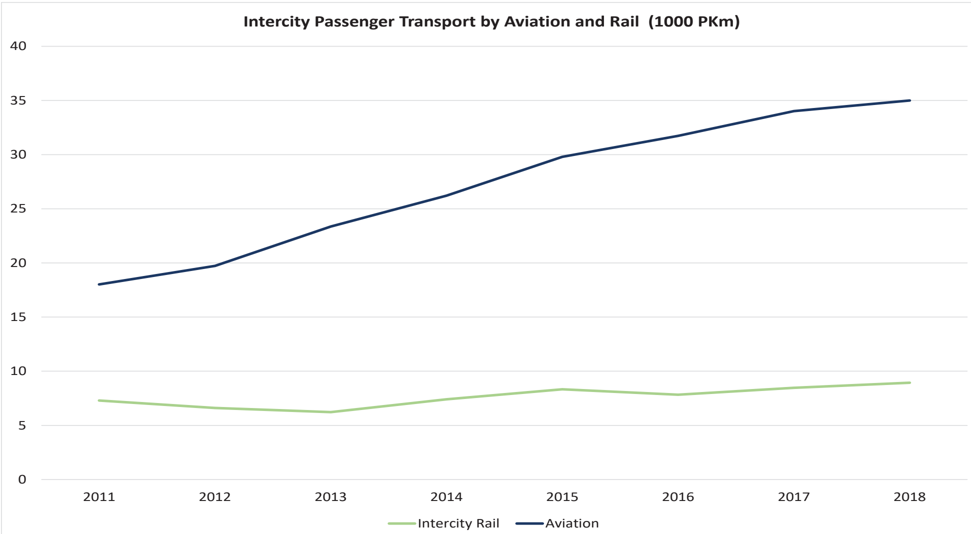
Turkey has participated in this global industry through joint ventures with various multinational corporations. As a result, it has provided value added production, knowledge and technological capabilities to Turkish industry as a whole. For example, about 90 of over 1200 Turkish research and development centers have been established by its automotive industry. The qualified workforce it employs to leverage technology is critical to other important strategic sectors in the country. The sector employs a very qualified workforce which has paved the way for continued development and increased competitiveness of the sector that is critical to the sustainable growth of the Turkish economy. It is fair to conclude that the Turkish auto industry has been a powerhouse for boosting innovation, employment and economic growth across Turkey.

Going forward, it will be important to consider tax policies that could be an obstacle to the industry's next round of structural transformation. Vital industries in developing countries tend to transit from export markets to domestic sales as the potential for the domestic market is strong in developing countries. For Turkey, its high auto sales and consumption taxes, while well motivated for other reasons, does inhibit the domestic demand for cars and can produce a lower scale of production for its automobile industry.

2.3.3 Aviation

Turkey is a geographic area that would allow domestic air travel to serve any city pair in 4 hours or less. In addition, most of these city pairs are served by much less convenient modes of travel, led by buses that require longer travel times. Although recent investments have kept passenger travel by intercity railroads from declining, air travel has gained an increasing share of Turkey's domestic travel and serves 2.9 more passenger kilometer-miles (Pkm), or almost 4 times more, than intercity railways (Figure 2.33). It now represents 9% of intercity passenger travel. This has been supported by Turkey's overall transport policies, increased connectivity among cities, and rising socio-economic fundamentals.

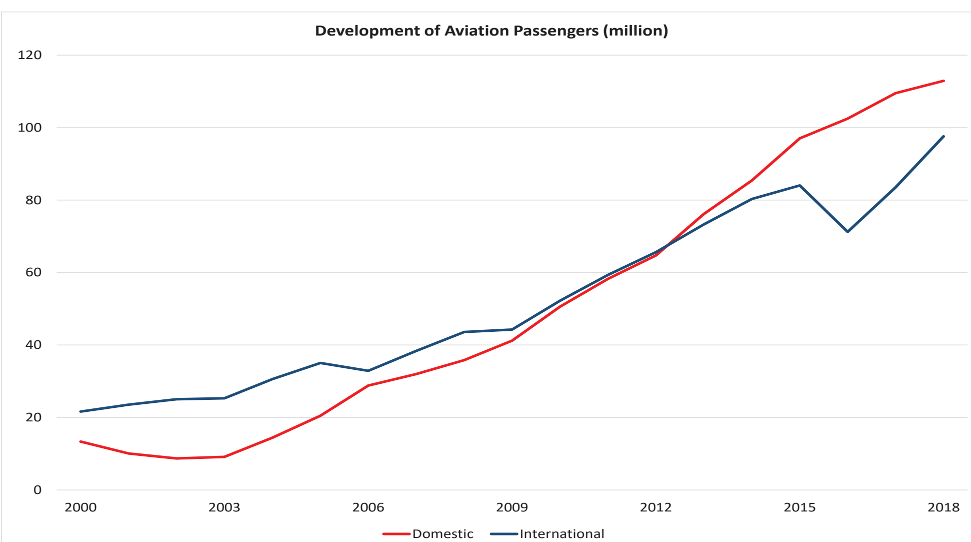
Figure 2.33 Intercity Passenger Transport by Aviation and Rail (1000 Pkm)



Note: Rail activity data including some urban railroads in some cities

This growth is a result of an expanding fleet and infrastructure. Between 2000 and 2018 Turkey's passenger and cargo capacity has soared with the number of commercial aircraft quadrupled and the number of airports open to commercial traffic more than doubled. As the second most popular passenger transport mode after road, domestic travel increased from 13.3 million to 121.9 million domestic passengers and from 21.6 to 97.6 million international passengers from 2010 and 2018 (Figure 2.34).

Figure 2.34 Development of Aviation Passengers (million)



With expansion of airports across the country, domestic passengers have exceeded international passengers since 2010. With this robust growth, Turkey is one of the leading examples globally in rapid expansion of aviation as a critical transport activity. Turkey is the fastest growing European country in expansion of domestic passenger flights. Domestic destination points reached 56 by the end of 2019.

Domestic aviation represents 7% of current passenger transport energy demand while satisfying 9% of intercity passenger travel activity and 4% of total passenger travel activity. This reflects decreasing energy consumption per passenger-km as a result of the aviation industry's investment and strategy efforts towards more efficient aircrafts and operations. In both scenarios, aviation is among the fastest growing passenger travel activity along with rail and marine. Despite activity increases until 2040 over a factor of 2 in both Scenario, energy consumption growth is lower, 1.9 times in the Reference Scenario and 1.7 times in the Alternative Scenario from 2018. These energy intensity reductions are fuel economy improvements as the fleet expands to serve to increasing travel demand. Energy intensity lowers from 1.5 MJ/Pkm in 2018 (compared to the global average of 1.8 MJ/Pkm[22]) to 1.2 MJ/Pkm and 1.1. MJ/Pkm by 2040 in the Reference Scenario and the Alternative Scenario respectively. The improvements expected are notable especially since Turkey's aircraft fleet is relatively young benefiting from recent gains in airframe and engine efficiency.

The aviation industry brings many benefits through expansion of trade, easier and faster travelling, and boosting tourism. Moreover, a modern and strong aviation system also supports realization of Turkey's goals within the scope of the EU harmonization process. The number of employees in Turkey's aviation industry increased to over 200 thousand by the end of 2019. Turkey's air travel has been developing faster in recent years than any other European country with a growth rate typically exceeding 10%/yr. The Turkish aviation sector has been undergoing a comprehensive transformation and so far the industry has already taken off to position itself as one of the leading in Europe. Recently achieved high growth rate does not only reflect the advantageous geographical location of the country which leaves it as a natural hub for air transportation but also a well-planned and coordinated policy planning which ranges from regulatory efforts to environmentally conscious designs and from intensive transparency policies to better quality services. Turkey's international airline industry has benefited significantly thanks to its advantageous geographic position and airport partners in other countries.

The liberalization policies and airport investments have paved the way for the aviation industry's strong role in Turkey's economic development. Turkey's airline industry, which has grown nearly 3 times over the world average, has introduced the "Turkish Model in Civil Aviation" of which with Istanbul International Airport (IST) is its emblem. IST is one of the largest and most modern airports in the world. Once fully operational, it will have three terminals, six runways, and annual capacity of up to 200 million passengers cementing Turkey's historical role into modern times as the geographic hub of the world.

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22 Aviation is among the most energy intensive passenger transport modes. According to the data by the IEA, it consumes 1.8 MJ/PKm at global average with a range of 1.0 to 3.1 MJ/PKm. Global average of aviation passenger transport energy intensity is equal to global average energy intensity of passenger travel by cars and about 50% lower than that for large cars and SUVs.

2.3.4 Rail

The railway network in Turkey has a long history dated back the late 1850s and has a strategic importance for Turkey's transport energy economy as it provides the least energy and emissions intensive mode of transport while connecting cities and supply and demand centers. Over the past decade, Turkey also took steps to introduce rail transit as part of its developing cities and urbanization process.

The transportation of passengers in intercity railroads was equal to 5.8 MPkm in 2000 and 5.5 MPkm in 2010. It increased to 8.9 MPkm in 2018, a 62% growth in 8 years as a result of increased focus on expanding both conventional and high speed rail. Rail freight activity has achieved 26% growth in the same period increasing from 11.5 MTkm in 2010 to 14.5 MTkm. Despite these improvements, rail still represents the second smallest share (marine being the smallest) in both passenger and freight transport activity. As discussed in Section 2.3.6 (Balancing Modes), expanding the share of rail to achieve more energy efficient transport is a policy priority.

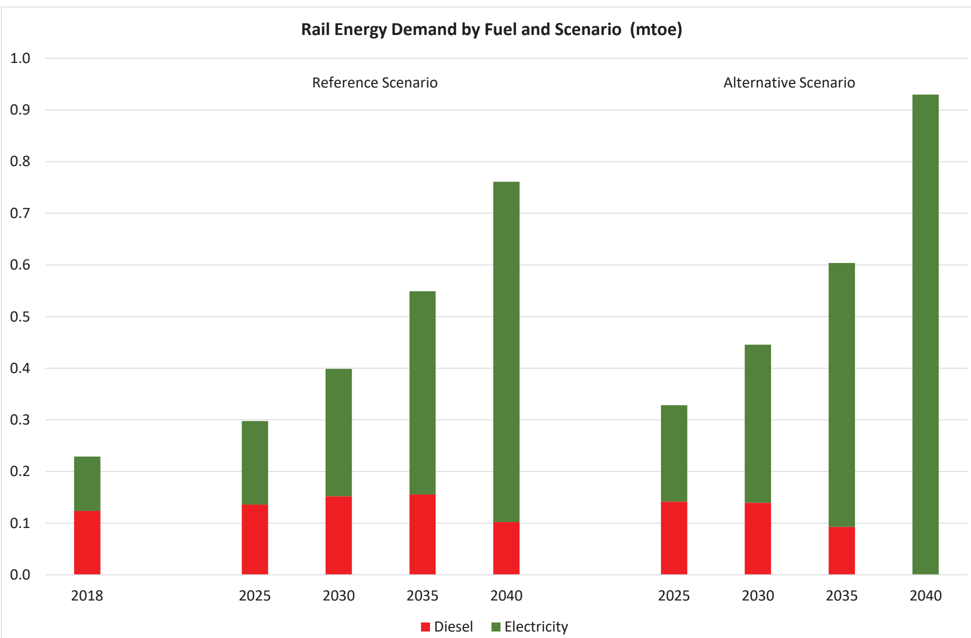
Turkey has a developing railroad infrastructure with over 12,800 km. Conventional lines still represent over 90% of total railroads. Developing HSRs is one of the main policy objectives related to passenger rail travel due to the comfort and speed offered by these technologies. Currently Turkey has over 1,200 km of HSR lines serving in four destinations, to 13 cities representing 42% of Turkey's population. Launched in 2009, HSR technology is one of the key enablers to balance the use of travel modes. The Ankara-İstanbul and Istanbul-Konya lines are proving the consumer appeal and benefits of these investments that will soon extend to more city pairs.

While Turkey's railway share is still low compared to many European and global peers (about 1% of passenger transport and 4% freight transport), the high speed connections and expanding logistics centers would give Turkey a more balanced transportation network that takes advantage of the best available technologies to transfer a portion of traffic from road to rail. The current investment program aims to increase the HSR lines to over 12,000 km based on an extensive project portfolio. In sum, Turkey's short to medium term rail expansion program targets to realize 13,000 km new railways (doubling of the current railroad capacity). Efforts are also underway to rapidly eliminate existing bottlenecks in the infrastructure using a technology-oriented approach. Turkey's railway industry is dominated by the state with only 18% of total rolling stock being owned and operated by private companies. Private rail travel is limited to freight transport at present and private carriers represent an 11% share in total road freight (in tonnage). Turkey's strategies include a privatization program that would open passenger travel to private carriers in the future.

Electrification is also a central strategy in expanding rail activity in Turkey. Currently over 5,500 km of the lines are electrified (43%) and with projects under construction and in planning it would well reach to two-thirds in this decade. Turkey eventually aims to electrify all railways, a direction with positive benefits to reduce imported fuels and improve environmental performance as rail further shifts from diesel to electricity. Tests for Turkey's first locally manufactured electric train were commenced in June 2020 with a target of 80% localization.

Both TEO Scenarios assume current trends and policy and investment programs to achieve short to medium targets in expansion of rail activity including wider electrification. The Alternative Scenario realizes a more aggressive development in railroads capacity supported by the developing electrified rail localization program combined with additional efforts necessary to develop logistic centers, junctional lines and other facilities that help multi-modal carriage of load (rail and road and rail and marine). Rail energy demand increases from less than 0.3 mtoe in 2018 to 0.7 mtoe in the Reference Scenario and 0.9 mtoe in the Alternative Scenario. In the Alternative Scenario, rail contributes to 3% of transport energy demand compared to 1% at present. The Alternative Scenario achieves complete electrification of rail until 2040. In the Reference Scenario, on the other hand, 13% of rail demand is met by diesel by 2040 compared to more than half in 2018 (Figure 2.35).

Figure 2.35 Rail Energy Demand by Fuel and Scenario (mtoe)



Despite increasingly growing activity levels over the years, fuel economy and switching benefits result in lowering energy intensity in both passenger and freight travel. Energy intensity of rail passenger transport improves by 12% in the Reference Scenario and 18% in the Alternative Scenario between 2018 and 2040. Freight energy intensity improvements are more significant as load carriage also gradually shifts from diesel to electricity with superior fuel economy performance. Rail freight consumes 66% less energy per Tkm in 2040 in the Alternative Scenario compared to 2018.

2.3.5 Domestic Marine

Water transport has been one of the most important aspects of human history. Since ancient times it enabled human settlements and facilitated social progress and trade. Today, the maritime industry has the largest share in international commercial transport. In addition to its ability to efficiently move freight over longer distances, marine freight rates are very competitive.

Turkey's geographic location is critical not only in terms of land transportation corridors but also in terms of presenting a potential maritime transportation network. With approximately 8,200 km of coastline and more than 450 seaports, 220 of which are open to commercial traffic, the share of freight maritime transport in Turkey is of great importance. While international shipping has been rapidly developing and contributing to Turkey's growing imports and exports, expansion of the domestic marine sector remains rather limited. While intracity ferry connections are expanding in Istanbul and connecting a few cities, maritime passenger travel represents less than 1% of total passenger travel in Turkey. On the other hand, freight by marine is a key element in Turkey's expanding freight travel with activity increased from 12.6 MTkm in 2010 to 17.8 MTkm in 2018. However, its contribution to overall freight travel has remained largely unchanged at 5% of intercity freight activity due to similar growth patterns in road and rail over the past decade. Future growth activity will depend on several factors such as expansion of the port intake and loading capacities, development of the fleet and competitiveness with rail and road that serve similar destinations.

Both scenarios undertake Turkey's policy objectives to achieve shifts from road travel to marine. Energy demand increases from 0.4 mtoe to 0.8 mtoe in the Alternative Scenario while efficiency improvements in shipping technologies and anticipated operational performances offset over two times activity increases in freight and passenger travel until 2040. Marine doubles to 2% of total transport demand by 2040 in both Scenarios but remains the least employed mode of passenger travel and shipping.

2.3.6 Balancing Modes

Modal shifts are an essential element of transport energy policies because they shift travel away from energy intensive modes such as road to less energy intensive modes such as rail and marine. However, modal shift decisions and realizations depend on factors beyond energy. Any modal shift policy, to be successful, requires that the favored mode become more advantageous to the shipper or traveler.

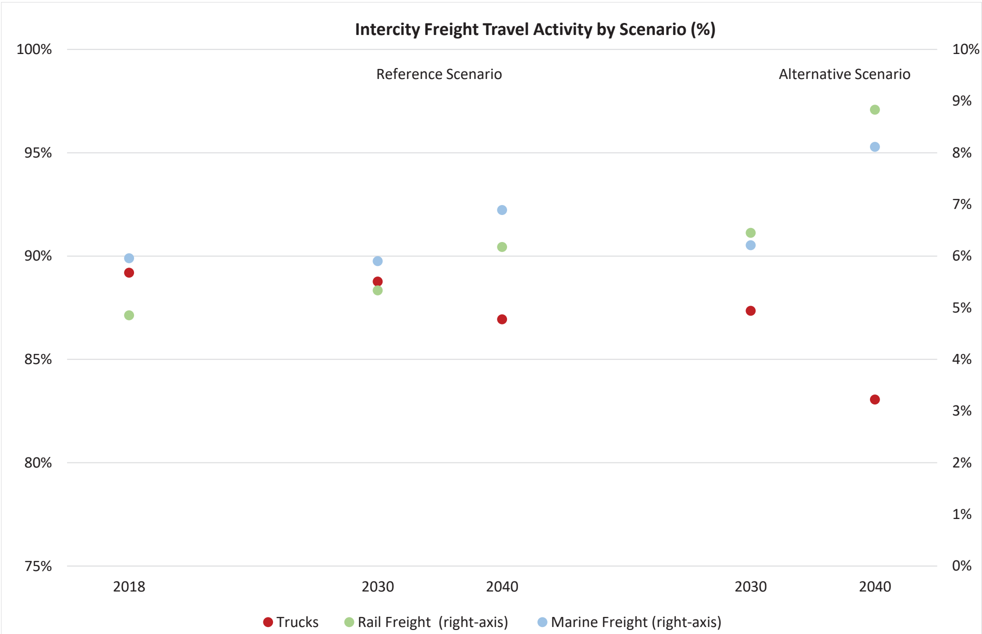
Different modes can either compete or complement with each other with regard to speed, safety, comfort, accessibility or frequency. Cost is also one of the most important factors that determines the modal choice. An integrated approach that changes consumer preferences would provide the sustainable basis needed to achieve improved energy intensity, thus lower fuel demand, through modal shift.

When shipping bulk goods, rail and marine options are logical choices but it takes policy efforts to keep these modes' overall share of freight stable over the years. Part of the challenge is that the composition of freight has been changing away from bulk commodities. Shipments of manufactured products and other non-bulk items are very well served by Turkey's expanding road infrastructure connecting supply and demand centers. Therefore, policy actions to reverse this trend through aggressive policies are needed in order to achieve a more sustainable balance among Turkey's travel modes. Taking account of the predominant share of road transport (over 90% in both passenger and freight travel at present), efforts are necessary to achieve shifting travel to other modes from road passenger and freight.

The major transport and energy policy documents reflect this objective and targets reducing the share of road to 60% in freight and 72% in passenger transport travel. Considering the factors by which different modes compete with the robust growth foreseen in travel activity to satisfy the needs of Turkey's increasingly urbanized population and growing economy, these targets are not easy to achieve. A particular objective is to increase railway freight to over 15% of the total, and passenger travel to over 10% (from 4% intercity freight and 1% passenger transport). Further growth in aviation and an expanded marine share can also contribute in achieving a more balanced modal structure that enhances Turkey's overall transport fuel economy and emissions performance. But, changing the current patterns will require integrated, intermodal and multimodal applications backed by integrated transport and energy policies and infrastructure planning. With Turkey's rapid urbanization patterns and emergence of new population centers, special attention is also needed to optimize urban transport choices reflecting energy use and environmental performance.

Both TEO Scenarios reflect current trends in user choices and policies that support a more balanced modal structure in both freight and passenger transport. In both Scenarios, truck continues to dominate freight activity. However, expanding rail and marine infrastructure including logistic centers and other necessary connections to enable multi-modal travel does constrain somewhat the growth in truck travel. In the Reference Scenario, trucks' share in intercity freight decreases from 89% in 2018 to 87% by 2040 while rail freight increases from 5% to 6% and marine freight from 6% to 7%, respectively, in the same period. The Alternative Scenario realizes more challenging targets such as a faster and more dispersed growth in rail activity across the country that requires a more intensive investment program. Realizing these advantages that more integrated and distributed electrified railroads provide in terms of energy and GHG emissions intensity can only be realized by sustaining investment allocation to these infrastructures. Turkey invested over $25 billion to expand railroads in the past two decades and capital spending, both from the state and private sector, should continue for increasing the contribution of rail in total travel activity. Further expansion in marine freight also requires expanding port capacities while enabling their enhanced interconnections with road and railways. The rail and marine freight combined represents 17% of total intercity freight activity in the Alternative Scenario by 2030 and 2040 respectively compared to 13% in the Reference Scenario and 11% at present (Figure 2.36). These developments affect total energy use, in particular slowing diesel demand growth.

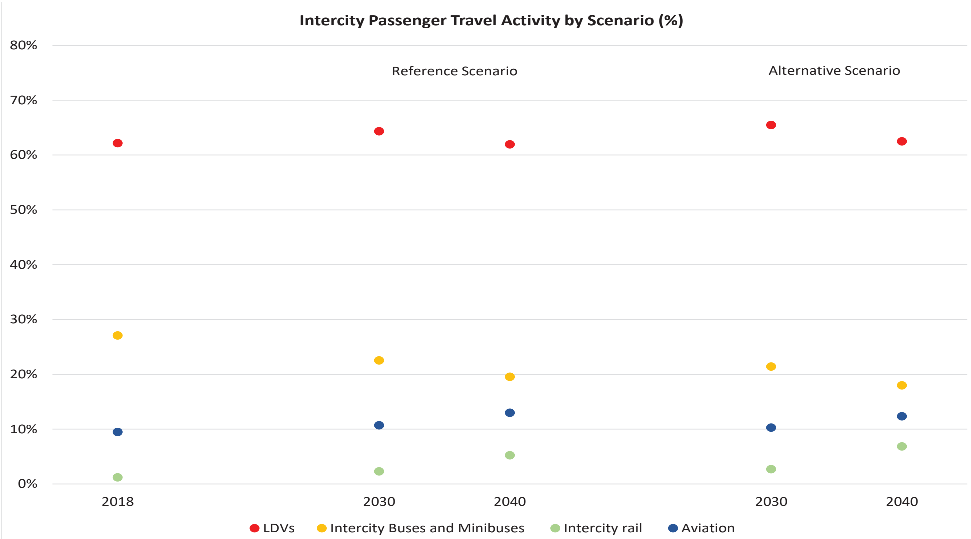
Figure 2.36 Intercity Freight Travel Activity by Scenario (%)



Turkey's intercity passenger travel is also dominated by road (about 90% in 2018) followed by aviation (9%) while intercity rail only provides for 1% of Pkm travel between cities. Intercity marine passenger travel represents only a marginal share. As aviation taking up as a comfortable option and with introduction of HSRs already connecting some large cities, the legacy high occupancy road passenger activity (intercity buses and minibuses) is losing interest. Over 60% of intercity passenger travel takes place in private cars in Turkey. It is anticipated that this will not change significantly in both TEO Scenarios. Major shifts will continue to occur from buses and minibuses to both aviation and rail. These two modes will be the main axis of growth for high occupancy travel and be in competition as HSR infrastructure will be expanding to reach more cities and urban areas.

As long as rail customers are served at prices that are competitive with flying, it is reasonable to anticipate a sustained growth in intercity rail passenger activity. The Alternative Scenario sees some shifts from aviation to rail as it achieves a more distributed HSR infrastructure. Nonetheless, aviation will continue to have a higher share than rail in both Scenarios backed by Turkey's modern aviation infrastructure and services, expanding connections, and rising socio-economic conditions. Non-road based travel modes increase their share from 10% in 2018 to 17% in the Reference Scenario and further to 19% in the Alternative Scenario (Figure 2.37).

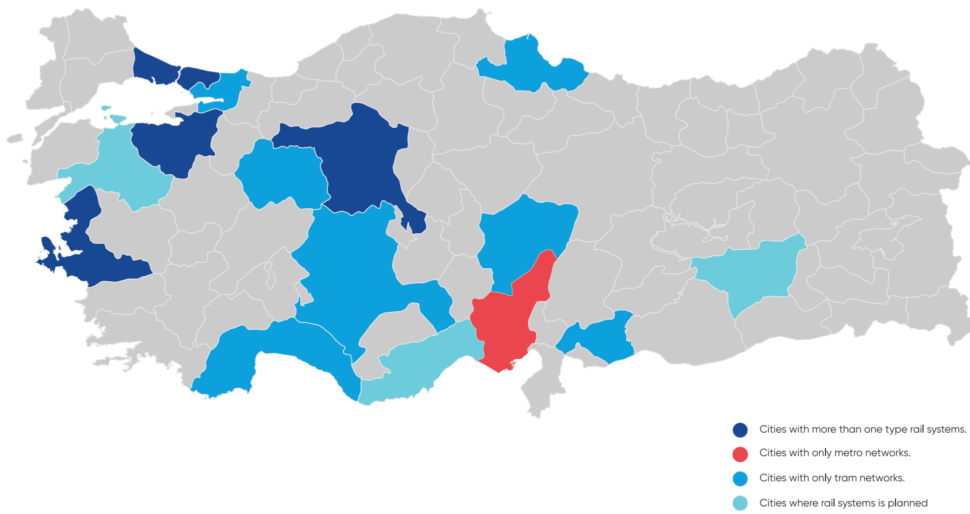
Figure 2.37 Intercity Passenger Travel Activity by Scenario (%)



Turkey's urban travel activity is also dominated by road. Private cars and high occupancy vehicles each provide for about half of total urban passenger travel while the contribution of more efficient modes such as light rail, metro and marine remains at less than 3%. However, Turkey has sizeable opportunities to enable a more balanced and sustainable modal structure in intracity travel if transport policies are well-integrated with broader urbanization and city planning efforts. The rise of new demand centers with high population density require developing travel options that help avoid traffic congestion and pollutant emissions, particularly in densely populated areas, commercial and trade zones. Rail transit stands as an effective instrument to satisfy growing urban travel activity in an energy efficient and environmentally conscious manner. Currently 12 out of 81 large cities has at least one rail based system in operation but this number will increase as both the Government and municipalities are seeking ways to expand light rail and metro infrastructure in more cities (Figure 2.38). 5 cities have 2 or more rail transport types (such as light rail, tram, conventional rail, and metro).

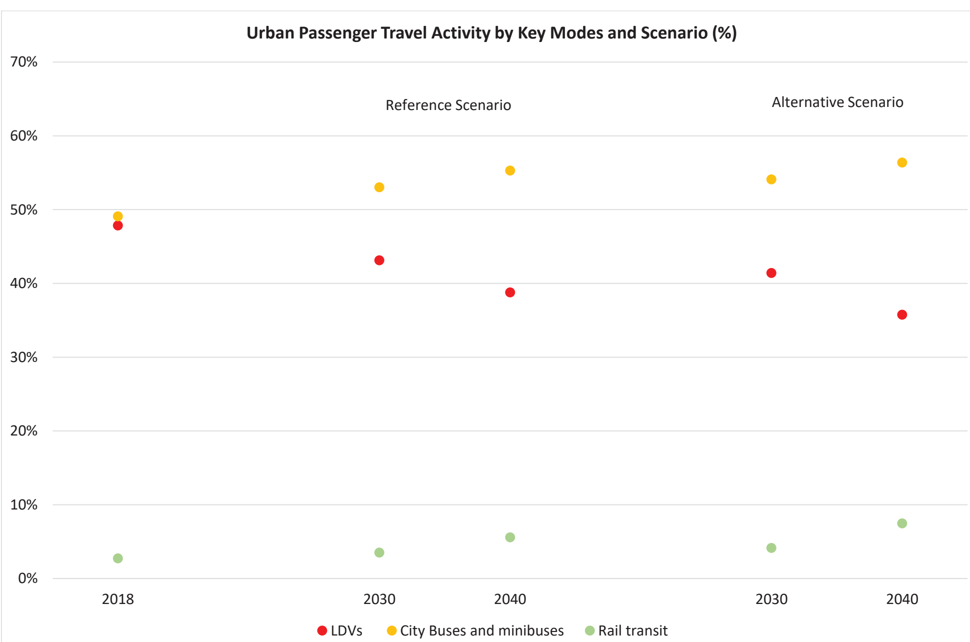
Both TEO Scenarios realize a rapid expansion of urban rail in the next two decades backed by policies and investments. Its contribution to Turkey's rising urban passenger travel activity increases from 3% in 2018 to 5% in the Reference Scenario and 7% in the Alternative Scenario by 2040. Urban planning and city transport strategies also shift a portion of private travel to more efficient high occupancy vehicles. In the Alternative Scenario, the share of private travel in total urban travel drops to under 40% from almost 50% at present (Figure 2.39). Although it brings tangible congestion related advantages as well as fuel use and emission performance benefits, effective realization depends on strategies that motivate user choices besides relative travel costs. Speed, comfort and convenience play equally important roles.

Figure 2.38 Cities with Rail Based Urban Travel (2018)



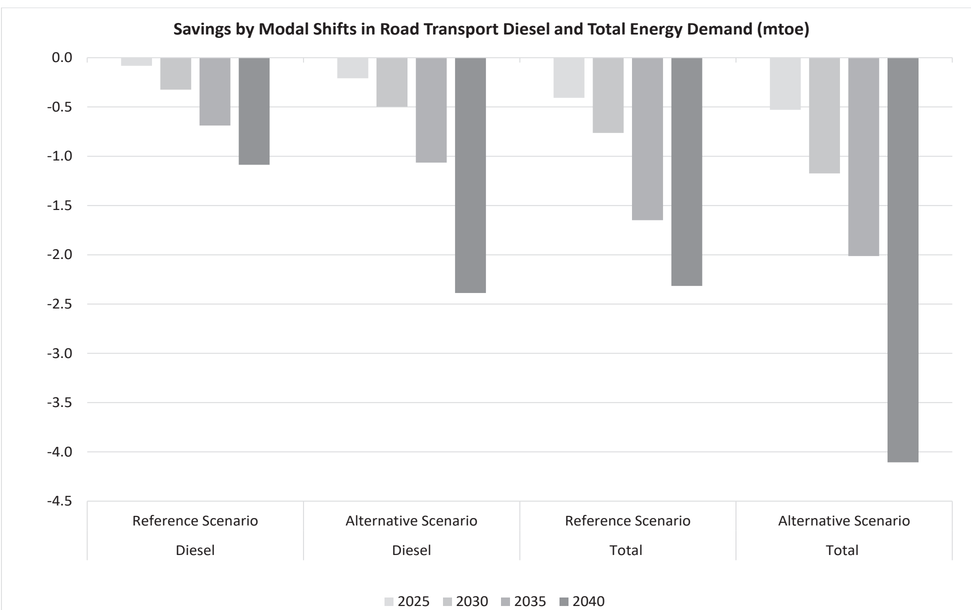
Source: RailTurkey

Figure 2.39 Urban Passenger Travel Activity by Key Modes and Scenario (%)



Modal shifts reflect solid benefits in achieving less energy use for meeting the same level of travel activity. Shifting freight from trucks to rail and marine and passenger travel from road vehicles to aviation, intercity rail, rail transit, and marine lowers road transport diesel consumption by 1.1 mtoe in the Reference Scenario and 2.4 mtoe in the Alternative Scenario by 2040 compared to a "no-modal-shift case". Diesel fuel demand is 10% lower by 2040 as a result of achieving modal shifts across freight and passenger travel. The total energy savings are even higher reaching 2.0 mtoe in 2030 and 4.1 mtoe in 2040 in the Alternative Scenario (Figure 2.40). These additional reductions in energy demand occurs by shifting private passenger travel across all fuels to public transportation, aviation, intercity rail and intercity marine. Total road transport demand in the Alternative Scenario is lowered by 12% (or 4.1 mtoe) as a result of mode shifts reducing the modal share of road from above 90% to 80%.

Figure 2.40 Savings by Modal Shifts in Road Transport Diesel and Total Energy Demand (mtoe)

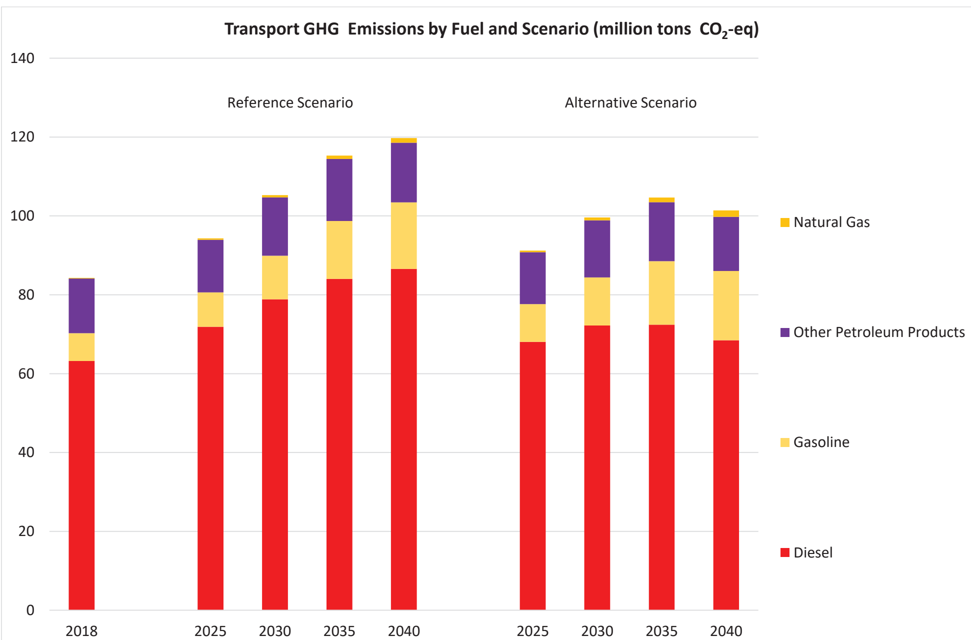


2.3.7 Emissions

The transport sector is the second largest contributor after the power sector to energy related GHG emissions in Turkey. This is due to heavy dependence of the current transport energy demand services on oil products. According to the latest inventory of emissions, transport sector CO_2-eq emissions account for 23% of total energy related CO_2-eq emissions with 84.5 million tons.

Neither Scenario includes a defined CO_2 emissions reduction target. However, both scenarios show a slowed growth in emissions in terms of CO_2-eq from 2018 to 2040, 1.6% per year in the Reference Scenario and 0.8% per year in the Alternative Scenario from 2018 to 2040 compared to 4.9% per year from 2000 to 2018. Although absolute emissions continue to increase, albeit at a much lower rate in the Reference Scenario, the Alternative Scenario shows that peaking in CO_2-eq emissions is achievable before 2040 (Figure 2.41) by implementing integrated actions around fuel economy, modal shifts and benefitting from technology advancements. By 2040, the Alternative Scenario CO_2-eq emissions are 15% less than the Reference Scenario.

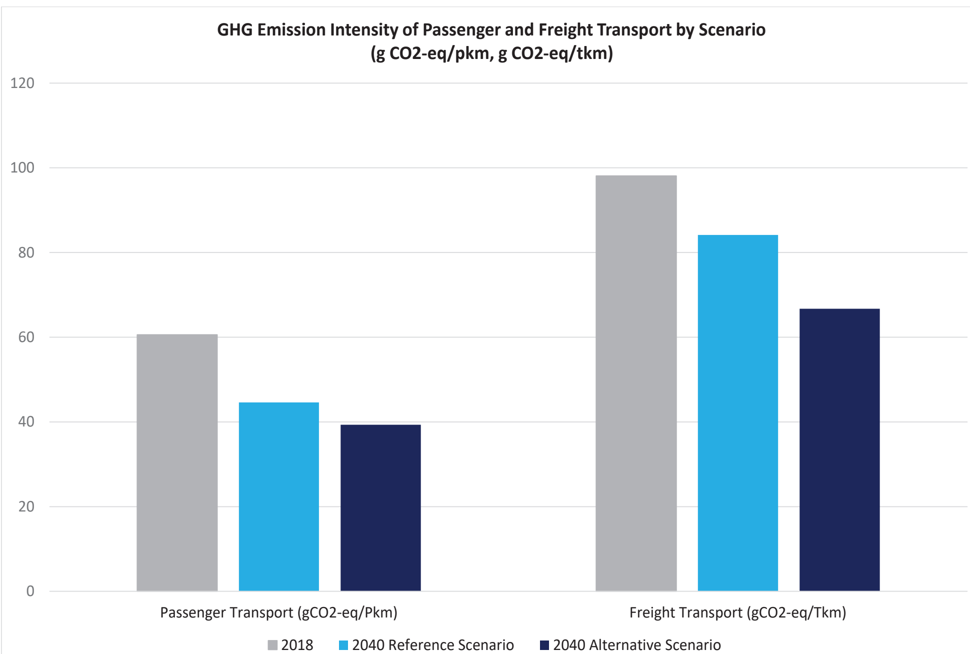
Figure 2.41 Transport GHG Emissions by Fuel and Scenario (million tons CO_2-eq)



Lowering the growth in emissions towards achieving a peak depends on the ability of the transport energy economy to become more efficient and less dependent on oil. Significant improvements in emissions and decoupling from energy demand growth is a direct result of a more efficient transport sector with a more diversified fuel mix demonstrated by the Alternative Scenario. The notable differences in the fuel mix patterns between the Reference and Alternative Scenarios drives the emission differences between scenarios. In the Alternative Scenario, demand for oil products decreases by 4.8 mtoe (-13%) compared to the Reference Scenario.

Figure 2.42 shows the improved carbon footprint of travel projected in both TEO Scenarios. Both scenarios result in significant reductions in GHG emission intensity of transportation (measured in gCO_2-eq/Pkm and gCO_2-eq/Tkm). GHG intensity of passenger transport decreases by 26% in the Reference Scenario and over one-third in the Alternative Scenario by 2040. The Alternative Scenario achieves 32% reduction in GHG emissions per Tkm of freight activity compared to 14% in the Reference Scenario in the same period (Figure 2.42). This improvement is a direct result of implementation of a widespread truck park renewal program and policy measures enabling further intermodal shifts over the Reference Scenario.

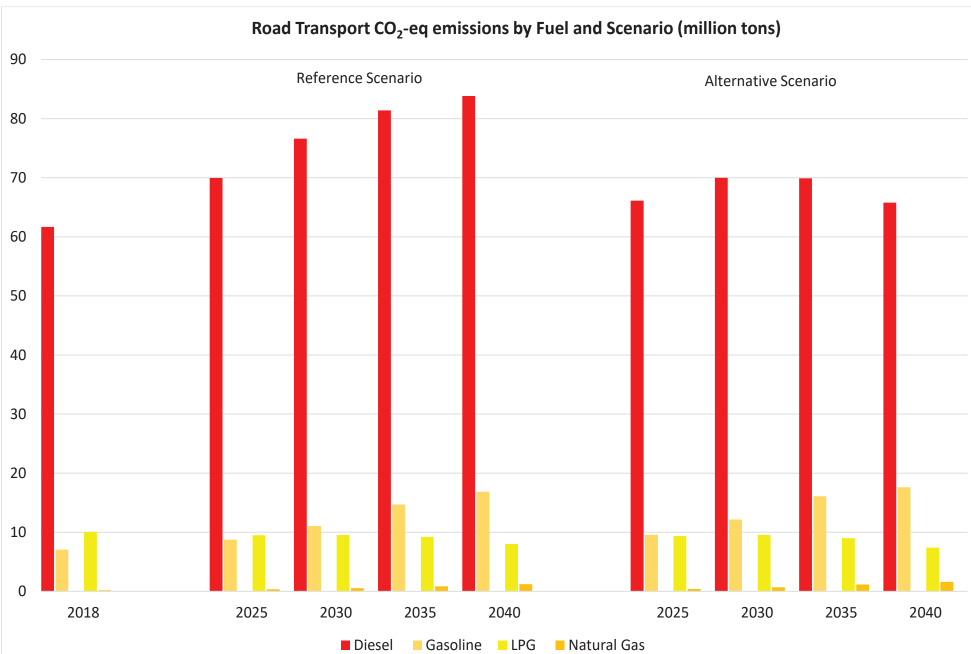
Figure 2.42 GHG Emission Intensity of Passenger and Freight Transport by Scenario (gCO_2-eq/Pkm and gCO_2-eq/Tkm)



These efficiency and emission improvements are achieved by enhanced policy efforts and market developments, particularly in the areas of new vehicle fuel economy, retirement of older inefficient and high polluting vehicles and inter-modal shifts. Wider electrification of transport including road and rail and stronger uptake of natural gas as a sustainable fuel in HDVs also contribute to more sustainable development of the transport sector. Increases of CNG (+33%) and electricity (+63%) also improve the carbon intensity of energy use in transport in the Alternative Scenario over the Reference Scenario.

Figure 2.43 shows that road transport will remain as the major contributor to emissions. It still represents 91% of transport CO_2-eq emissions in the Alternative Scenario and 92% in the Reference Scenario compared to 94% in 2018. As a result of policies and technology advancements lowering diesel demand growth, in the Alternative Scenario diesel fuel contributes to 71% of road CO_2-eq emissions (61.7 million tons) compared to 76% in the Reference Scenario (83.8 million tons) by 2040 and 78% in 2018 (83.8 million tons). CO_2-eq emissions from gasoline increases from 7.1 million tons in 2018 to 16.9 million tons in the Reference Scenario and 17.6 million tons in the Alternative Scenario (Figure 2.43). Emission reductions in road transport is a strong contributor to the overall reduction of the transportation sector's total carbon footprint reported above. By 2040, in the Alternative scenario the truck emission footprint (gCO_2-eq/Tkm) is 32% lower than in 2018 and 21% lower than projected in the Reference Scenario.

Figure 2.43 Road Transport CO_2-eq Emissions by Scenario (million tons)



Both aviation and marine emissions increase compared to 2018 as a result of increased activity despite significant fuel economy improvements introduced by uptake of new aircraft and vessels. Nonetheless, these efficiency improvements are important. For example, in aviation GHG intensity reduces by 23% and 28% in the Reference Scenario and the Alternative Scenario, respectively, until 2040. Technology breakthroughs, such as electric hybrid aircraft or hydrogen fuels could significantly lower the carbon footprint but are not foreseen to be commercial opportunities to make an important difference by 2040.

Transportation is a "hard-to-abate" energy sector but opportunities will exist beyond 2040 to greatly reduce emissions and fuel use through a more fundamental energy transition as will be discussed in Chapter 6 (The Energy Transition).

Rail transport has the lowest energy intensity among modes for both passenger and freight transport. Supported by a wider electrification, rail related emissions show a strong decrease from 2018 in the Reference Scenario (-17%) and diminishes in the Alternative Scenario where the whole rail infrastructure is electrified. CO_2-eq intensity of rail freight decreases from 7.6 g/CO_2-eq in 2018 to 2.5 g/CO_2-eq in the Reference Scenario by 2040.

2.4 IICEC Policy Recommendations

- **Overview**

Turkey has rapidly advanced transport services for its citizens in the recent two decades with significant infrastructure investments, improved vehicle fuel efficiency, improved rail services, sophisticated freight logistics to serve the growing economy and robust aviation growth with its many economic and personal benefits. The Turkish automobile industry has also advanced from basic assembly plants to a fully integrated industry with R&D capabilities that have favorably impacted Turkish R&D in other sectors. IICEC's policy recommendations build on this record of success continuing the push to a more fuel efficient road transport sector and emphasizing the Government's policies to move more passengers and freight away from road travel to rail and marine. In addition, current policies to provide infrastructure support for a rapid uptake of electric vehicles and, in particular, the TOGG project to localize production of BEVs and the rail electrification program is in line with this policy agenda to make Turkey's transport sector more sustainable. Nonetheless, as our analysis in this chapter has shown, and will be discussed further in Chapter 3 (Oil), moving away from Turkey's oil dependency is not an overnight proposition and will take time before these multiple efforts cause large changes in Turkey's transport energy use. Nonetheless, Turkey's transport policies should be sustained along these lines to achieve a reduced share of road passenger and freight transport, improving the energy efficiency in all transport modes and advancing electrified vehicles to the maximum extent practicable.

There are strong headwinds against rapid reduction of transport oil use that need to be acknowledged. Turkish passenger car ownership is the lowest across Europe and socioeconomic factors will drive higher auto ownership per capita. This should not be avoided and, given the importance of the automobile industry in Turkey, is something to be encouraged as the economy matures from one with an export focus to a domestic focus. In addition, Turkey has a growing population and will have robust economic growth meaning that, even with a significantly lower oil footprint per passenger-km or ton-of-freight-km, the trend is for oil use to substantially increase. Therefore, minimizing and stabilizing Turkey's oil demand growth is a challenging goal. Achieving a lower oil intensity for the Turkish energy economy requires an integrated policy and technology approach that only can be achieved by a progressive agenda to improve efficiency and sustainability of the transport sector.

- **Enhancing Inter-Modal Shifts and Achieving a More Sustainable Modal Balance**

The future growth and characteristics of the vehicle stock will have a major role in the energy demand patterns for road transport. Following global trends, trucks will remain a major user of energy in Turkey with their increasing activity to enable industry and commerce. Additional transport services will be needed to accommodate the growing urban centers as they become more important elements in Turkey's producing and consuming economy. In addition to these main dynamics defining energy use by modes and fuels, some other characteristics such as aging of the trucks, and intra city transport also require attention.

Achieving the best balance between reducing the energy and environmental burdens of transport while accommodating Turkey's growing population and economy will require integrated planning. Urban planning will be particularly important as the opportunities for the rationalization of transport in cities are the greatest especially if supported by effective policy instruments and persistent infrastructure investments. At the same time, attention must be paid to consumer preferences as a successful transition to higher occupancy modes of travel will only be achieved by offering travelers a preferred alternative. The challenge is to present new ways of getting around that consumers find attractive and new ways of conducting commerce that are effective and efficient.

Increasing the shares of domestic marine and rail should be achieved with a better integration with road travel. Shifting road travel to rail, in urban and intercity travel, has the most significant potential to reduce energy use. The rail use targets for both passenger and freight are important but to realize them requires policy coordination and large infrastructure investments. It requires sustained infrastructure investments guided by integrated planning and policy coordination. Even then, especially for intercity passenger travel, the induced travel caused by improved rail services can offset some of the gains expected from mode shifts. This is because improved transport services cause two types of effects: substitution of travel from other modes and new travel that would not otherwise have occurred (induced demand).

Induced demand is less likely to offset the benefit of shifting freight away from road travel. Expanding marine and rail freight transport, by taking advantage of Turkey's long coast lines and Turkey's expanding rail infrastructure offer a good potential if shippers are offered cost-effective options supported by modern intermodal connections and the employment of data and logistics software. As with urban transportation planning, integrated planning supported by more detailed shipping surveys will ensure the wider use of multi-modal freight transportation. Not only does this help realize Turkey's ambitious modal shift goals but provides Turkey's economy with a more efficient and data-driven freight distribution system.

- **Improving Road Vehicle Fuel Economy and Reducing Road Vehicle Oil Use**

A more efficient transport sector requires sustained improvements in fuel economy. Turkey's existing vehicle taxation system favoring small engines brings advantages for reducing unit fuel consumption in a growing passenger car fleet. It also provides tax benefits for electric vehicles compared to gasoline and diesel engines.

While these mechanisms can continue to support improving fuel economy, additional or revised tax regimes should be considered in light of changing technological opportunities and Turkey's refinery balances. Consideration should also be given to other instruments that set new vehicle excise taxes according to oil consumption and carbon intensities. While fuel efficiency standards may be redundant for passenger automobiles because Turkey's excise tax policies encourage the purchase of smaller vehicles with smaller engines. In addition, the global automobile industry is producing a set of relatively homogenous fuel economy technologies in each vehicle class due to fuel economy regulations in key consumer countries, especially Europe and the United States. In contrast, consideration should be paid to establishing fuel economy requirements for commercial vehicles, especially medium and heavy trucks. Because of the diverse way medium and heavy trucks are marketed and purchased, compared to passenger vehicles, such standards are more complex. They typically require that the fuel economy standards be placed on the truck engine rather than the truck itself. That means that other aspects of truck efficiency relating to the truck chassis and drive train require separate initiatives. Even for countries that have had a long history of fuel economy regulations, systems to regulate heavy truck fuel economy came much later and were more complex.

For the next 20 years, how quickly older vehicles are retired can be more important in reducing Turkey's oil consumption as will be caused by improvements in new vehicle efficiency. Most older vehicles have poor fuel consumption and cause high pollution that harms public health. IICEC does not believe that long-term retirement rebate programs are an effective measure and even unexpected short-term programs are of limited value. The most effective measure to retire old vehicles is to establish pollution standards that all vehicles must meet. They could be phased in to gradually force the retirement of older cars and trucks. This would move Turkey's vehicle fleet fuel economy to be more in line with its new vehicle fuel economy and provide significant air quality benefits to Turkey as the high polycyclic organic hydrocarbon emissions of these older diesel trucks are particularly harmful. While this approach requires a careful implementation to maintain public acceptance, there would also be benefits to Turkey's economy from the domestic motor vehicle industry. All these approaches would help deliver substantial economic and environmental gains to Turkey.

Current policies discouraging gasoline vehicle purchase and fuel consumption such as higher gasoline prices than the diesel prices should be reconsidered. While gasoline vehicles in Turkey may be particularly associated with luxury and high performance, leisure vehicles, recent data shows that the purchase of smaller engine, less expensive gasoline vehicles is on the rise. Considering the recent controversies concerning diesel automobile emissions, trends in Europe and new technologies to improve gasoline vehicle fuel efficiency, a reassessment of these policies is due. As discussed in Chapter 3, Turkey's refinery balances are long on gasoline and short on diesel fuel. This requires export of gasoline and import of diesel fuel. The net cost to Turkey of these trades is high and constitutes a high share of Turkey's fuel import bill. Consequently, an increasing share of gasoline light-duty vehicles will help to reduce these import costs.

Besides considering the national payments benefits from rebalancing Turkey's product slate demand to better match what Turkish refineries produce, a more neutral tax policy between diesel fuel and gasoline might better accommodate trends in vehicle technologies, especially gasoline lean burn and hybrid vehicles that are almost always powered by gasoline engines. From the fiscal perspective, lost tax revenue from lower gasoline taxes could be reimbursed in other ways including vehicle taxes that especially target the least fuel efficient or highest polluting road vehicles.

For heavier vehicles, diesel engines are far superior to gasoline engines. Electric drive is not practical for most trucks and hybrid systems do not offer the benefits they do for light-duty vehicles. Therefore, diesel remains the logical fuel choice for trucks and buses over long distances. IICEC analysis suggests that efforts to substitute older vehicles with more fuel-efficient trucks will be important. While hydrogen-powered trucks may be a long-term answer, they cannot be expected to be important in the time horizon of the IICEC Scenarios (2040). Until then, improved truck efficiency and reduced pollution remain a more urgent priority. As discussed above, vehicle pollution standards should be employed to remove older trucks from the fleet and modernize Turkey's truck fleet as one of the most important ways to keep Turkey's oil import bill from rising. The renewal of the truck fleet would take advantage of the most recent developments the motor vehicle industry has been advancing in terms of medium and heavy truck efficiencies. More sustainable solutions could also be developed around a continued utilization of CNG, LNG and LPG, where Turkey has been a world leader in using these fuels. Global oversupply in the natural gas market, regional gas glut and Turkey's extending natural gas infrastructure support the competitiveness of LNG and CNG heavy duty vehicles. Also, with a well-developed infrastructure and ongoing investments, LPG's role should continue to be strong in the Turkish transport economy.

- **Increased Use of Alternative Fuels and Achieving a More Localized, Sustainable Transport Energy Economy**

Policies to promote a less-oil dependent transport sector also goes hand in hand with Turkey's energy localization efforts. Government policy and industry support are expected to produce a strong increase in electric vehicle sales and use. While introducing and adopting these new technologies, Turkey would become a technology player and an industrial participant in technological advancements in the transport sector. As has been shown to be the case in Turkey's automobile industry, this will have wider implications for other R&D and high profit opportunities in other sectors. The local BEV car project is a key element in this strategy. Localization efforts in growing charging infrastructure software and hardware also complement the transport localization strategy besides being necessary to enable consumer use of BEVs and PHEVs. Turkey has already achieved substantial progress in the electrification of railways. Technology development and investment pathways indicate a progressive growth that can be increasingly localized.

As the use and share of electricity gradually increases in transportation, the growth in clean electricity supply options becomes more important. A less carbon intensive power generation mix serves multiple objectives including localizing Turkey's high technology economy, reducing urban pollution and greenhouse gas emissions. These developments will increase the synergies between the electricity ecosystem and the transport economy and may create new business models and innovation opportunities. Technology oriented policies and investments are necessary to achieve the localization goals for the overall energy sector as well as the adjacent key industries positioned around the transport sector including automotive, rail, and logistics. These R&D efforts in emerging road transport technologies offer significant localization capabilities and would establish Turkey as an exporter of sustainable transport technologies to developing energy economies.

The recent government announcements also envision prospects for introduction of hydrogen as an energy carrier in Turkey's growing and developing energy economy. Although use of hydrogen as a transport fuel is not an immediate priority for Turkey due to the current immaturity of HFCV technology globally, it would become a sustainable option to diversify the fuel mix over a longer horizon. Turkey can timely benefit from emerging regional or international cooperation efforts and initiatives that aim at improving technical and economic performance of hydrogen vehicles.

- **Urban Transportation Planning**

As the transport sector encompasses different modes and technologies with varying characteristics, achieving desired objectives increasingly requires data-based assessments. The compilation and evaluation of data regarding transportation activity is not an easy task compared to several other economic sectors. Each transportation mode has different dynamics including different infrastructure characteristics and technologies. Differences in urban and intercity transportation dynamics and a wide spectrum of vehicle technologies with differing technical, economic and environmental features are also the reasons for the need to achieve a more structured and detailed energy accounting framework. This is particularly important in urban areas where the interaction among different modes of transport on each other is so significant, with its main adverse consequences, traffic congestion and urban air pollution.

Turkey's transport policies are becoming increasingly driven by data as recent legislation puts emphasis on gathering and analyzing transport related energy data with further detail on activity, vehicle and fuel characteristics and benchmarking. With respect to urban transportation planning, it is essential that the integration of data and planning decisions be taken at a local level with significant public input. However, to be successful, detailed data is required on local transportation activity and the consequences of that activity. In addition, an administrative structure needs to be established with the authority to execute a transportation planning process. For this transportation planning process to be meaningful, capital investments should be planned as a part of urban transportation plans.

Consequently, IICEC recommends that a new initiative be established to create the data that is required for effective urban transportation planning. Supported by the Government, all urban areas should be given the resources and the methodologies to conduct a comprehensive and detailed travel survey. New urban transportation planning centers would utilize this data to establish long term plans using a process that includes effective public input. Capital outlays for heavy and light rail, bus on exclusive right of way and possible disincentives for private vehicle use would have to correspond to these plans. As different urban areas might pursue different approaches, over time, because of the consistent data systems being employed, each city or urban area can learn from the experience of the others to fine tune their plans as these plans should not be set in stone but be flexible to accommodate new information. The success of this initiative will be to convince commuters and other urban travelers that attractive public transportation services are preferable to the use of private auto travel despite the fact that private auto ownership is likely to be increasing across the board in Turkey. Broad public support can be established for this approach because of the traffic congestion that is caused by unrestricted private automobile use.

It would be widely recognized that measures to tame traffic congestion (e.g., parking restrictions, high occupancy travel lanes, low emission zones in urban centers, etc.) and the urban pollution it causes are in the public's interest. In addition, these planning efforts could provide new tools to promote other elements of Turkey's transport policies. For example, they could provide privileged access for BEVs which would be a powerful incentive to encourage their purchase.

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CHAPTER 3:
OIL

Summary

- Oil, representing 35% of Turkey's energy demand, has been in the decline in all sectors except for transport that remains 99% dependent on oil.
- Turkey is around 90% reliant on crude oil imports and also imports some petroleum products, notably diesel fuel representing 40% of Turkey's diesel fuel use. Turkey also imports LPG, a fuel that represents an important share in Turkey's LDV fleet. Turkish refineries are long in gasoline while jet fuel production is largely on par with demand. Increasing aviation activity could alter this balance in the long term, but much depends on the rate of recovery of air travel in a post-Covid-19 environment.
- The future development of oil trade balances and Turkey's oil security will depend on a variety of policies as well as market, investment, and technology drivers.
- Although global oil demand growth may be slowing and then stall over the next decade, oil consumption will remain as an important economic factor for the foreseeable future.
- Oil security concerns remain inevitable and will represent an important policy objective for Turkey even in globally balanced oil supply and demand. Turkey has established a stockholding regime and, as an IEA Member country, should continue to strongly support IEA's stockholding programs. Considering Turkey's reliance not only on imported crude oil but also on imported diesel fuel, substituting a share of the crude oil stocks with petroleum products would add further improvements to Turkey's oil security.
- Although Turkey has achieved a diversified oil import portfolio over the decades, it is largely reliant on a few choke points. Therefore, further diversification including source regions and the trade routes would contribute to improved oil and broader energy security in a dynamic global oil market economy.
- Turkey is largely unexplored and recent policies have expanded exploration and production activities. Supported by recent investments, these activities across onshore and offshore areas, including unconventionals and use of enhanced oil recovery techniques, will be instrumental to contribute to a less import-dependent oil economy. IICEC's current domestic supply expectations are conservative with an emphasis on reducing oil use in transport.
- Road transport represents over 50% of Turkey's oil consumption. As discussed in Chapter 2, the most important ways to save oil in transport include:
    - o Increasing new vehicle fuel efficiency;
    - o Retiring inefficient and high polluting vehicles (especially trucks);
    - o Promoting electric vehicles and recharging infrastructure;
    - o Moving road travel to more efficient high occupancy modes, especially rail;
    - o Reforming the urban transportation planning process by conducting a data-driven assessment for achieving the best public transportation investments along with measures to restrain private automobile travel.

- In other sectors besides transportation, efficiency improvements and fuel switching opportunities will significantly reduce oil demand, especially in the Alternative Scenario (Chapter 5). For example, it represents 7% and 2% of total demand in the industry and buildings by 2040, respectively.
- As a result of stronger fuel switching, wider mode shifting, fuel efficiency policies, and deployment of new technologies, annual oil demand growth in the Alternative Scenario drops from 1.3% in the Reference Scenario to 0.5% until 2040. This produces 17% less oil consumption by 2040 than in the Reference Scenario. Oil savings are effective among all sectors: industrial demand declines by 25%, agricultural demand by 21%, residential and service demand by 15%.
- Although transport does not achieve the savings achieved in some other sectors (16%) due to more difficult fuel switching opportunities, the savings achieved in this sector, represent, by far, the largest contribution to oil demand savings in the Alternative Scenario compared to the Reference Scenario (76% or 8 mtoe).
- Oil's share in final energy demand, excluding non-energy uses, drops from 35% at present to 29% in the Alternative Scenario by 2040.
- Both scenarios demonstrate significant shifts in the demand for oil products. Diesel remains the predominant product due to its sustained role in road transport, in particular in freight by heavy trucks, but it's share declines to 63% of total oil demand in the Alternative Scenario compared to 69% in the Reference Scenario by 2040. This helps match Turkey's refinery slates with product demands and limit the trade deficit in Turkey's diesel fuel balance.
- Petrochemicals is a strategic industry for Turkey due to a growing domestic market, significant trade deficits, and high value-added capabilities (Chapter 5). This has been already reflected in recent industry initiatives to expand Turkey's petrochemical capacities. An effective petrochemical strategy requires enhancing Turkey's poly-based production capabilities. Natural gas based feedstocks and competition from other suppliers will be important factors to watch.
- Turkey has two international pipeline systems connecting to Ceyhan at the Mediterranean coast: the Baku-Tblisi-Ceyhan Pipeline and the Kirkuk-Yumurtalık Pipeline. With Azeri BTC's rating as a benchmark crude oil, increasing flows from the latter pipeline would position Ceyhan as the loading point for two of the highly globally demanded crude grades with an increasing role in regional and global trade.

3.1 Global Developments in the Oil Market

3.1.1 Oil Supply and Oil Security

The international oil market has undergone major and surprising shifts over the last decade. These changes reflected rapid changes in oil fundamentals as well as shifting geopolitical concerns. As a result, we have seen sudden large swings in international oil prices causing the oil market to be much more volatile than other energy markets. Changes in oil prices can be swift and large because even relatively small percentage changes in oil supplies are amplified by extremely low short term price elasticities of oil demand. Significant fuel switching is not possible in the transportation sector. In addition, transport service demand remains stubbornly unchanged in the face of large fuel price swings. This reflects the nearly linear relationship that transport has to all other economic activity for both personal travel and freight shipments. Another phenomenon that sometimes causes abrupt price changes is how energy markets fail to react to underlying changes that may be more gradual. For example, several trends affecting the supply and demand for oil since 2011 did not fully assert themselves until the sudden oil price collapse of 2014. This underlying trend was the large year on year additions of U.S. tight oil supplies beginning in 2011. Another trend was the maturation of automobile demand in most OECD countries combined with distinctly less interest in auto ownership by younger consumers. A third trend was increasing efforts by governments to combat climate change and the prospects for stronger policies to emerge in future years.

The consequences of these trends had been masked by the loss of Libyan oil exports and other oil supply uncertainties as the 2011 political upheavals destabilized certain Middle Eastern and North African countries. Oil prices sharply rose ("spiked") in 2011 as they had a number of times since the 1973 "energy crisis." This price spike and consequent economic damage would have been much worse had it not been for the fortunate but unrelated emergence of U.S. tight oil production. As the technology to produce tight oil was just emerging in 2011 from the application of hydraulic fracturing methods being used to produce natural gas, tight oil would not had been available to offset the Libyan outage had it occurred only one year earlier.

Throughout this period of oil-market instability that began in February 2011, the United States typically added 750 thousand barrels per day (b/d) to world oil supplies. While these U.S. additions to world supply were just offsetting losses from the Middle East and North Africa in 2011 through most of 2013, by the end of 2013 they began to grow world oil inventories. Despite this inventory build, through the first half of 2014, oil traders continued to be concerned about supply risks and oil prices remained above $100/b until the summer of 2014 when prices suddenly collapsed to $50/b. By January 2016, they dropped to $30/b.

Contrary to similar episodes in the past, OPEC maintained its output assuming that the U.S. was a high cost producer and could not maintain its production with the new low prices. That turned out to be mistaken. While U.S. production stopped adding almost 1 million b/d each year to the world market, U.S. production did not decline and actually rose slightly in the year following the 2014 oil price collapse.

U.S. tight oil producers concentrated on their "sweet spots" increased production per well and had a number of financial reasons to keep producing including forward contracts and obligations to well service companies. From December 2016 through February 2020, OPEC, in cooperation with Russia (now OPEC+), changed its strategy and agreed on production cuts to increase prices. However, these efforts were noticeably less successful than they would have been before U.S. tight oil. With the motivation of higher oil prices from OPEC+ cuts, U.S. producers responded with higher production thus offsetting the desired outcome of the OPEC+ cuts. With increased production resulting from even moderately elevated oil prices, the United States has since become the world's largest oil producer as well as a major oil exporter.

In 2020, the Covid-19 pandemic has again sent shock waves through the oil market. After stabilizing Brent oil prices in the $55/b - $65/b range during 2017-2019, oil prices collapsed in May and April 2020 due to an unprecedented worldwide destruction of oil demand. Oil demand fell first in China, where the Covid-19 pandemic began, and soon after by the worldwide spread of the virus. Measures to reduce Covid-19 fatalities shut down the world's economies crashing the demand for petroleum fuels. As mentioned above, the near linear relationship between transportation demand and the economy along with the very small price elasticity of oil demand led to a sharp decline in oil prices. This decline was amplified by the initial response of Saudi Arabia and Russia to increase production in a fight for market share cementing oil prices at around $20/b. After a few weeks, OPEC-Russian cooperation was resumed and on the 12th of April 2020 OPEC+ announced a production cut of 9.7 million barrels per day (mb/d). Despite this, Brent oil prices, remained below $30/b until mid-May 2020. WTI continued to suffer lower prices[23] The expiration of contract obligations caught many traders by surprise to the extent that they to pay their purchasing counterparties to close out the contract without physical delivery of oil to Cushing OK.

While the Covid-19 pandemic has affected all energy sectors, the transport sector has suffered the most dramatic change since the social-distancing policies have not only caused almost all business conferences to be replaced with virtual events, the required closing of many businesses and "shelter-in-place" orders have slashed road travel and fuel demand. The scenario projections in this report have been revised from the numbers that were estimated prior to the Covid-19 outbreak. As discussed in the Introduction, they have been adjusted in line with the consequences over time that the Covid-19 recession will cause. Permanent economic consequences caused by fears or measures taken to control future pandemics are not assumed. Nonetheless, of all of the energy sectors, transport and oil may be affected in the longer term by less personal travel due to more "home-office" work arrangements and Internet conferences in lieu of physical meetings.

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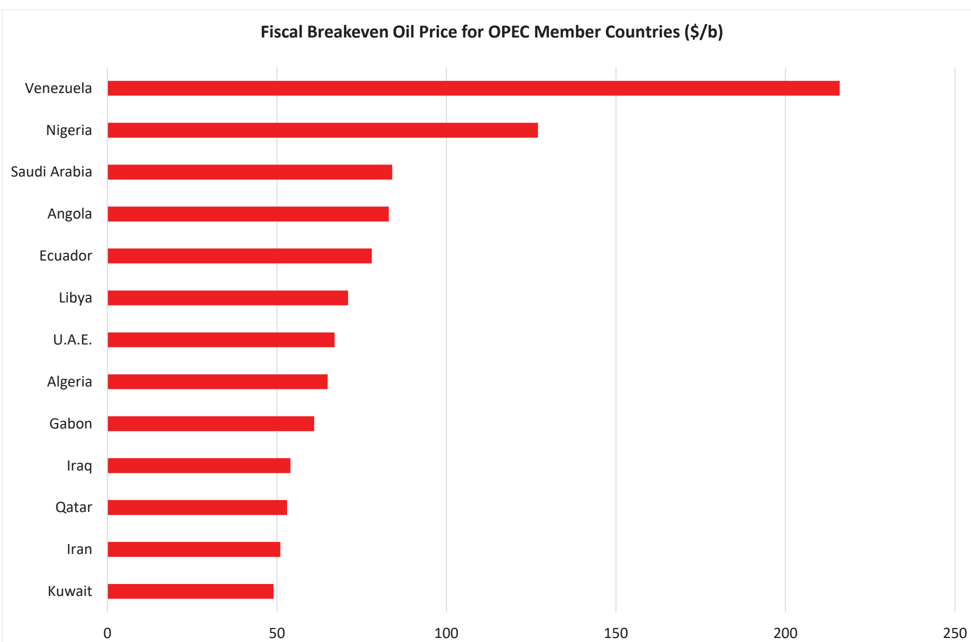
23 On 20 April 2020, WTI prices dropped below zero. The expiration of contract obligations caught many traders by surprise. Sellers had to pay their purchasing counterparties in order to close out the contract without physical delivery of oil to Cushing OK.

Consequently, commuting and intercity business travel could be permanently affected. This will be taken up in Chapter 7 (Long Term Implications of Covid-19) where a "Covid-19" Scenario is compared to the Reference and Alternative Scenarios. The Reference and Alternative Scenarios assume that medical advances and sensible behaviors will permit restoration of the world's economies and an ability to resume normal life. This would include the transportation energy economy where prior preferences for face-to-face interaction will restore personal travel within and between cities.

Prior to mid-2014, oil prices were often well above the marginal cost of new oil supplies providing ample incentives for E&P investments outside of OPEC. Conversely, low prices pose a new challenge to international oil companies and most oil exporting countries. Current oil prices are lower than the marginal cost of additional supplies. Oil prices, even before the Covid-19 pandemic, are also challenging to many Middle Eastern countries that have easy-to-produce, low-cost oil because these low prices do not produce enough revenue to support their national budgets (Figure 3.1). In sum, "oil scarcity" has been replaced by "oil abundance" making the oil market more competitive and favoring oil consumers.

Figure 3.1 Fiscal Breakeven Oil Price for OPEC Member Countries ($/b)



Source: Bloomberg, 2020

Environmental concerns are another trend that may make oil abundance a long-term condition. World-wide climate policies require more significant vehicle fuel efficiency and greater numbers of alternative vehicles than previously thought possible. This has led to expectations of "peak oil demand" and decoupling world economic growth from increased oil consumption. Similar factors such as the likely development of autonomous vehicles and emerging social trends may cause a movement away from traditional private vehicle ownership to the use of on-demand vehicle services.

Trends come and go, so caution must be exercised in thinking that any oil market condition is permanent. Past expectations have turned out to be wrong such as peak oil supply and what may have been an over-emphasis on OPEC and, in particular, the Middle East and North Africa (MENA), as the world's sole oil suppliers. Even during the long period of OPEC oil supply dominance, OPEC was steadily losing market share to non-OPEC producers. For several decades, almost all additions to world oil production capacity came from non-OPEC countries. Without these new supplies, the growth of world oil demand could not have been met.

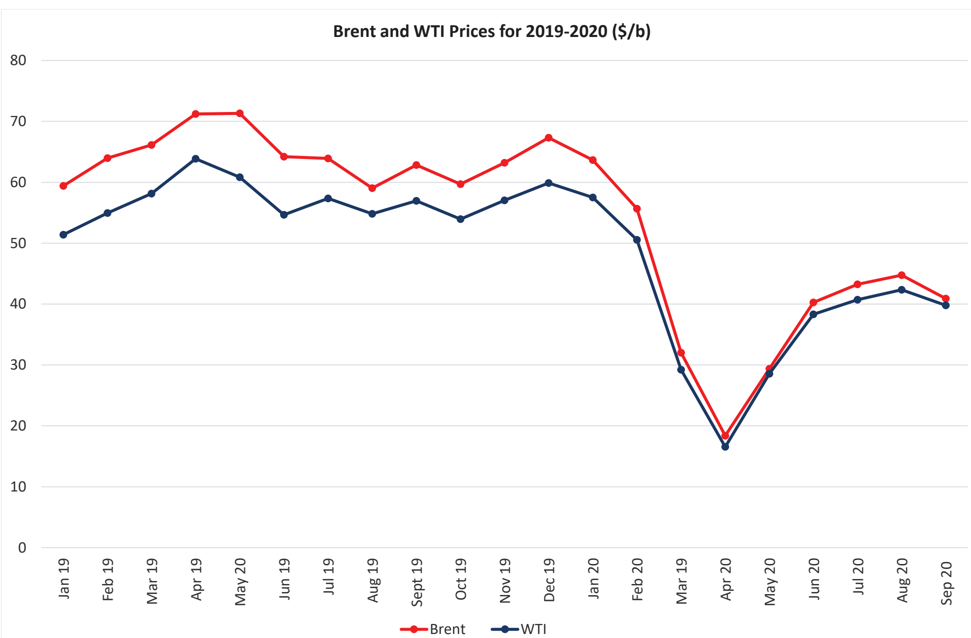
Going forward, it is important not to be complacent that U.S. or other non-OPEC supplies will be able to provide for growing oil demand, even oil demand that is increasing at a slower pace than before. A long-term expansion of U.S. tight oil production might be a likelihood but is not an established fact. Investor dissatisfaction with oil profits has caused the U.S. industry to restructure with international oil companies taking a significant equity in U.S. tight oil plays. A period of more modest supply growth might result as U.S. and international oil companies seek higher profits instead of maximum production. In addition, prior to the Covid-19 epidemic, political risk premiums returned to the market with increased tension in the Middle East. As a global crude oil chokepoint, the Hormuz Strait has remained a concern. The attack at Saudi Arabia's Abqaiq and Khurais crude oil processing facilities on September 14th, 2019 saw the return of oil risk and higher insurance premiums but the price effects were short lived as production was quickly restored and tensions de-escalated. While oil price volatility still exists, it is centered around a much lower oil price than it was during the period from 2004-2014 as OPEC struggles to keep a more favorable balance between growing oil supply and weak demand. Added to this, the U.S. has, in recent years, increased world oil supply as high or higher than world oil demand growth. The larger oil stocks that have prevailed in recent years and the proven resiliency of unconventional oil production lessen the oil price consequences of even large unplanned oil outages. The loss of 5 million b/d day from the Abqaiq attack would have, in the recent past, sent oil prices "through the roof," but the price response this time was, by past standards, very modest.

Oil security is achieved by avoiding the sharp and significant increases, as it is the "price spike" that damages the economies of industrial countries rather than an inability for refiners to acquire feedstocks. The combination of larger-than-normal commercial stocks, IEA's emergency stocks and the ability of tight oil producers to quickly ramp up production that have currently created an era of relative oil security and, especially after accounting for inflation, low "real" oil prices.

It should be a concern that international oil producers have not fully recovered from the 2014's collapse in oil prices. Then, this year, the oil companies suffered severe additional losses after the Covid-19 price collapse.

The fundamentals of the oil economy have changed due to expanding low-cost U.S. tight-oil production and uncertain prospects for a global economic recovery. However, even before the Covid-19 pandemic, declining investments in complex conventional oil projects, declining production from mature fields and supply risks among several major oil exporting countries could change the picture in future years. OPEC was already facing serious challenges to limit production sufficiently to balance the oil market even before the 30% fall off in demand during the Covid-19 pandemic. At the time of this publication, OPEC is still struggling to raise prices and will likely need help from a stronger world economy that was weak even before the Covid-19 pandemic. The shock that oil markets have suffered from the Covid-19 pandemic, including the additional time it took for a new market management agreement between OPEC and Russia, sent prices plummeting to historically low levels (Figure 3.2).

Figure 3.2 Brent and WTI Prices for 2019-2020 ($/b)

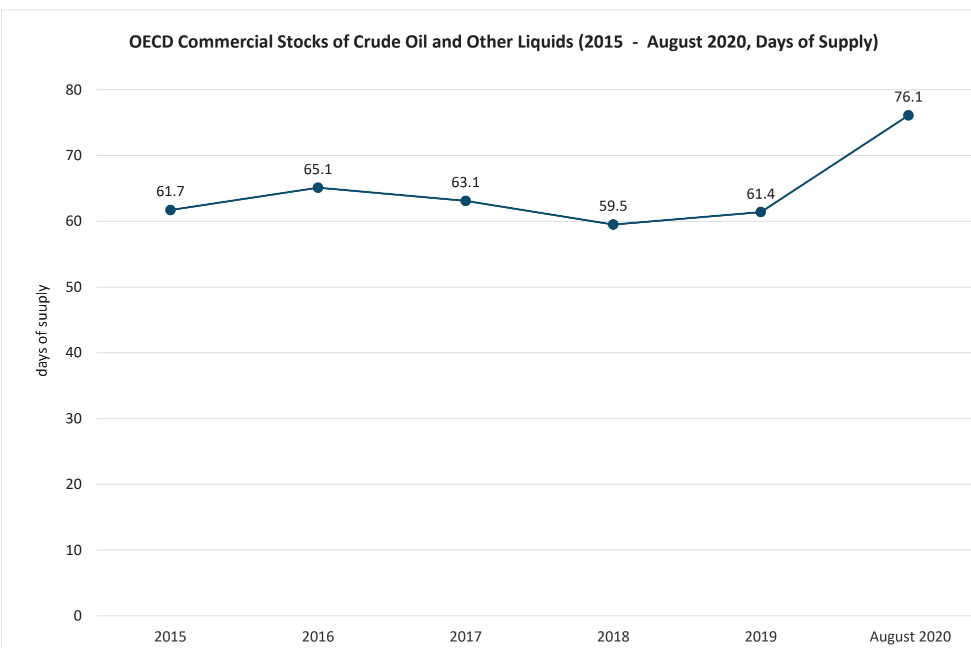


Source: EIA, 2020

The cumulative impact of both events may have longer term consequences. Several oil companies have gone bankrupt and ceased operations. For U.S. tight oil there are prospects that production could resume more quickly than for other producers. Canadian oil sands production may turn out not to be as resilient and the impacts on conventional oil production will depend on how the reduced E&P investment affects non-OPEC oil production. An assessment will be needed on how much non-OPEC production capacity has been affected by lower E&P spending, how much spare OPEC production capacity exists, the decline in the production from mature fields and the resumption of oil demand growth.

After all of these developments are more fully understood, there remains the possibility that, in the mid-term, the oil market could move from chronic oversupply to a much tighter market and higher oil prices. While ample oil stocks would buffer an emerging tighter market, once they returned to normal levels, an era of higher and volatile oil prices is possible (Figure 3.3). If this occurs, supply risks such as those we now see in Libya, Nigeria, and Venezuela could occur due to unforeseen circumstances but have a much greater impact on oil prices than recent supply risks have had because they have occurred in an oversupplied market.

Figure 3.3 OECD Commercial Stocks of Crude Oil and Other Liquids (2015 - August 2020, Days of Supply)



Source: IEA, 2020

A rapid return to normal oil stock levels could result from lower fuel prices that are prevailing while economies and travel patterns begin to return to normal. Clearing excess oil inventories may be hastened by the recent disinvestment in supply and stronger-than-expected oil demand growth. It is even possible that a tight oil market could evolve within the decade. Supply risks are likely to remain throughout OPEC, especially Libya, Nigeria, and Venezuela.

With greatly reduced E&P investment, a future mismatch of supply growth to meet demand growth is possible if there is a world-wide economic recovery in future years. If the United States does not continue to supply the lion's share of future world oil demand growth, this lack of upstream investment could cause a return to a tight oil market and higher prices. It should also be remembered that world oil production needs to increase by 4 to 5 million b/d just to offset declining production from mature oil fields since almost 40% of oil production currently comes from oil fields older than 40 years. If we witness high prices along with oil price spikes, we could see economic problems for industrial economies, especially those that manufacture motor vehicles and capital equipment. Certain sectors, particularly the travel and housing sectors especially suffer from oil price spikes adding to the economic strain of higher household energy prices on consumer spending and employment.

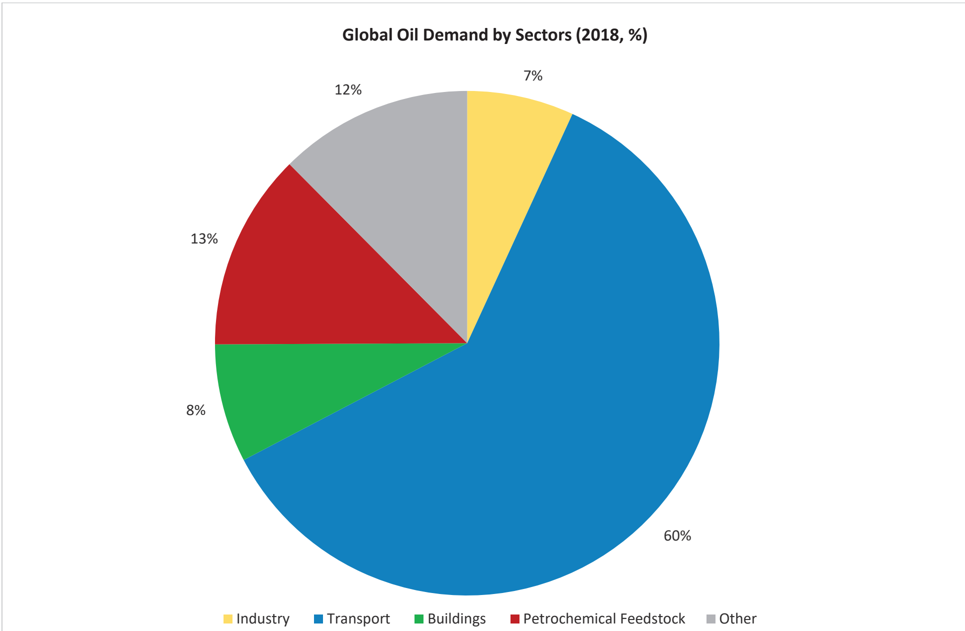
Volatile oil prices also create ambiguity interrupting investment. If the market does again tighten and oil supply disruptions cause price spikes, the industrial economies will have to rely on their main line of defense in such circumstances; strategic petroleum reserves. Consequently, maintaining adequate strategic oil stocks remains a priority. Ensuring and coordinating strategic oil stocks is a key responsibility of the International Energy Agency (IEA). It is also one of the reasons the IEA has engaged the large energy-consuming countries outside of the OECD as less than half of the world's oil is consumed by OECD countries.

3.1.2 Global Oil Demand

The transportation sector is the largest consumer of petroleum and other liquids, particularly motor gasoline and distillate fuel oil. Despite efforts to reduce oil use in transport through efficiency measures and modal shifts, the transport sector is currently responsible for about 60% of global oil demand. As the predominant mode of travel for passengers and freight, road transport accounts for 75% of transport oil use. Therefore, trends in road transport will heavily influence future oil demand.

Oil use in sectors other than transport has been losing ground as a result of increasing deployment of alternative fuels and technologies with better technical and environmental performance. Buildings and industry accounts for 8% and 7% of global oil demand, respectively. Petrochemicals correspond to 13% of oil demand worldwide (Figure 3.4).

Figure 3.4 Global Oil Demand by Sectors (2018, %)



Source: IEA, 2019

Oil combustion in industry is mainly used to generate steam and process heat in the chemicals and cement sectors and to power certain equipment in manufacturing. Although electricity and natural gas can, in principle, replace oil use, for a variety of economic and technical reasons, oil use remains in industry.

LPG and kerosene is largely used for cooking and lighting and heavy fuel oil is used for heating buildings, although this is declining. In 2018 around two-thirds of building oil demand occurred in the developing economies. Small increases in building oil use in Africa, India and Southeast Asia were offset by reductions elsewhere.

Oil is used in power generation mostly in countries with major fuel subsidization regimes or where there is a legacy fleet of power plants. Developments in natural gas and renewables continue to reduce oil use in electricity production. However, the new IMO regulation on shipping fuels leads to a surplus of heavy fuel oil, which in turn could lead to a near-term boost in oil use in power in some regions with electrification challenges.

Oil demand for petrochemicals is particularly strong given expectations for new capacity. Petrochemical products are found almost everywhere in modern societies including plastics, fertilizers, packaging, clothing, digital devices, medical equipment, detergents, tires and are extensively used in motor vehicles. They are also relied upon in the modern energy system including solar panels, wind turbine blades, batteries, thermal insulation for buildings and many other needs. The oil demand for petrochemicals is expected to increase driven by increasing demand for plastics, fertilizers and other products. Demand for plastics has outperformed other bulk materials such as steel and aluminum in recent years and nearly doubled since 2000. However, an increasing number of countries aim to curb single-use plastics. Around 15% of plastics were recycled globally in 2018. Most of the future growth in plastics comes from developing countries with relatively low levels of recycling.

As petrochemicals are rapidly becoming the largest driver of global oil consumption, along with road freight, the petrochemical sector will have a significant impact on the global oil market. LPG, ethane and naphtha are expected to contribute to about half of total oil demand growth in oil products. Several factors will affect how this plays out including the prices and availability of alternative feedstocks, oil and natural gas prices, and refinery integrations.

Without fuel efficiency policies and the introduction of alternative fuels, there would be little restraint on the pace of oil demand growth in the medium term. In addition to growing the petrochemicals sector, truck freight and the aviation sectors are also expected to increase demand. Nonetheless, with an expected decline in oil demand for passenger automobiles and expected gains in fuel efficiency, many projections expect that oil demand will reach a plateau and then slowly decline. However, there is a wide variation among estimates about how quickly this would happen.

3.1.3 Oil Products Demand in the Global Transport Sector

Due to fuel efficiency and the torque characteristics of diesel engines, diesel engines dominate medium and heavy trucks. Even though the number of passenger cars are expected to increase, worldwide, by 70% from 2018 to 2040, the oil consumed by passenger cars is expected to peak by 2030 due to government fuel economy policies and advancing fuel economy technologies. On average, a diesel car on the road in 2040 could be 25% more efficient than today (IEA, 2019a). This translates into nearly 9 mb/d less oil demand in 2040. However, the growing truck fleet will offset some of the savings from improved passenger car fuel efficiency. While only 15 mb/d of oil was consumed by trucks in 2018, truck oil demand is estimated to grow in the next two decades, the second largest source of oil growth after the petrochemicals sector (IEA, 2019a).

In addition to their increasingly predominant role in oil demand growth, emissions from heavy duty diesel are also causing a growing concern about air pollution due to high emissions of polycyclic organic hydrocarbons (particulate emissions) by many trucks as the environmental regulation of trucks is often lacking and there are many older trucks on the highways around the world. The pollution profile of passenger cars, including all light-duty vehicles (automobiles, SUVs and pick-up trucks), is generally much better due to more widespread emission standards for these vehicles and the fact that auto manufacturers tend to produce a uniform product for international markets. In contrast, medium and heavy duty trucks are not standard vehicles. Truck chases and engines are often separately sourced and not subject to uniform emission requirements.

For a variety of reasons, gasoline vehicles typically have improved emission characteristics compared to diesels. As stricter NOx standards were applied to diesel engines, an alarming level of unscrupulous behavior by major companies occurred. Instead of fairly meeting these standards (or switching to gasoline model offerings) a large number of diesel passenger vehicles were fitted with electronic controls that made them appear to be cleaner on official tests than they were on the road. These electronic controls recognized when the vehicle was being tested by government agencies and switched on the emission controls. When the vehicle was not undergoing a test cycle, the emission controls were turned off.

Despite the "diesel-gate" scandal, modern light duty vehicles produce very low emissions per vehicle, about two orders of magnitude fewer pollutants than "analog" vehicles produced before emission controls were first implemented in the mid-1970s. One factor was that "analog" vehicles lacked digital controls. Gasoline vehicles typically used carburetors to mix the fuel with air and had no catalytic convertors, exhaust gas recirculation or any other modern emission control system. Diesel engines also lacked digital and other emission controls so they also produced high emissions, especially soot. Despite the impressive per vehicle reduction of urban air pollution, the number of vehicles has dramatically increased in most urban areas and, collectively, they still cause smog (low-level ozone) and health problems, especially for people with asthma or other medical conditions. Cities that are located in air sheds with poor air circulation are often especially affected by auto air pollution.

Since 1990, the concern about motor vehicle emissions has shifted from particulate matter, nitric oxides, volatile organic compounds and carbon monoxide to carbon dioxide (CO_2), in normal quantities, a harmless gas that escaped policy attention until scientists began to realize that increasing concentrations of CO_2 in the atmosphere are changing the world's climate and posed a severe environmental threat. That has led to an increased effort to reduce CO_2 emissions from transport. Unfortunately, unlike the other pollutants just mentioned, CO_2 is a fundamental and irreducible emission from internal combustion engines that is directly proportional to the amount of fuel they combust. Consequently, in order to reduce CO_2 emissions from vehicles, policies have focused on improving fuel efficiency (to reduce the volume of fuel that is combusted) and replacing petroleum fuels with alternatives. These options were discussed in Chapter 2 (Transport).

Up until now, petroleum has remained as the main source of energy for worldwide transportation. In 2018, petroleum products accounted for over 90% of the total world transportation sector energy use. Biofuels, mainly ethanol and biodiesel and natural gas accounted for the rest except for less than 1% provided by electricity (IEA, 2019a). Whether or not biofuels, almost entirely derived from sugar, grains and oil seeds, have effectively reduced CO_2 emissions, or are mainly motivated by agricultural support policies, has been a topic of considerable debate. U.S. motor gasoline supplies are comprised of 10% ethanol but this requires about half of the U.S. corn crop. Similarly, rising levels of U.S. biodiesel use is pushing the share of the U.S. soybean crop devoted to producing biodiesel fuel to similarly high levels. Biofuel use has been widely facilitated by the fact that ethanol and biodiesel can be blended into gasoline and conventional diesel fuel. This eliminates the need to have dedicated alternative fuel vehicles. In addition, apart from restrictions on the way ethanol is shipped from refineries to blending terminals, the fuels are distributed to consumers as normal finished petroleum fuels.

While studies have not conclusively shown how much biofuels decrease or increase CO_2 emissions when their indirect land-use impacts are taken into account, the enthusiasm for biofuels among the environmental community has waned significantly since certain papers were published in Science that quantified the impact of biofuels on croplands and indirect greenhouse gas emissions (Searchinger et. al., 2008). Cellulosic biofuels were widely heralded since 2000 as a replacement for food-derived biofuels. Either using corn stover, bagasse or fast growing tree crops, these cellulosic biofuels were often estimated to produce far greater CO_2 reductions and eliminate the potential problem of devoting such high levels of food production to produce relatively small volumes of motor fuel. Unfortunately, the commercial cellulosic biofuels industry has yet to emerge despite strong incentives, especially in the United States (U.S. EPA, 2019).

The fuel choice of transportation is determined by factors including vehicle type, length and weight limitations, type of cargo, commuter preferences as well as driving conditions. Road freight has increased faster than marine and rail reflecting the flexibility of trucks to serve a wide variety of shippers' needs. For automobiles, rising incomes in many countries have greatly increased ownership causing a shift away from public transportation to private automobile. This created serious urban pollution problems leading to automobile emission controls in the early 1970s. As mentioned above, these standards, which have become increasingly strict, have been successful to vastly reduce the urban pollution from individual vehicles but, at the same time, the growing automobile fleet continues to cause urban air pollution in many cities. Carbon dioxide emissions per vehicle often remain high because consumers continue to prefer large vehicles in many parts of the world. To reduce the environmental impact of road transportation, many governments pursue different policies to limit local and global pollution. During the 1980s, there was a considerable push to using natural gas or methanol to reduce local pollution but subsequent light-duty vehicle emission standards have vastly reduced the advantage such alternative fossil fuels can provide. Still, for trucks, natural gas can provide significant air pollution benefits, especially in urban areas where centrally-fueled heavy vehicles (e.g., buses, garbage trucks, etc.) are replaced with natural gas or electric drive alternatives. Governments around the world are employing fuel shift policies, often with effective results when the programs well reflect national and local circumstances.

These policies along with changing technological opportunities have stimulated a transportation energy transition with far-reaching consequences in spite of its many challenges. The choice of fuel is becoming an increasingly crucial decision for road and sea transportation, impacting profitability as well as environmental concerns. The need to diversify away from oil is more widely believed to be an inevitable requirement and thereby, marine and road transportation market investors are seeking more options.

Gasoline and diesel are still the major fuels used in road transportation, making up a big share of the world's primary energy demand. Two-thirds of worldwide refined oil products stem from these two particular fuels. LPG is an established fuel of choice in several markets, including Turkey, with notable environmental gains. Natural gas in the form of CNG and LNG also plays an increasingly greater role in helping diversification while improving overall air quality, especially when employed in buses and trucks. Although renewables appear the best option among other energy sources to greatly reduce CO_2 emissions, renewable energy has not emerged as a particularly promising method to achieve large transport sector CO_2 emissions except indirectly through the use of electric vehicles that are recharged from an electric grid that is powered by renewables. Another pathway for renewables in transportation, that has received increased attention in recent years, is "green hydrogen" produced from renewable energy (IEA, 2019b). While the commercialization of hydrogen production, transport, distribution and retail sales is currently limited to some government-supported demonstration projects, there are reasons to believe that, given enough time, hydrogen fuel cell vehicles can provide a wider replacement for gasoline or diesel vehicles, including heavy trucks, than can be expected from electric vehicles. Most modeling studies show that, in order to achieve worldwide greenhouse gas emission targets, the transport sector will need an urgent uptake of electric vehicles joined a decade later by hydrogen vehicles, especially to serve the markets that are not well suited to electric vehicles (IEA, 2019b).

Penetration of battery electric vehicles (BEVs, i.e., vehicles powered only by batteries and electric motors) is on the rise all around the world, reflecting national policies to reduce greenhouse gas emissions in the transport sector. Policies include subsidies to purchase battery electric vehicles (BEVs), support for recharging infrastructure and, especially, challenging fuel efficiency/CO_2 emissions regulations that give vehicle manufacturers credits for producing and selling BEVs. By setting these CO_2 emission standards high enough, manufacturers will cross subsidize BEV production and sales in order to sustain sales of petroleum powered vehicles while meeting overall standards. This approach is particularly important in the EU and the United States.

Widespread consumer acceptance and the current high battery costs still linger as an obstacle to the larger deployment of BEVs in comparison to conventional vehicles. In addition, even optimistic projections of BEV sales through 2040 do not show significant declines in oil consumption due to the high use of diesel fuel in transport (IEA, 2019c), an application that is currently unsuited to electric drive in most situations. As mentioned earlier, as a result, there is a strong interest in hydrogen fuel as a replacement for diesel power in trucks. Unfortunately, the time schedule for widespread hydrogen use in transport is well beyond BEV uptake where millions of BEVs are currently operating compared to thousands of hydrogen fuel cell vehicles (HFCVs) whose use is effectively restricted to limited geographic areas that have installed hydrogen refueling infrastructure. The pathways leading to wider deployment of hydrogen in transportation and other sectors are discussed in Chapter 6 (The Energy Transition).

3.2 Turkey's Oil Policies

Reducing Turkey's oil import dependence, that currently accounts for over one-third of Turkey's energy demand, is a central strategy of Turkey's energy policy. It's strategic importance is evident by the fact that Turkey imports over 90% of its oil consumption. Consequently, improving oil security is an integral part of the National Energy and Mining Policy of Turkey (NEMP).

Oil sector policies aim to reduce reliance on foreign oil imports. Having a better geological inventory of Turkey's largely unexplored fossil fuel resources provide one avenue to reduce imports as well as the use of advanced oil exploration and production technologies. NEMP policies foster a more favorable investment regime and the Petroleum Market Law enhances productivity and efficiency across upstream activities. The Petroleum Market Law provides a more investor-friendly framework supported by a favorable tax and royalty regime to increase oil production capabilities. Turkey also intends to streamline the permitting processes and providing improved data by expanding a technologically driven information base, particularly for its largely unexplored regions and basins.

The future development of energy and oil trade balances and Turkey's oil security will depend on a variety of policy, market, investment and technology drivers. Turkey's policies have expanded its exploration and production activities but, nonetheless, a significant portion of Turkey's crude supplies will continue to be sourced from a diversified imports base unless large discoveries alter current domestic crude supply expectations. Consequently, lowering oil demand will be the most important objective to improve Turkey's energy trade balances.

As transport accounts for the vast majority of Turkey's oil consumption, Turkey's transportation policies, discussed in Chapter 2 (Transport), are the most important parts of Turkish oil security and economic policies, including improving fuel economy, the uptake of BEVs and further electrification in road transport, shifting passenger travel to public transportation, electrifying railroads and shifting freight from trucks to rail and marine. Beyond transport, Turkey's policies also support reduced oil use in buildings and industry.

The key Turkish oil sector policy documents considered in this study include the 11th Development Plan issued by the Presidency of Turkey in July 2019 and the Strategic Plan of the Ministry of Energy and Natural Resources for 2019-2023. Each of these documents provide plans and goals through 2023. The National Energy Efficiency Action Plan also provides actions and policies to reduce petroleum product demand across all end use sectors. These are among the most important oil policy statements the Turkish Government has recently published.

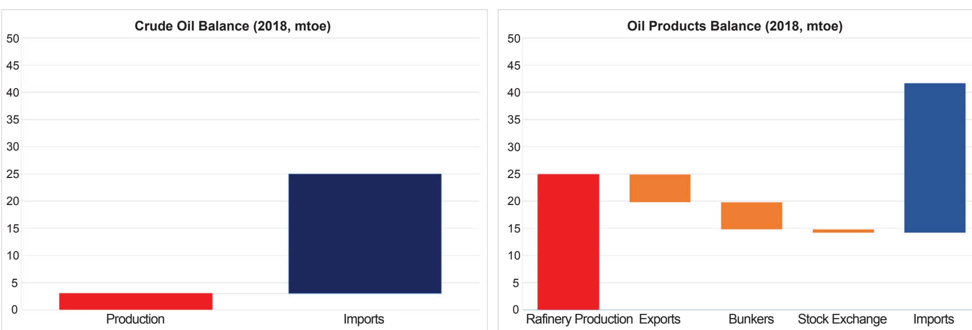
3.3 IICEC Overview, Scenarios and Analysis

3.3.1 Recent Trends

The oil sector is one of the most strategic components of the Turkish energy economy for several reasons. It stands as the backbone of the transport activity. Despite significant fuel substitutions in other sectors such as buildings, industry and agriculture, oil products still contribute to over one-third of total final energy demand in Turkey (38% in 2018). Crude (25.1 mtoe) and oil products (16.8 mtoe) correspond to 29% of total primary energy supply (TPES) in 2018. Turkey remains largely dependent on imports to meet increasing demand services requiring oil products, mainly driven by the transport sector.

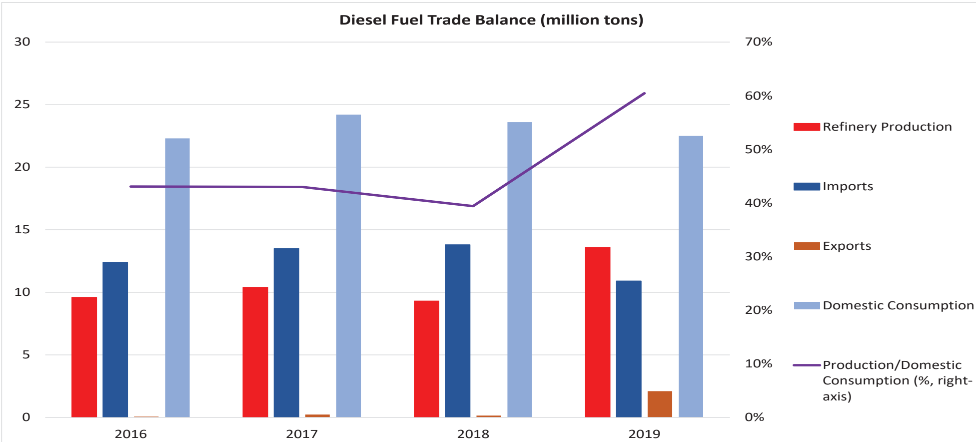
Despite efforts to increase domestic oil production in recent years, 88% of crude supplies were met by imports in 2018. Import dependency is not limited to crude supplies as Turkey's total oil products imports was 27.5 mtoe compared to total exports of 5.1 mtoe. Turkish refineries' output at 25.1 mtoe provided 60% of total final oil products demand (41.7 mtoe) in 2018 (Figure 3.5) Turkey imports diesel, LPG and petcoke and exports gasoline.

Figure 3.5 Turkey's Crude Oil and Oil Products Trade Balance and Refinery Production (2018, mtoe)



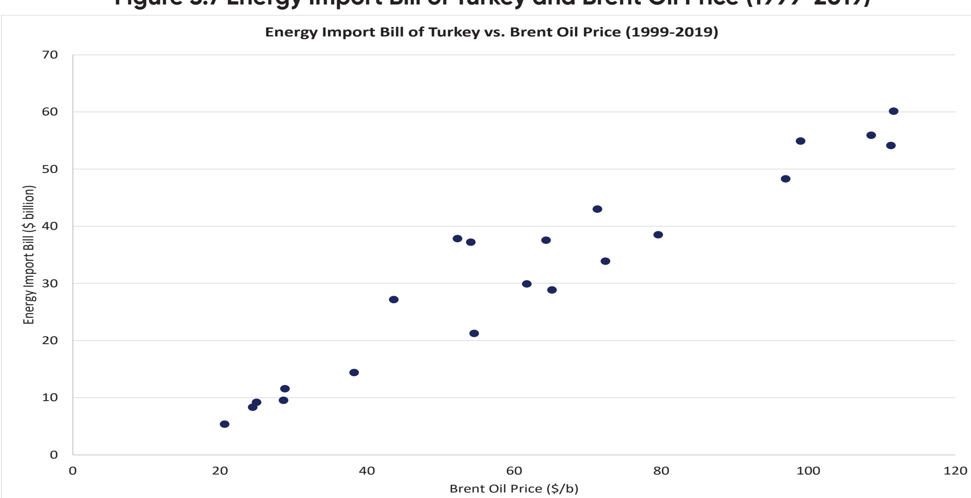
Turkish refineries produce more gasoline than domestic demand but do not produce enough diesel fuel and LPG, nor the petcoke used in the cement industry. Turkey does not need to import jet fuel at present as Turkish refineries satisfy domestic demand. However, increasing aviation activity and jet fuel demand could substantially alter this balance depending on the rate of recovery of the air travel due to Covid-19. As these trends show, Turkey's petroleum product imports affect the trade balance as much as its crude oil imports. With the opening and full capacity operation of the new STAR refinery in 2019, net diesel imports reduced to 8.7 million tons from 13.7 million tons in 2018 and crude imports increased from 22 mtoe to 33 mtoe. The STAR refinery is unusual in that it refines no motor gasoline and is instead designed to produce a maximum output of middle distillates mainly from Azerbaijani crude oil. Despite significant expansion of diesel production capacity, Turkey remains reliant on imports to meet 40% of its domestic diesel fuel demand at current levels of consumption down from 61% in 2018 (Figure 3.6).

Figure 3.6 Diesel Fuel Trade Balance (million tons)



As shown in Figure 3.7, Turkey's energy import bill is highly correlated with the global price of oil. This correlation partly reflects the relationship between international oil prices and Turkey's natural gas bill. The price of a significant share of Turkey's natural gas imports is tied, by contract, to the price of oil. There is a lag time between cause and effect, but the effect is quite strong as will be discussed in Chapter 4 (Natural Gas). If higher oil prices increase Turkey's purchases of foreign exchange to acquire crude oil and petroleum products, they will, within a number of months, also require more foreign exchange purchases to acquire its natural gas imports. As discussed above, reducing these foreign exchange obligations that are tied to Turkey's energy imports is a cornerstone of Turkey's energy security policy.

Figure 3.7 Energy Import Bill of Turkey and Brent Oil Price (1999-2019)



Note: Each dot represents a year

Upstream: Turkey's state owned upstream company, TPAO, leads exploration and production activities and aims to increase its production by 75% to reach 70,000 b/d, expanding its unconventional wells from 2 to 23 and tripling its 3D seismic data including gas until 2023. In addition to intensified upstream campaigns that require sustained investments, coping with declining yields from existing fields is a major focus for Turkey. Secondary production methods and enhanced oil recovery techniques, similar to global practice, should also be prioritized in line with the targets to improve overall productivity in the oil upstream industry. Compared to onshore activity with a long history, exploration in offshore has been quite limited until very recently. Ongoing investments are advancing offshore and deep sea activities where TPAO is the sole holder of offshore licenses. Localization related policy objectives also aim at achieving increasing use of locally developed equipment and technologies. TPAO is guided by policy objectives to promote use of innovative methods and new technologies while sourcing more equipment from Turkish companies. These include data processing capabilities and several upstream methods targeting enhanced prospects for exploration and production.

Vehicle Fuel Efficiency: Although the share of oil in energy demand has been continuously decreasing, it is important to rationalize its consumption. Oil demand is largely driven by the transport sector similar to many developing energy economies. Turkey's socio-economic fundamentals imply significant growth in both passenger and freight transport. Despite notable global advancements, fuels and technologies that could substantially replace oil in the transportation sector are limited. While new light-duty vehicle fuel efficiency has significantly improved over the last decade, continued improvements in new vehicle and fleet fuel efficiency will be needed to reduce oil use across the Turkish economy as outlined in Chapter 2.

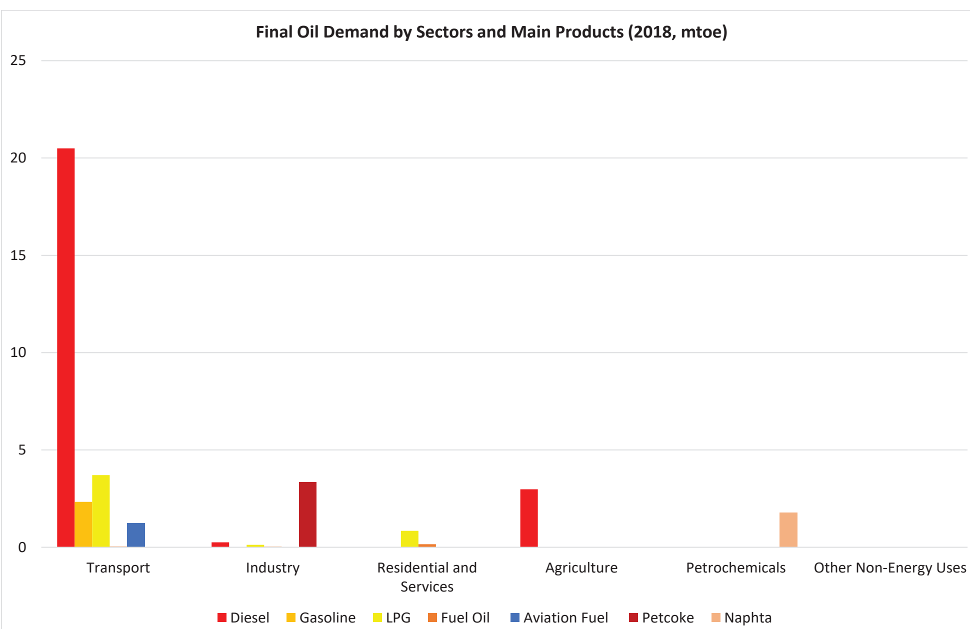
Petrochemicals: Petrochemicals are identified as one of the most strategic sectors for Turkey to improve trade and current account balances. Overall demand for petrochemical products in Turkey has been growing faster than that of most developed countries and is above the world average. In contrast, domestic supply of petrochemicals has not developed at the same pace. This remaining imbalance urges Turkey to realize new investments into the petrochemical sector. An advantage for an expanding Turkish petrochemical industry is the strong domestic demand. This would allow the establishment of facilities with world-scale capacities. A number of parameters need to be assessed in pursuing a strong expansion in petrochemicals capacity such as targeting a value-added product portfolio, competition from other regions, an increasingly oversupplied commodity market, different feedstock options and emerging technologies.

Petroleum Product Taxes and Pricing: The Petroleum Market Law (no: 5015) governs the downstream activities while regulatory oversight is run by EMRA. Under the same law, EMRA monitors global free market prices and can intervene to the market price. However, EMRA's authority in this regard was applied only a few times in those instances where a lack of competition was observed. EMRA is authorized to determine ceiling prices at a regional or national basis if there is a reason to believe that high prices reflect an uncompetitive environment.

The government has a strong role in setting retail petroleum product prices through its fuel excise tax structure (similar to most other countries). Oil products are subject to different tax rates with higher rates for gasoline compared to diesel fuel. These differentials strongly affect the long-term demand of diesel fuel vs. gasoline. As diesel fuel is relied upon for commercial purposes, it receives relatively favorable treatment compared to gasoline. As discussed in Chapter 2, vehicle excise taxes also favor the small turbocharged diesel engine as the prevalent light-duty power plant. It offers excellent low-end torque and overall performance while achieving high fuel efficiency. These smaller diesel engines contribute to reducing Turkey's oil consumption and oil import bill. Nonetheless, gasoline fuel efficiency is improving and the gasoline hybrid electric vehicle also offers best-in-class fuel economy. As will be discussed below, removing the "tax-surcharge" on gasoline could lower Turkey's petroleum product import bill while being consistent with favoring high fuel efficiency.

Where is oil used: Oil products provided 38% of final energy demand in 2018. It remains the leading primary energy source in meeting Turkey's overall final energy demand followed by natural gas (22%), coal (12%), and renewables (9%) while electricity satisfies one-fifth of final demand services. Excluding non-energy uses, the transport sector is the predominant consumer of oil (78%), followed by industry (11%), agriculture (8%) and residential and commercial services (3%). Diesel fuel has the largest share of oil demand at 63%. LPG is second at 12%, followed by petcoke (10%), gasoline (6%), naphtha (5%), aviation fuel (3%) and fuel oil (0.5%) (Figure 3.8).

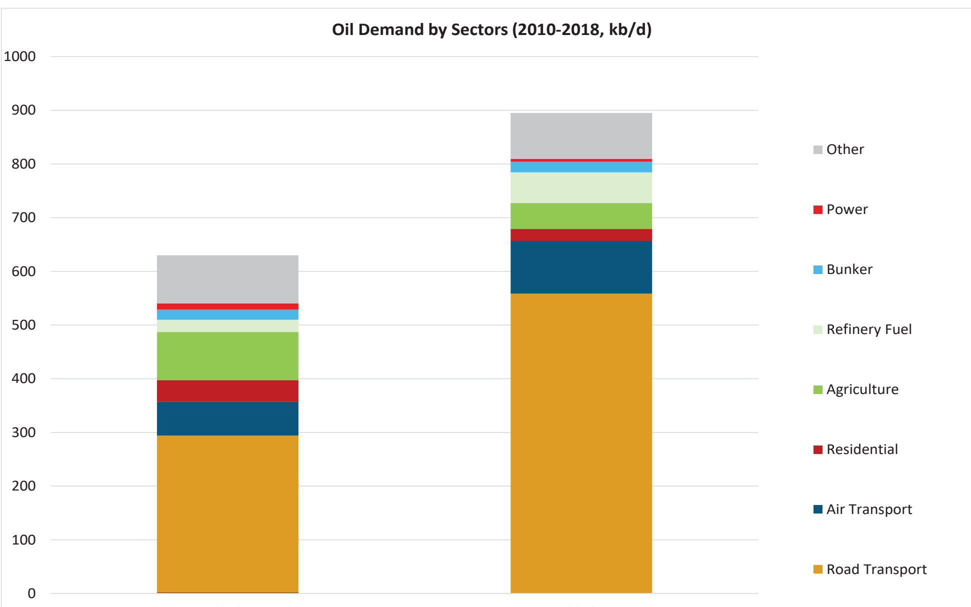
Figure 3.8 Final Oil Demand by Sectors and Main Products (2018, mtoe)



Road transport leads total oil demand representing over half of total consumption. From 2010 to 2018, Turkey's oil demand has grown by 42%. Road transport has been the largest contributor to growth accounting for 88% of the increase (Figure 3.9). Oil demand from road transport is driven mainly by diesel fuel use. It accounts for over 70% of Turkey's road fuel consumption. While the majority of the demand comes from commercial vehicles such as trucks and buses, the dieselization of the private car fleet has contributed greatly to growing demand.

The growth in road fuel largely depends on motorization rates and economic activity. It is also likely that auto ownership will expand as Turkey has a car density of about 150/1,000 people, which corresponds to less than half of the EU average. Freight fuel demand will closely follow economic growth while fuel and vehicle taxes will also shape the demand for road transport fuels.

Figure 3.9 Oil Demand by Sectors (2010-2018, kb/d)



Oil use in the residential/commercial sector has decreased strongly since 2000. The majority of residential/commercial demand was LPG, mainly used for cooking but also used for heating. A large expansion of Turkey's natural gas network has caused a large shift away from LPG in this sector. There is little growth potential left in this segment as residential/commercial use of LPG or other oil products will remain limited to remote areas, not connected to the gas grid.

Turkey's aviation sector has experienced strong growth, especially in the last decade as the number of flights have doubled. With growing prosperity and the increase in airport infrastructure, two-thirds of the increased flights came from the domestic market. New budget airlines along with the expansion of the country's flagship air carrier, Turkish Airlines, suggest continued growth of Turkey's aviation sector. The addition of the new Istanbul Airport (IST) will increase Turkey's role as an international hub and facilitate increased business and tourism to Turkey. Compared with Europe, there is a significant growth potential for domestic air travel as per-capita flights are still low.

The rail sector's consumption of diesel fuel is only 0.2% of Turkey's oil consumption. While recent developments of Turkey's high speed and electrified rail network suggest an outlook for increased rail growth, electrification may decrease the rail sector's share of Turkey's oil use even further. Oil demand in Turkey's power generation has nearly disappeared. There is now less than 300 MW of installed oil generation capacity (less than 0.4% of Turkey's total generating capacity).

Industrial demand growth is second largest after road transport with 37 kb/d addition between 2010 and 2018. Industrial oil demand outside petrochemicals has increased by 50% and accounts for 10% of Turkey's current total oil consumption. 80% of Turkey's industrial oil use consists of petcoke mainly used in the cement industry. Agricultural oil use has lost ground. Oil demand in this sector is predominantly diesel to fuel 2 million agricultural tractors and machines.

Future of the Petrochemicals Sector: The petrochemical sector is growing globally at 8.5%/yr. In the next five years, the demand for petrochemicals is expected to grow by $1 trillion more than the $700 billion market in 2018. While the global growth rate for petrochemicals has been exponential, the growth of Turkey's petrochemical demand is even higher. In contrast, Turkey's domestic supply is not keeping up and needs more investment to expand capacity. This imbalance urges Turkey to realize new investments into the petrochemical sector since without expanded capacity Turkey would have increased imports and balance of trade issues. An advantage for an expanding Turkish petrochemical industry is the strong domestic demand. This would allow the establishment of facilities with world-scale capacities. A number of parameters need to be assessed in pursuing a strong expansion in petrochemicals capacity such as targeting a value-added product portfolio, competition from other regions and facilities in an increasingly oversupplied commodity market, and different feedstock options and emerging technologies. While Turkey is dependent on imported natural gas and petroleum, there is still a rationale for developing world-scale capacities within an increasingly competitive global environment. One of the key reasons is that the petrochemical and refinery sectors can be integrated in a way to produce reasonably competitive feedstock prices even though Turkey produces little of its own crude petroleum or natural gas.

Decreasing petrochemicals imports is among the strategic objectives of Turkey to alleviate the current account deficit. The foreign trade deficit just from the petrochemical industry was $13 billion in 2018, an 18% increase over the 2017 deficit. Currently, the annual petrochemical import bill is estimated at around $20 billion.

Petkim has played a crucial role as a sector leader in Turkey. Petkim is Turkey's first and only integrated petrochemical plant and has been an indispensable supplier of raw material for the industry. Being the largest petrochemical facility in Turkey and the sole producer of basic petrochemicals and the biggest producer of thermoplastics and intermediates, Petkim is increasing its capacity but still constituted only 18% of Turkey's demand in 2018. It produces, among other products, olefins, polyolefin, vinyl chains and aromatics. Petkim also exported products to the USA, Italy, Greece, Spain and Belgium. It has a 588,000 ton/year ethylene capacity. The steam cracker runs mainly on naphtha as well as on LPG, C4 and condensate. Petkim has signed a 20-year offtake agreement with the STAR Refinery A.S. to consume 270,000 tons/year of mixed xylene and 1,600,000 tons/year of naphtha. The agreement with STAR refinery will significantly lower Petkim's import requirements and reduce costs. In February 2019, the STAR refinery delivered its first 1,300 tons of naphtha via pipeline to Petkim's petrochemical plant.

SOCAR Turkey will develop a new $1.8 billion petrochemical plant, associated with its STAR Refinery, aiming for a 2024 start date. This new plant could increase Turkey's domestic share of petrochemical products to 40%. There are several other initiatives towards expanding petrochemical production in Turkey. The Turkish Wealth Fund Management Company has a plan to construct a $10 billion refinery and petrochemical complex in Ceyhan, the region considered as a hub for petrochemical products. Construction of the plant could begin as early as 2021.

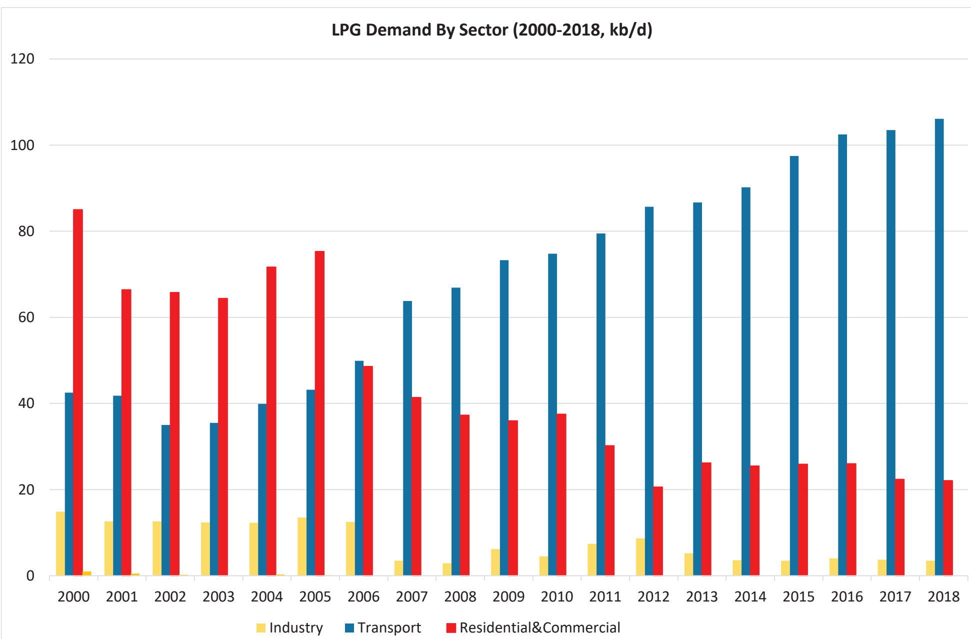
As Turkey imported over 2 million tons of polypropylene in 2018, another project under construction aims to cut this by one-fourth by 2023. This will require a $1.2 billion investment in the Ceyhan Mega Petrochemical Industrial Zone. With a capacity of 450 thousand tons, it should reduce Turkey's current account deficit by $500 million per year. There have been other plans to develop other projects to expand Turkey's petrochemicals industry.

While these developments are encouraging, it should be noted that the global petrochemical market is currently oversupplied. Therefore, Turkish companies need to focus on strategic and value-added products. The current trend to link petrochemical investments with refineries is important as standalone petrochemical plants, without a guaranteed feedstock supply, is challenging in today's environment that has many integrated Asian petrochemical crackers and a massive new wave of U.S. ethane crackers flooding the market with petrochemicals. Use of natural gas based fuels could also play a role to diversify the supply mix with the best available technologies.

Oil product demand: Turkish oil demand has growth over the last ten years from 700 kb/d to over 1 mb/d. Demand growth has been driven mainly by diesel fuel, which has accounted for almost half of the incremental oil consumption. Aviation fuel and petcoke use has grown as well. Gasoline consumption has mostly stagnated, while the demand for fuel oil has declined mainly due to reduced fuel oil use in power generation, a similar trend to many developing energy economies.

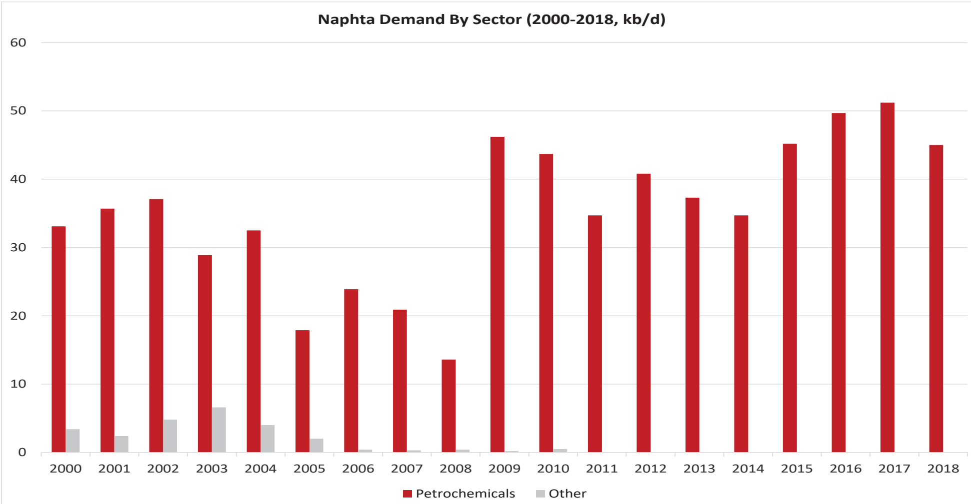
LPG: Turkey is Europe's largest LPG consumer. Its use as a road transport fuel did not start until 1996 but quickly grew to about a third of the LPG demand by 2000. Currently, road fuel use represents around 80% of the total LPG consumption. With over 100 kb/d LPG used by motor vehicles, Turkey is the world's largest road LPG market. A main driver of this growth are the lower fuel taxes that encourage its use. While LPG use as a transport fuel has increased, its use in the residential sector has sharply declined since the mid-90s as a result of the extensive expansion of Turkey's natural gas network. The share of residential sector LPG use has declined from 60% in 2000 to 15% in 2018. LPG growth is mainly restricted to transport while further declines in residential and commercial use can be expected (Figure 3.10). Turkey's LPG deficit has averaged at roughly 100 kb/d since 2013 while imports in the same period averaged 105 kb/d. Algeria is the largest LPG supplier to Turkey (43 kb/d in 2018), followed by the United States (22 kb/d in 2018), then Russia, Kazakhstan and Norway.

Figure 3.10 LPG Demand by Sector (2000-2018, kb/d)



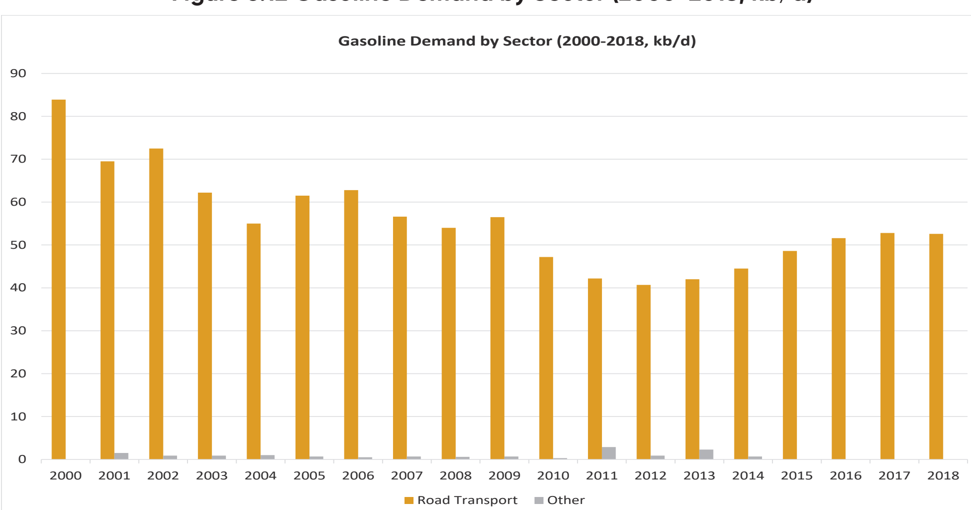
Naphtha: Naphtha demand in Turkey is driven entirely by the petrochemical sector. Steam cracker capacity in Turkey has remained unchanged with Petkim's 590 ktpa plant being the sole operator. Demand has fluctuated in the past and mainly reflected economic activity (Figure 3.11). Turkey exports minimal amounts of naphtha. Imports averaged a little over 35 kb/d between 2013 and 2018. Until 2018 naphtha production was not sufficient to meet domestic demand. However, the recent commissioning of the STAR refinery will dramatically reduce Turkey's naphtha import requirements.

Figure 3.11 Naphtha Demand by Sector (2000-2018, kb/d)



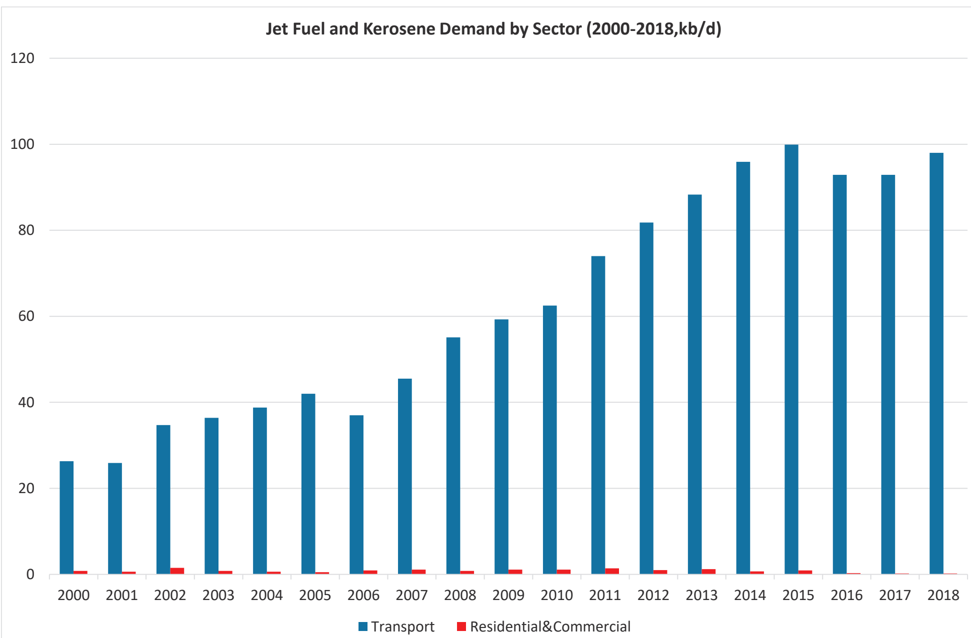
Gasoline: Gasoline, mainly used by passenger cars and other light-duty vehicles, accounts for only 6% of Turkey's total oil consumption. Demand has halved from over 100 kb/d in 1998 to 50 kb/d in 2018 (Figure 3.12). Although Turkey's car fleet has grown substantially during the last decade, the gasoline fleet has been stagnant. Relatively high retail prices reflecting tax policies have resulted in a substantial shift from gasoline to LPG and diesel in Turkey's growing passenger car fleet. As a result, and as a consequence of Turkey's refinery balances, gasoline is Turkey's only significant oil product export at between 50 kb/d to 75 kb/d in recent years. Egypt, the UAE, the United States and Spain are among the main export outlets.

Figure 3.12 Gasoline Demand by Sector (2000-2018, kb/d)



Aviation Fuel: Jet fuel and kerosene has posted the strongest percentage increase over the past two decades as demand has quadrupled on the back of surging air traffic in Turkey. During the last decade, air passenger figures in Turkey have tripled from 70 million to 210 million, while departures have more than doubled from 700 thousand to 1.5 million. As a consequence, jet fuel consumption has increased from 50 kb/d in 2008 to over 100 kb/d in 2018 (Figure 3.13). Turkey's aviation fuel imports and exports are minimal. However, strong aviation activity backed by Turkey's socio-economic fundamentals could lead to higher aviation fuel imports in the future.

Figure 3.13 Jet Fuel and Kerosene Demand by Sector (2000-2018, kb/d)



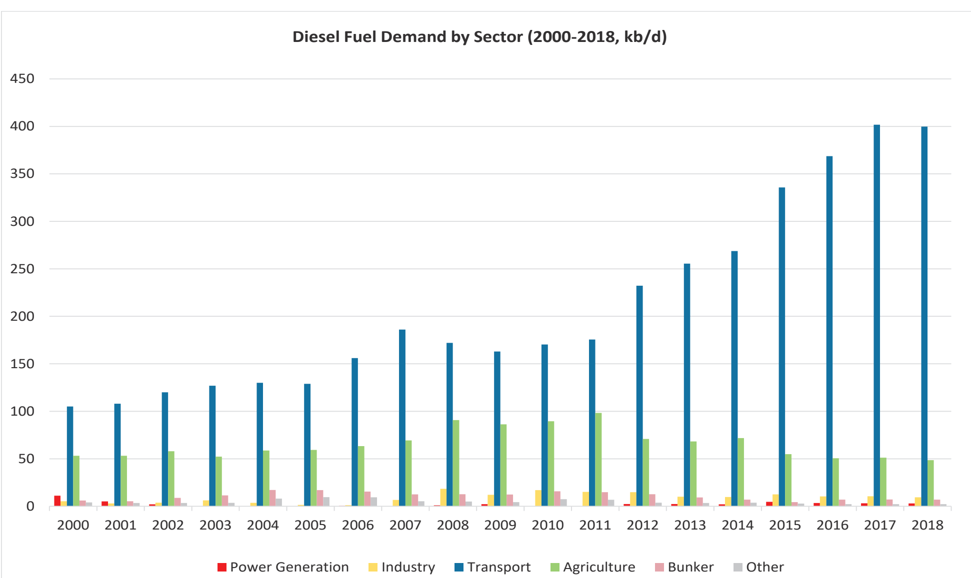
Diesel Fuel: Diesel fuel accounts for the largest share of Turkey's oil consumption, accounting for over half of total oil products demand. The vast majority of diesel fuel use is in road transport (85%) followed by agriculture (10%). Other users include the marine sector railways, and industry (Figure 3.14). There has also been a strong growth of diesel fuel use in the last decade reaching almost 500 kb/d in 2018 as a result of increased diesel vehicles. Light, medium and heavy duty freight vehicles have increased by almost 2 million between 2008 and 2019, while agricultural tractors have expanded by over 500,000. In addition, as noted above, since 2001, diesel car purchases have quickly grown, increasing from 10% in 2001 to over 60% between 2011-2017. Since then, the diesel share has been on decline with 58%, 52% and less than a half in 2018, 2019 and the first half of 2020 respectively. However, passenger diesel cars still lead the total passenger car park at 38% followed by LPG (37%) and gasoline (24%).

These car purchase changes reflect the importance of reducing oil demand as diesel vehicles are more efficient than (non-hybrid) gasoline vehicles, especially in urban driving cycles. Europe, also a region dependent on oil imports, has also emphasized diesels. In contrast, the United States' light-duty vehicle emission requirements have discouraged the uptake of diesel automobiles. In addition, there were almost no light duty diesel vehicles in the United States prior to the advent of emission requirements but, at that time, the United States had only recently become dependent on oil imports, so oil conservation was never an issue, and its fuel taxes were always low. Consequently, the less expensive and high performance gasoline engine was favored.

The strong growth in Turkey's diesel cars has helped cause diesel fuel use to increase by 20 kb/d in 2004 to over 120 kb/d in 2018 along with continued expansion of truck commerce and buses. Other sectors, that account for 15% of diesel fuel use, are either showing declines or are stagnant. Agricultural consumption, the second biggest segment after road transport, consumes 50 kb/d, no larger than what it consumed in 2000. Diesel generators are now using less than 3 kb/d. Industrial consumption holds steady at 10 kb/d. Rail demand, albeit marginal, is declining reflecting Turkey's progress in electrifying rail lines (Figure 3.14).

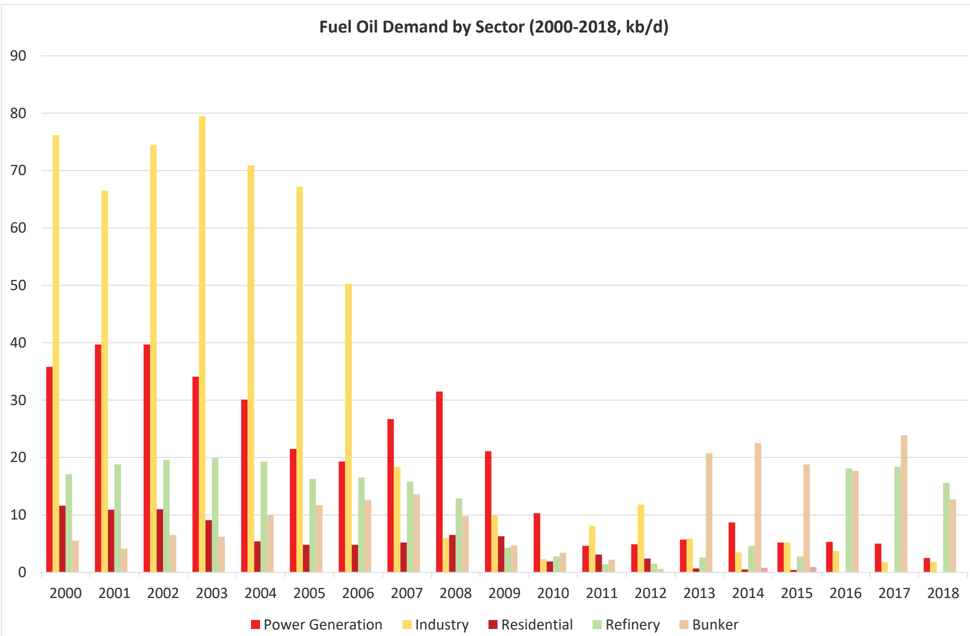
Turkey's refineries produced 40% of its diesel fuel demand in 2018. Turkey's diesel fuel imports averaged at 300 kb/d and Russia was the largest supplier of diesel fuel to Turkey with nearly 125 kb/d. Turkey imports significant amounts of diesel fuel from India and the Mediterranean region. The start-up of the STAR refinery reduced Turkey's diesel import requirements to around 40% in 2019.

Figure 3.14 Diesel Fuel Demand by Sector (2000-2018, kb/d)



Fuel oil: Turkey's fuel oil demand has dropped rapidly as a result of gasification in the buildings and industry and modernization of power generation through new investments over the past two decades. Currently, its use is mostly limited to fueling marine transport and refineries (Figure 3.15)

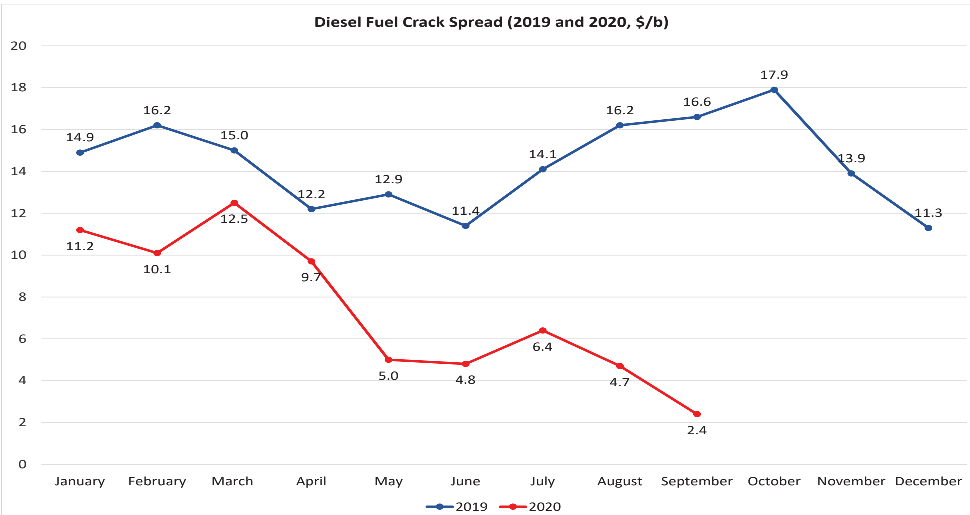
Figure 3.15 Fuel Oil Demand by Sector (2000-2018, kb/d)



2020, Impact of the Covid-19 Pandemic: In Turkey and worldwide, closures of businesses, cancelling of business conferences and other large gatherings, widespread use of home office for businesses that remained opened, curfews, stay at home orders and other measures, in addition to causing a worldwide recession, had a particular impact on the energy sector. While the postmortem on the impact of Covid-19 on the energy sector is yet to be written, it is likely that it will show that the oil sector was the most greatly affected. As discussed in Section 3.1.1 above (Oil Supply and Oil Security), Brent oil prices collapsed from near \$70/b to less than \$20/b after the rapid travel demand destruction caused by the pandemic. Perhaps the best evidence of the impact of the pandemic on Turkey's oil sector is shown in Figures 3.16 and 3.17 (diesel fuel and jet fuel crack spreads respectively). The crack spread is a measure of the economic gain achieved by refining crude petroleum into a particular petroleum product. It reflects the difference between the refiner's acquisition price of crude oil and the price the refiner receives for the product it has refined. As shown in Figure 3.16, notwithstanding the sharp drop in the acquisition costs of crude oil between May of 2019 and May of 2020, the crack spread for diesel fuel dropped from \$13/b to \$5/b, a strong measure of how quickly diesel fuel demand had declined in Turkey.

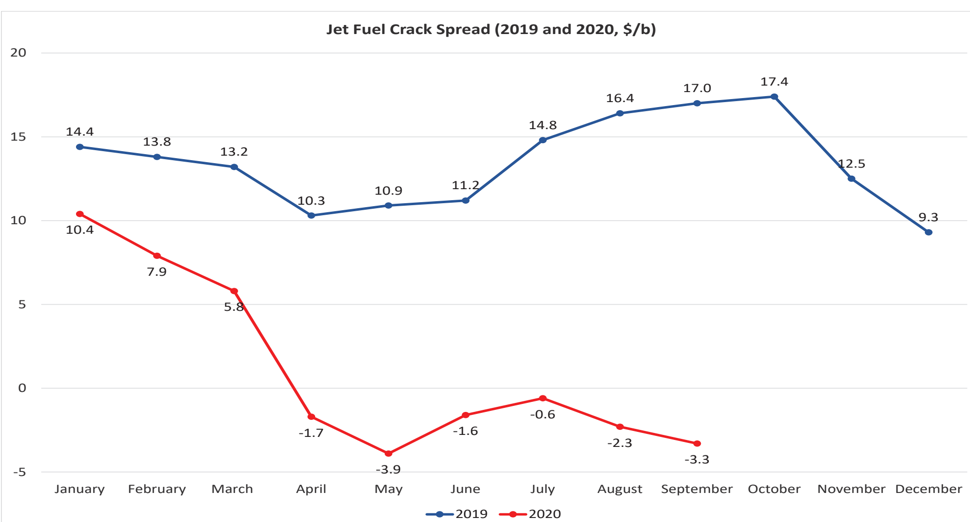
As is apparent from Figure 3.17, the decline in road travel was minor compared to the virtual shutdown of air travel. The crack spread of jet fuel declined from $11/b in May of 2019 to minus $4/b in May of 2020. This means that the crude oil was $4/b more expensive than the jet fuel that was made from it. Despite some recovery since May of 2020, the crack spread of jet fuel remained negative as of September 2020.

Figure 3.16 Diesel Fuel Crack Spread (2019 and 2020, $/b)



Source: Tüpraş,2020

Figure 3.17 Jet Fuel Crack Spread (2019 and 2020, $/b)



Source: Tüpraş,2020

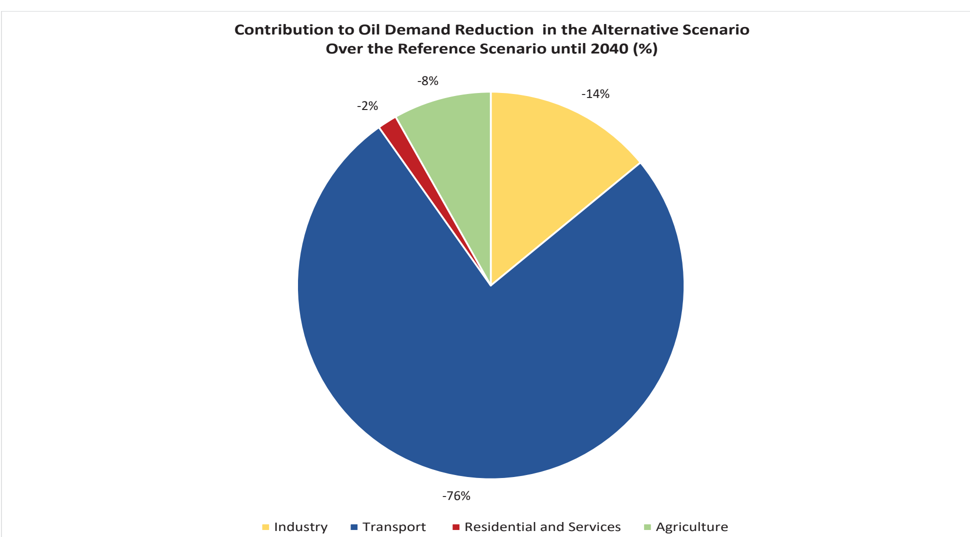
3.3.2 Oil Demand Outlook

As a brief recap. the Reference Scenario reflects a baseline set of policy initiatives that can be reasonably expected in future years. The Alternative Scenario adds greater uptake of new technologies, enhanced government support and application of new policy incentives.

Each Scenario shows continued increase in oil demand until 2040, albeit at much lower rates compared to the past 20 years (Table 3.1). In the Reference Scenario, total oil demand grows by 1.3% per year, resulting in 11.9 mtoe more demand in 2040, a 34% cumulative growth over 2018. Industrial demand is 18% higher compared to 2018 but it represents only a 4% increase compared to 2017 reflecting the sensitivity to industrial output changes between 2017 and 2018. Agricultural demand grows by only 5% over the forecast period while demand from the residential and service sectors declines by 15%. This leaves the transport sector as the primary source of Turkey's oil demand growth. Transport oil use increases by 11.2 mtoe over 2018, a 40% increase.

As a result of stronger fuel switching, mode shifting and fuel efficiency policies and a wider role for new technologies, annual oil demand growth in the Alternative Scenario drops from 1.3% to 0.5%. This produces 17% less oil consumption by 2040 than in the Reference Scenario. Oil savings are spread among all sectors. Between the scenarios, industrial demand declines by 25%, agricultural demand by 21%, residential and service demand by 15% and transport demand by 16%. As shown in Figure 3.18, while transport does not achieve the savings achieved in some other sectors due to more difficult fuel switching opportunities, the savings achieved in the transport sector comprise, by far, the largest contribution to oil demand savings in the Alternative Scenario compared to the Reference Scenario (8 mtoe or 76%)

Figure 3.18 Contribution to Oil Demand Reduction in the Alternative Scenario over the Reference Scenario until 2040 (%)



The Alternative Scenario achieves these higher savings through more fuel switching or more efficiency or more of both. The non-transport sectors have increasingly competitive and more sustainable alternatives to oil with which to fuel those services. However, transport accounts for almost all of Turkey's oil demand and fuel switching is much more difficult than for the other sectors. There are three methods to save oil in transport: use more efficient modes of travel, use non-fossil fuels to power road vehicles and improve the fuel efficiency of conventional vehicles. The Alternative Scenario includes stronger policies to shift road freight to rail and marine, encourage more intercity passenger travel by rail and stronger policies to promote public transportation.

IICEC analysis indicates that electricity is the most promising alternative fuel for road vehicles due to its low cost per mile, ready availability, active commercialization by the motor vehicle industry, programs to establish recharging networks, and lower CO_2-eq footprint per km compared to internal combustion engines. As discussed in Chapter 2 (Transport), strong BEV and PHEV light-duty vehicle sales are estimated for the Reference and Alternative Scenarios. However, electric drive systems have only limited applicability for trucks with the exception of short range heavy duty vehicles, for example, urban busses. Hydrogen-powered trucks offer a good long-term option, but IICEC analysis suggests that they would enter the fleet too late to have any significant effect on 2040 fuel consumption. While we expect strong Turkish BEV/PHEV automobile sales, given the high share of diesel fuel demand from trucks and the time it takes to replace the existing stock of cars, these sales do not translate into large reductions of oil consumption.

Fuel efficiency improvements are possible for both light-duty vehicles and trucks. However, as shown in Chapter 2 (Transport), stronger policy measures to retire older less efficient vehicles, especially trucks are needed to bring down average fuel use. This can be achieved with strict enforcement of truck tailpipe emission standards to ensure that old, polluting and inefficient trucks are removed from the fleet.

Turkey's trade deficit from diesel fuel imports will also increase based on anticipated refinery capacities and product slates. To limit this, as discussed below, the Alternative Scenario includes policies to shift some light-duty diesel demand to gasoline with the aim of reducing Turkey's balance of payment obligations.

Adjusting Turkey's fuel tax policies can stimulate more light-duty gasoline vehicle sales at the expense of diesels. This would reduce the excess production of gasoline from Turkey's refineries and reduce Turkey's diesel fuel imports. Such a switch would not necessarily compromise fuel efficiency due to Improving gasoline fuel economy technologies and the availability of gasoline hybrid vehicles. Gasoline hybrid vehicles, in particular, have excellent urban fuel efficiency, even compared to diesels.

Table 3.1 Summary of Oil Demand by Scenarios

Scenarios			Reference Scenario		Alternative Scenario	
mtoe	**2000**	**2018**	**2030**	**2040**	**2030**	**2040**
Oil Demand Excluding Non-Energy Uses	22.4	35.6	43.0	47.5	40.1	39.5
of which						
Industry	3.9	3.8	4.3	4.5	3.8	3.3
Residential and Services	3.7	1.0	1.1	0.9	1.0	0.7
Agriculture	2.8	3.0	3.1	3.1	2.6	2.5
Transport	11.9	27.8	34.6	39.0	32.7	32.9
Share of Transport in Total Oil Final Consumption	53%	78%	80%	82%	82%	83%

Factors Affecting Future Demand: Between 2000 and 2018, total oil demand including non-energy uses had increased by 15.6 mtoe that is equal to increase in oil demand from the transport sector alone. Excluding non-energy consumption such as petrochemical feedstocks, the oil demand increase between 2000 and 2018 was 13.2 mtoe. Again excluding non-energy uses, between 2000 and 2018, transport's share of total oil consumption increased from 53% in 2000 to 78% in 2018.

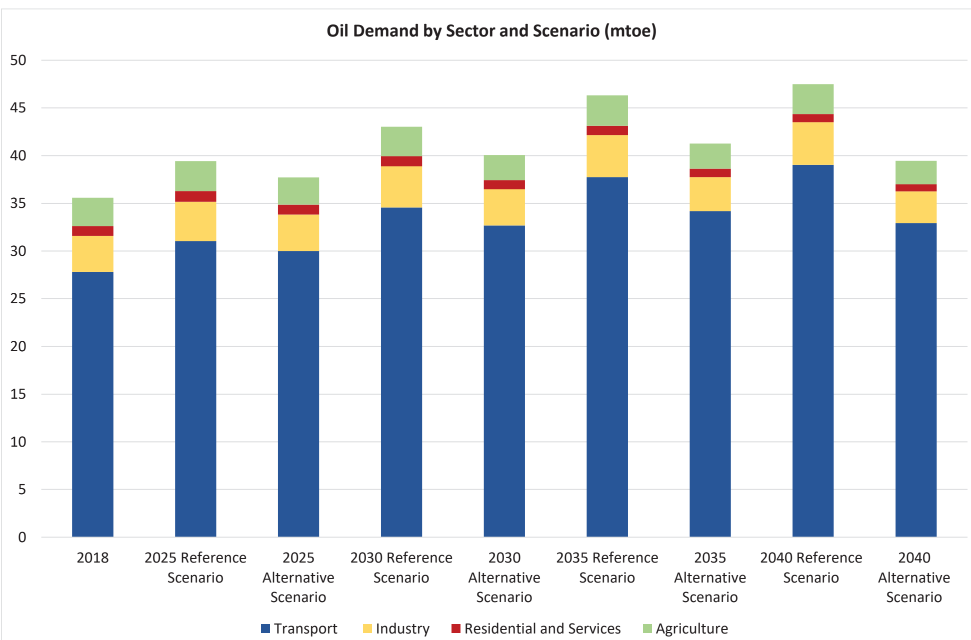
A major reduction has occurred in residential and services sector with consumption dropping from 3.7 mtoe in 2000 to 1.0 mtoe in 2018. Oil products met 3% of total final demand in this sector in 2018. Total demand in industry remained largely unchanged between 2000 and 2018, albeit by significant shifts resulting in lowering distillate use in many industrial sectors and through increasing uptake of petcoke in the cement industry in the last decade. 10% of final energy demand in the industrial sector is met by oil products, 90% of which is from petcoke, in 2018. Agricultural oil demand stemming from diesel fuel use is largely saturated in line with modest growth in agricultural activity and output. However, oil still represents over two-thirds of the final energy demand in the sector. The transport sector remains mostly an oil story as 99% of transport energy demand is still met by oil products while the contribution from natural gas, biofuels and electricity is summing up to just 1%.

IICEC analysis on Turkey's oil demand growth rate indicates a significant drop from 2.6% per year realized from 2000-2018. Slowing demand growth is partly driven by continuing reduction in oil demand growth in the buildings, industry and agriculture sectors. Efficiency improvements in these sectors and fuel shifts by expanding gas infrastructure, electrification, increasing use of renewables and waste, and availability of other thermal fuels continues to limit oil use in these sectors.

Turkey's economic growth and social development, notably rising incomes, ongoing urbanization, emerging connectedness and mobility trends will continue to drive energy use in transport. While policy measures as well as global and national technological advances are enabling the wider use of alternative transportation fuels such as electricity and hydrogen, transport energy use will continue to be largely met by oil, 96% in the Reference Scenario and 93% in the Alternative Scenario by 2040 (from 99% in 2018). In addition to the larger use of alternative fuels in road transport, these reductions are achieved by efficiency improvements in Turkey's fleet of road vehicles as well as modal shifts, mainly from road to both intercity and urban rail, that require integrated planning and infrastructure investments.

The transport sector will be the fastest growing sector for oil demand with annual growth rate of 1.6% in the Reference Scenario and 0.8% in the Alternative Scenario from 2018 to 2040. These rates represent a strong reduction compared to 4.8%/yr. from 2000 to 2018. Growth of oil demand by sector is shown in Figure 3.19. It shows that the transport sector will remain the main driver of total oil demand as the share of oil demand in the other sectors decrease, particularly in the Alternative Scenario.

Figure 3.19 Oil Demand by Sector and Scenario (mtoe)



Industrial oil demand shows an 18% increase in the Reference Scenario supported by economic activity particularly in the cement industry as the major consumer of oil products. Consumption in the sector in 2018 was 0.6 mtoe lower than 2016 (4.4 mtoe) due to changing economic conditions resulting in lower cement sector demand. Compared to 2016, industrial oil demand remains largely unchanged. This reflects sustained efficiency improvements and switching to more sustainable alternative fuels.

In the Alternative Scenario, increasing cement production is offset by efficiency improvements and fuel switching from petcoke. Industrial oil demand in the Alternative Scenario is 3.3 mtoe and corresponds to a 12% reduction from 2018. These achievements are a direct result of further efficiency improvements, structural changes in the overall industrial sector, and realization of economically attractive fuel switching and technology opportunities as discussed in Chapter 5 (Other Sectors and Fuels).

Oil demand in the residential and services sectors is mainly due to LPG use for cooking and fuel oil for heating. Demand in this sector has been largely saturated in recent years as a result of wider access to natural gas by continuous expansion of the domestic natural gas infrastructure. The Reference Scenario indicates a 15% reduction until 2040 compared to 2018 while the Alternative Scenario estimates a further decline by 27% due to wider access to gas, stronger electrification in addition to efficiency improvements lowering demand for heating. Nonetheless, LPG will still remain the fuel of choice for cooking for some households and services, particularly in some rural areas.

Agricultural oil demand has been largely flat since 2000 as a result of lowering activity. Demand is mainly driven by diesel use in tractors and agricultural equipment. The Alternative Scenario shows a 17% reduction from 2018 to 2040 as a result of improved fuel efficiency of the tractor fleet and some electrification.

Oil demand in the transport sector increases by 40% in the Reference Scenario and 18% in the Alternative Scenario from 2018 to 2040. These data show a substantial slowdown of growth when compared to the 2.3 times increase between 2000 and 2018. As shown in Figure 3.20, even though the percentage growth of oil demand has slowed for both Scenarios, Turkey's oil demand growth in the Reference Scenario is still too high. Expanding auto ownership, truck freight and the high inertia restraining quick switching of transport fuels and travel modes makes reducing oil demand growth a challenging proposition. However, with the strong transportation policies identified in Chapter 2 (Transport), the Alternative Scenario cuts the growth of transport oil use by more than two-thirds compared to the growth experienced in the past two decades. In addition, the growth of oil use in the Alternative Scenario is less than half of the growth of oil use in the Reference Scenario.

As shown in Figure 3.21, in the Alternative Scenario by 2040, the share of oil demand by industry declines from 11% to 8%, residential and services from 3% to 2%, agriculture from 8% to 6%. The share of transport sector in oil demand increases from 78% in to 83%.

Figure 3.20 Change in Oil Demand by Sector and Scenario (mtoe)

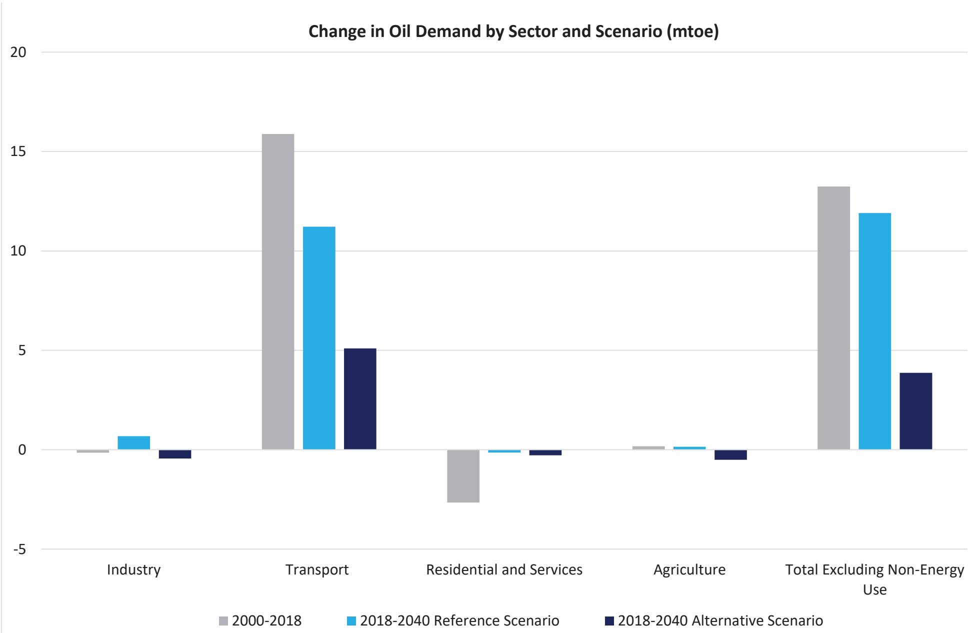
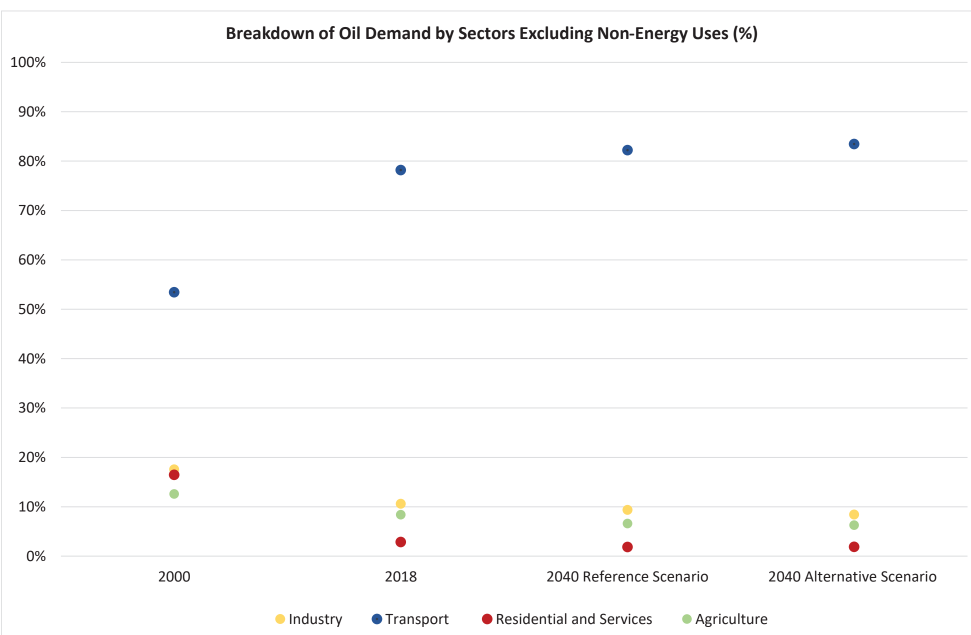


Figure 3.21 Breakdown of Oil Demand by Sectors Excluding Non-Energy Uses (%)



Expected Demand by Products: Both scenarios demonstrate significant shifts in the demand for oil products. In the Reference Scenario, diesel demand increases by 32% compared to only by 5% in the Alternative Scenario until 2040 reflecting major efficiency improvements and fuel shifts in transport. Nonetheless, diesel remains the predominant fuel due to its sustained role in road transport, in particular in freight by heavy trucks and represents 63% of total oil products demand in the Alternative Scenario compared to 69% in the Reference Scenario by 2040 and 73% in 2018 (Figure 3.22).

Aviation fuel demand sees the largest percentage increase in both scenarios due to forecasted increases in domestic air travel. This is partly offset by efficiency improvements. Aviation fuel use by 2040 increases by 93% and 71% in the Reference Scenario and the Alternative Scenario respectively. However, aviation fuel demand is only 9% of the diesel demand in the Alternative Scenario by 2040 (Figure 3.22).

Gasoline demand also increases in both scenarios. The share of gasoline relative to diesel demand is smaller in the Reference Scenario and larger in the Alternative Scenario. 15% of the oil products demand is from gasoline by 2040 in the Alternative Scenario up from 7% in 2018. As will be discussed below, Alternative Scenario policies to reduce Turkey's oil product import bill encourage a shift to more gasoline passenger cars. This is in line with global auto industry orientations due to environmental concerns and is facilitated by improved gasoline fuel efficiency technologies as well as the increased availability of efficient gasoline hybrid vehicles in all market segments. While the share of gasoline demand in the Alternative Scenario more than doubles from 2018 to 2040, gasoline demand increases by 1.5 times in the Alternative Scenario compared to 1.4 times in the Reference Scenario (Figure 3.22).

Total LPG demand decreases by 18 % in the Reference Scenario and further by 24% in the Alternative Scenario as a result of reduced use in the industrial, residential and services sectors (Figure 3.22). LPG demand in the transport sector sees a 20% decrease in the Reference Scenario and a 26% decrease in the Alternative Scenario. LPG use will continue to be driven by passenger transport in road but its share gradually reduces as a result of increased uptake by gasoline vehicles, gasoline-hybrid vehicles and EVs.

Diesel fuel, by 2040, is expected to increase by almost 8 mtoe in the Reference Scenario. The Alternative Scenario sharply cuts this increase to less than 2 mtoe as a result of stronger transportation policies (discussed in Chapter 2). While gasoline growth is just slightly higher in the Alternative Scenario than the Reference Scenario, it becomes the fastest growing transport fuel. There are also savings of LPG and aviation fuel between the Reference and Alternative Scenarios (Figure 3.23).

Figure 3.22 Oil Product Demand by Scenario (mtoe)

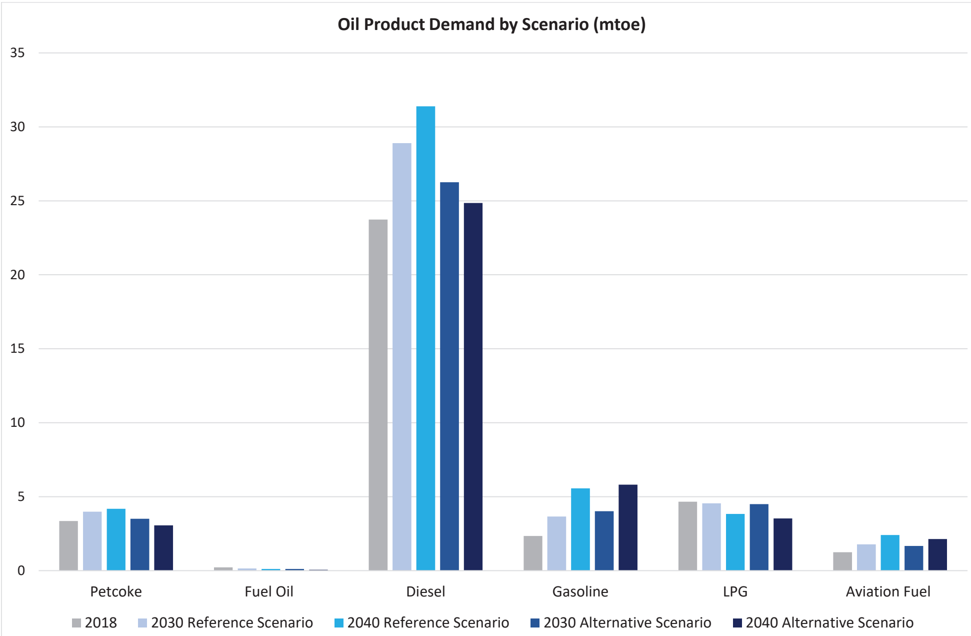
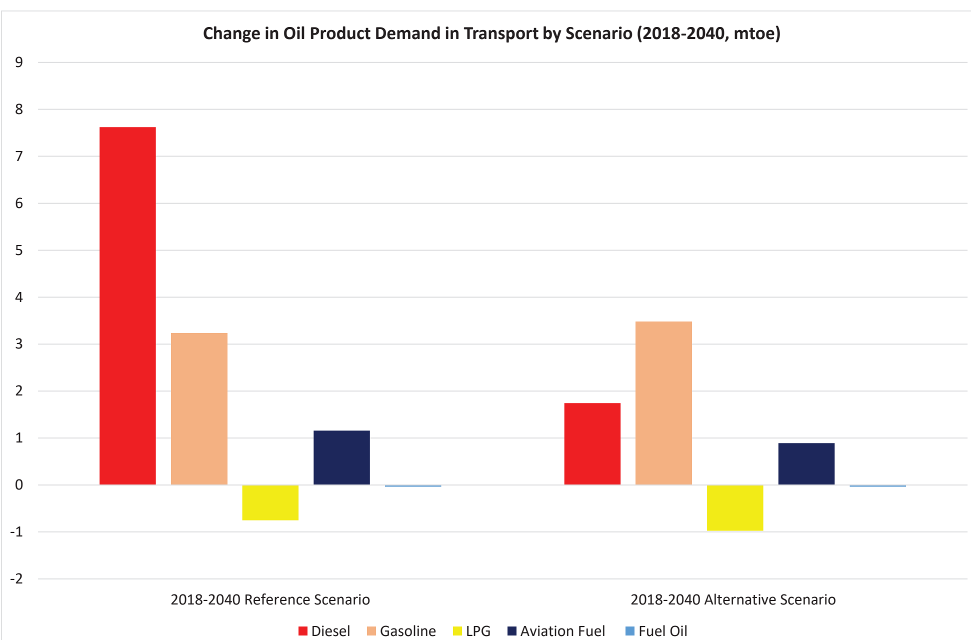
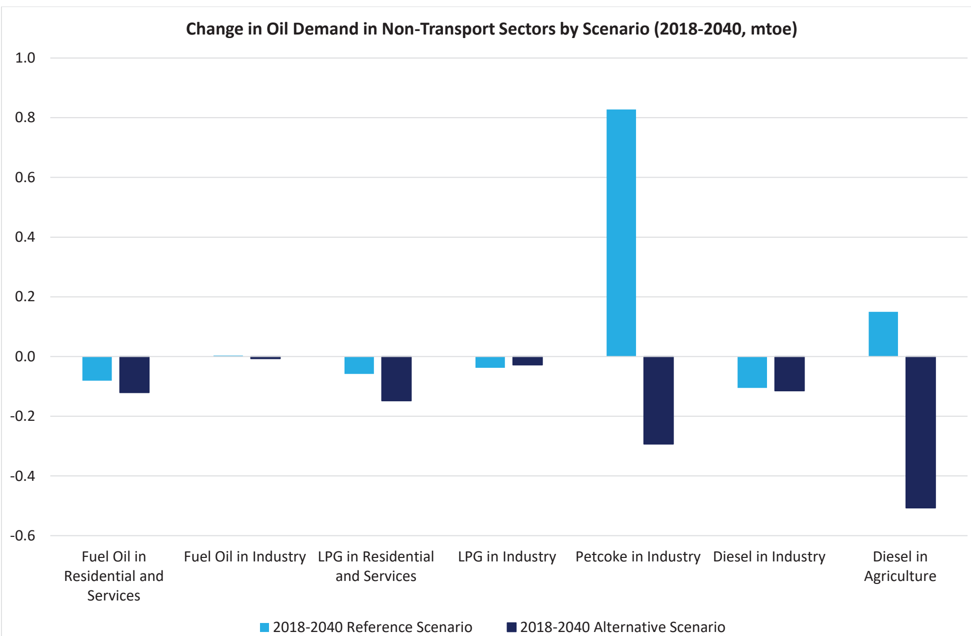


Figure 3.23 Change in Oil Product Demand in Transport by Scenario (2018-2040, mtoe)



Total oil product demand in non-transport sectors decline as result of continued efficiency improvements and wider fuel shifts. For the Reference Scenario, product demands in the non-transport sectors decline with only two exceptions: petcoke use in industry and diesel fuel in agriculture. In the Alternative Scenario, all non-transport products show decline including industry, residential/commercial services and agriculture (Figure 3.24). Combined, they represent 1.2 mtoe decline, about a quarter of increase in transport demand until 2040.

Figure 3.24 Change in Oil Product Demand in Non-Transport Sectors by Scenario (2018-2040, mtoe)



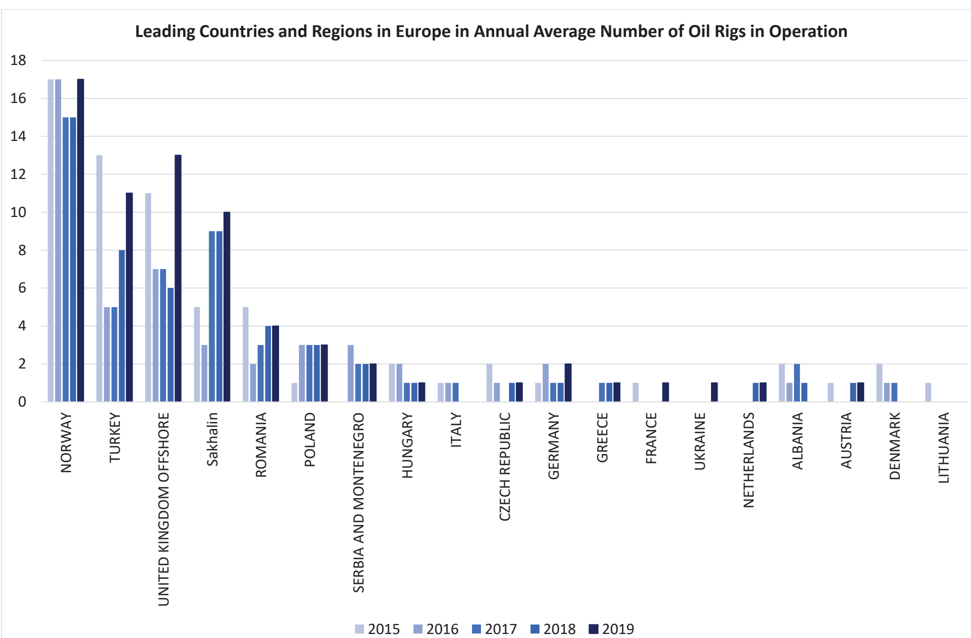
3.3.3 Oil Supply Outlook

Overview: Turkey has always been a country with limited natural energy resources including crude oil and natural gas. Turkey is among the minor global producers with an annual average crude oil production of 57,000 b/d (2019) but at the same time Turkey is a major oil consumer. This results in about 90% dependence on crude oil and oil product imports. While there has been increasing crude oil production in the last decade, these have been offset by higher oil consumption leaving the ratio of import dependence relatively unchanged.

Improvements to the energy and production (E&P) sector should be stressed in order to use all means at Turkey's disposal to reduce its oil import dependency, particularly because the large surface area of Turkey is largely unexplored. Economically recoverable crude oil reserves are estimated at 200 million barrels. Dividing this by current production yields 18 years but this figure should not be interpreted as how long Turkey's domestic oil production will last.

Efforts to build Turkey's E&P sector are already underway. Over the last three decades, 2019 witnessed the most intensive oil exploration in Turkey. Onshore drilling was performed using 24 rigs for 121 wells. Five offshore drillings were also completed using the Fatih and Yavuz drilling vessels. As a result, Turkey has become one of the most active oil exploration areas in Europe. Based on the Baker Hughes rig count, Turkey had the highest number of 2019 European onshore oil drilling rigs. Turkey ranked third in total number of oil rigs behind Norway and the UK offshore (Figure 3.25). Crude production in 2019 was 5% higher than in 2018. The highest daily petroleum production was also recorded in 2019 exceeding 150 thousand b/d of which 70% was realized by TPAO including its production in other countries.

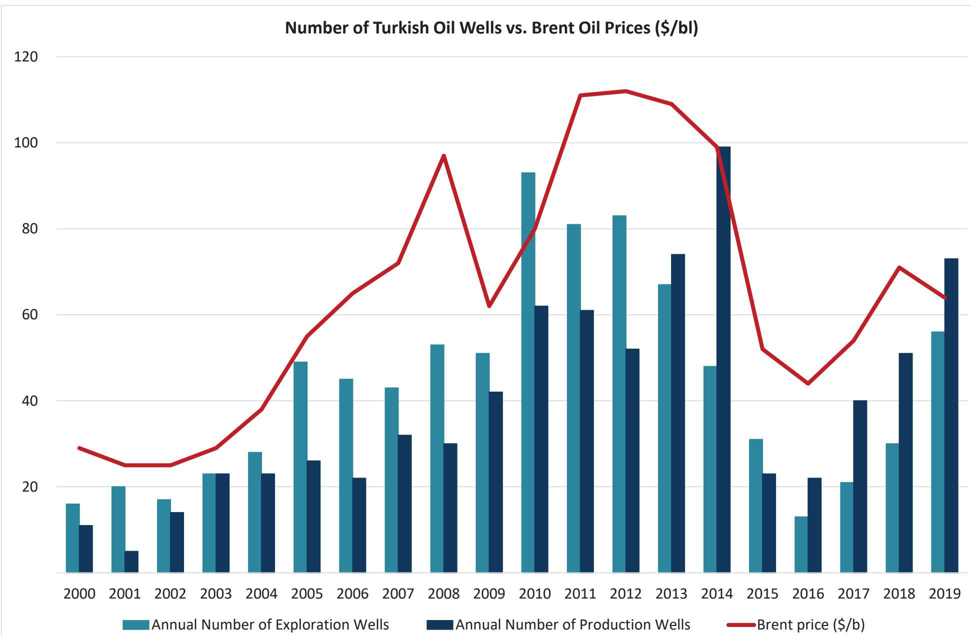
Figure 3.25 Leading Countries and Regions in Europe in Annual Average Number of Oil Rigs in Operation



Source: Baker Hughes, 2020

As one would expect, E&P activities are greatly affected by oil prices. As shown in Figure 3.26, Turkish E&P investments also tracked oil prices. Nonetheless, the recent increases in investment suggest a greater influence of policy as oil prices have been stagnant even before the Covid-19 pandemic. The recent trends of $500 million/yr. investment will likely continue or increase after oil prices return to pre-Covid-19 levels and start to approach the marginal cost of new oil production.

Figure 3.26 Number of Turkish Oil Wells vs. Brent Oil Prices ($/b)

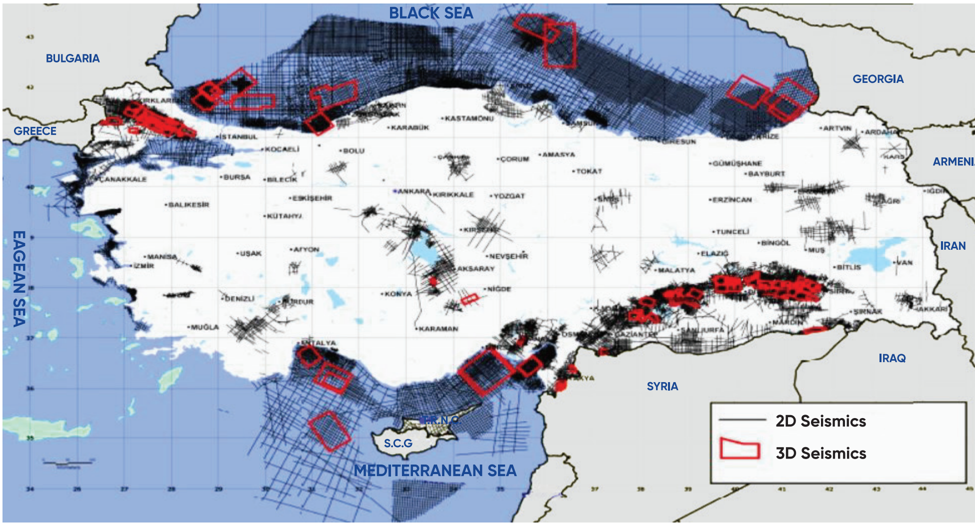


Source: MAPEG, 2020 & EIA, 2020

Currently 43 companies conduct upstream activities in Turkey of which 18 are foreign companies and 25 are domestic involving 345 thousand km^2 surface area and 297 licenses. The share of surface area and the total number of licenses owned by TPAO in E&P activities are equal to 92% and 77%, respectively. As of early 2020, a total of 231 oil and gas fields were discovered with a discovery rate of 11%.

Turkey's offshore district is divided into 2 regions; territorial waters and outside of territorial waters. 7 0% of the total wells drilled are located in the Southeast region and 20% in Thrace. Despite increasing efforts around offshore exploration, wells located at seas remain at only 1% of total wells but are estimated to increase. Turkey has been increasing seismic onshore and offshore mapping activities (Figure 3.27). As of January 2020, 381,000 km 2D seismic data has been collected (48% onshore). In 3D mapping, seismic database reached 88,000 km^2 (22% onshore).

Figure 3.27 Seismic Map for Oil and Gas E&P Activities (2019)



Source: MAPEG

The average API[24] for domestic crude oil is 28 API. This medium weight crude oil has become increasingly important for world refineries. Since the first decade of the 21st century when the shortage of complex refineries became economically significant, there have been many refinery upgrades to add cracking capability favoring medium and heavier crudes. This was also accompanied by a decreasing share of gasoline demand causing refinery yields to favor middle distillates.

Turkish gravity levels are well suited to Turkey's desired refinery slate to avoid excess production of gasoline. For example, even the heavy oil from the Batı Raman field provides, for Turkish refineries, middle distillate yield and a limited light product yield. Turkey's TÜPRAŞ İzmit and SOCAR Star refineries are complex refineries that are designed to process heavier crudes to achieve a high yield of middle distillates[25]. The sulfur content in domestic crude oil is generally high which poses an economic problem. The main demand product is Euro V and Euro VI class diesel, with maximum 50 ppm sulfur. Turkish refineries are well capable to limit sulfur with increased hydrodesulphurization. Despite this, it still creates an economic factor to consider. To alleviate the problem, Turkey still has an exemption for agricultural tractors to consume 1,000 ppm sulfur diesel fuel.

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[24] API gravity is an inverse indicator that is used to determine the weight of petroleum liquids relative to water (crude oil with an API lower than 10 or lower no longer floats on water). From the perspective of a refinery, oil with an API of 10 or lower is considered "extra heavy." "Heavy crude' has an API below 22.3. Medium crude is between 22.3 and 31.1. Light crude has an API higher than 31.1.

[25] It is worth mentioning that the heavy wax property of the Bati Raman field reduces secondary distillate yields compared to its foreign peers like Iranian Heavy, Basrah Heavy or Saudi Arabian Heavy.

The Turkish Petroleum Law[26], enacted in 2013, regulates the upstream oil and gas exploration and production operations. This law will further promote the Turkish upstream oil sector through incentives, more liberalization as well as improved efficiency of the State-owned petroleum company, TPAO. The main aim of the law is to attract more private and foreign investment to reduce the number of idle licenses, which are maintained but not used.

The current fiscal system for Turkish oil and gas production is a Royalty & Tax (R&T) system. It is a relatively attractive system for an underexplored country like Turkey where exploration and greenfield development risks are higher due to geological limitations or the lack of proven large reserves. The royalty rate of 12.5% is low compared to many international practices. Major tax incentives are also introduced with the Law extending from lifting all taxes, tariffs and fees for imported equipment used for E&P. Despite energy policy priorities and the progress achieved through incentives by the recently established liberal market, a number of factors can still be improved including government processes, land rents, price formation and accessing information. Seismic mapping and related technologies can also be further improved to encourage exploration and production. Low oil prices, made even lower by the Covid-19 pandemic, provide a poor economic backdrop to pursue upstream activities. It may make more economic sense to consume inexpensive oil imports than make investments until the prospects for economic returns are more favorable. Private sector interest in Turkey's upstream prospects will likely increase once world economic growth resumes, current high oil inventories are drawn down and oil prices begin to exceed the marginal cost of new oil production.

A number of incentives are available to increase private sector investment, especially by international oil companies (IOCs) such as the Product Sharing Agreement (PSA) arrangement in case of a large discovery. The PSA agreement could also be utilized in projects like Bati Raman where proven reserves are large, but investments and expertise are needed to overcome the technical challenges. Other challenges such as pipeline or transportation infrastructure could favor the R&T fiscal system to stimulate investments.

Onshore Potential: Most of the Turkish oil production is coming from three basins: Euphrates/Mardin basin, Zagros Fold Belt and Zagros Thrust Zone. These three basins are believed to have a large potential for additional discoveries especially in Cretaceous carbonates and Late Cretaceous carbonates. In addition to these three basins, Adana/Sivas basin is also assumed to have a potential for future discoveries in its offshore section. Oil production of 57,000 b/d is currently only being generated from onshore fields. This is mostly being supplied by the fields in South-eastern Turkey. Turkey has approximately 80 fields producing oil with an average unweighted gravity of 30.5 API. However, Turkey's biggest oil field, Batı Raman, is producing crude oil at 12 API, which is extra heavy crude oil. This brings Turkey's weighted crude oil gravity to 28 API.

[26] No: 6491

Turkey's main upstream production problem is that the country does not have many large oil fields. Turkey has only three oil fields with an original oil in place[27] (OOIP) volume exceeding 500 million b (Table 3.2). These are Batı Raman, Raman and Selmo. Among these three, Batı Raman is the only one in the giant field classification with an 1,840 million b OOIP, but the recovery rate[28] for Batı Raman is very low at 10.5% (initial recovery factor) with estimated total recoverable reserves of 192 million b.

Table 3.2 Major Oil Producing Fields in Turkey

Field	OOIP (million barrels)	Recoverable Reserves (million barrels)	Recovery Rate (%)	API Gravity
Raman	615.3	146.9	23.9	18
Batı Raman	1841.0	192.9	10.5	13
Kurkan	287.0	67.3	23.4	31
Bati Kayakoy	225.6	63.4	28.1	35
Beykan	432.8	89.8	20.7	33
Selmo	539.0	99.3	18.4	34
Karakus	209.1	61.6	29.5	30
Garzan	199.1	46.5	23.4	24
Kayaköy	99.9	31.2	31.2	38
Kuzey Karakus	87.8	42.2	48.1	30

Low recovery rates are not only a problem for the Batı Raman field. For the ten major producing oil fields shown in Table 3.2, the average recovery rate is estimated at 18.5%. This is one of the main reasons for Turkey to increase production having some large fields. When compared to its peers, the recovery factor of Turkish oil fields can be classified as low to medium. Recovery rates are directly related to formation rock quality, reservoir drive mechanisms, past applications in the fields and many other factors.

Unconventional Potential: Turkey has some known shale plays such as Dadaş shale which may be a promising source of unconventional oil in Turkey. Unconventional drilling achievements in the U.S. have created optimism for unconventional shale production globally although little progress has been made outside of North America. However, Turkey might have some of the most promising shale plays outside of North America. The Dadaş shale play is estimated to contain more than 4 billion b of oil. TPAO drilled two horizontal wells in this play. One was completed with a joint venture agreement with Shell. Shell recovered light oil from this well. Transatlantic Petroleum has also been active in

[27] OOIP is is a gross quantity independent of recovery efficiency or economics.
[28] The ratio of recoverable oil reserves to the original oil in place in a reservoir.

the Dadaş shale. Turkey also initiated the Unconventional Projects Roadmap to discover unconventional potential in Thrace and South-eastern Anatolia, the two most promising regions for both conventional and unconventional plays. Most recently, Turkey's deepest oil production was achieved in 2019 in Mermer-1 field at 3700 meters with hydraulic fracturing.

The Petroleum Law should be reviewed to assess how it could be improved to better facilitate unconventional oil development. While low oil prices are an impediment for conventional E&P they provide an additional challenge for the more speculative prospects of successful tight oil development especially considering the need for oil field services and infrastructure.

There are also risks that shale development activities could generate public opposition. Due to public opposition, tight gas and oil production has been banned in some EU countries and U.S. States. However, Dadaş is a world-class shale play with a huge potential as discussed in Chapter 4 (Natural Gas). All development activities should be undertaken with best practices to avoid the unnecessary adverse side effects of tight oil and gas development. These include well bore integrity and, what is very often the source of environmental problems, the proper handling of well waste fluids.

Enhanced Oil Recovery: Enhanced oil recovery (EOR) is a widely exercised practice to reverse or slow the decline in maturing fields and enhance the percentage recovered. EOR provides around 2% of total oil production globally. While the life-cycle cost of EOR is competitive with other production options, it typically has higher up-front capital requirements and longer pay-back periods. Therefore, 80% of global EOR production either benefits from government incentives or is prioritized by national oil companies for maximizing the return from domestic oil resources.

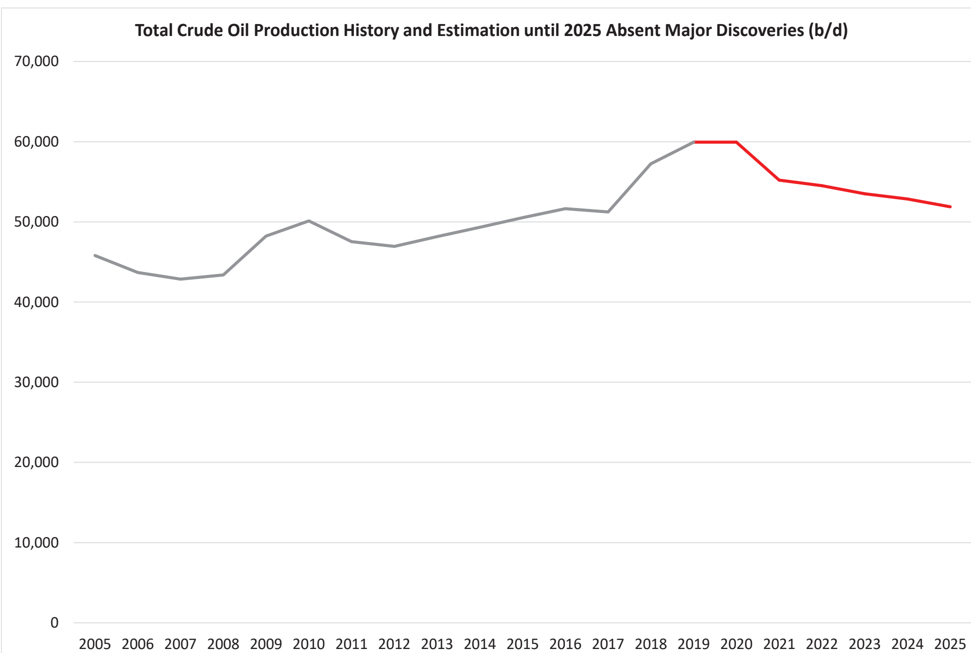
One of the most widely utilized EOR techniques involves injecting CO_2 into the well. In an immiscible process, the gas does not dissolve into the oil but pushes the remaining oil in place to yield increased output. New technologies are being developed to produce CO_2 from industrial applications where naturally occurring reservoirs are not available or as a result of government incentives. EOR techniques can result in a 30% to 60% increased production that would otherwise be recovered from a reservoir's original oil in place.

There has been increased domestic crude oil production in recent years, mostly due to increased drilling in the Bati Raman oil field. Bati Raman field production has been in an uptrend since 2005 with an estimated output of around 8,000 bpd in 2019. This suggests an increase of around 10% in total Bati Raman output since 2005.

EOR is being used in Turkey, including Bati Raman. However, Turkish crude oil fields are carbonate types in which EOR applications are limited due to reservoir rock properties, which do not give many technically feasible options for the operators. CO_2 injection is a capital-intensive application and, to be extensively applied in Turkey, it would require development of CO_2 capture, an expensive proposition, especially when oil prices are low. This adds further complexity to apply EOR extensively to oil fields in Southeastern Turkey with limited CO_2 availability. However, EOR applications could result in a successful outcome on a selective basis on fields like Raman, Beykan and Selmo. Studies suggest that EOR techniques could increase total recovery factor for the major oil fields by 8.5%, or 380 million b. Evaluating cost-effective methods to increase Batı Raman's recovery rate should be a priority R&D focus for Turkey to support localization oriented energy policies and investments.

Turkish oil production would enter a period of steady decline without new discoveries or improved production from existing fields. Due to the nature of the production activity in the Batı Raman field, the production profile is estimated to have a rolling pattern, to reflect the impact of EOR applications. However, all other fields are estimated to have an annual decline of 2%, absent any additional field development activity that offsets potential gains from Batı Raman EOR (Figure 3.28).

Figure 3.28 Total Crude Oil Production History and Estimation until 2025 Absent Major Discoveries (b/d)



Source: Kahin Consultancy

Offshore Potential: Although Turkey has a long history of onshore oil exploration and production, offshore activity has only recently become a focus. Offshore E&P is more capital-intensive and requires more advanced technical elements. Turkey has developed several projects over the past decade to undertake offshore drilling in the Black Sea with 44 wells drilled (see Table 3.3). Unfortunately, none of these wells discovered a promising oil reservoir.

Table 3.3 Black Sea Offshore Oil Exploration Wells in the Past

Well name	Water Depth (m)	TPAO Partner
Ayazlı-2	79	Promoteo
Istranca-1	85	-
İnebolu -1	106	-
Limanköy-1	854	ARCO
Sürmene-1	1,801	ExxonMobil
Yassıhöyuk-1	2,018	Chevron
Sinop-1	2,182	Petrobras

Nonetheless, offshore hydrocarbon exploration is continuing in line with the localization energy policy objectives and backed by investments into TPAO. Two deep-sea drilling ships, Fatih and Yavuz, employing advanced technologies, have expanded their operations, including the Mediterranean. A third ship, Kanuni, joined this fleet and was focused on the offshore drilling campaign.

The potential for Black Sea production including gas cannot be discounted especially considering the success of some other states neighboring the Black Sea. The major gas discovery, as discussed in detail in Chapter 4 (Natural Gas) will contribute to energy balances of Turkey. The Black Sea has also been one of the most auspicious locations for successful oil discoveries.

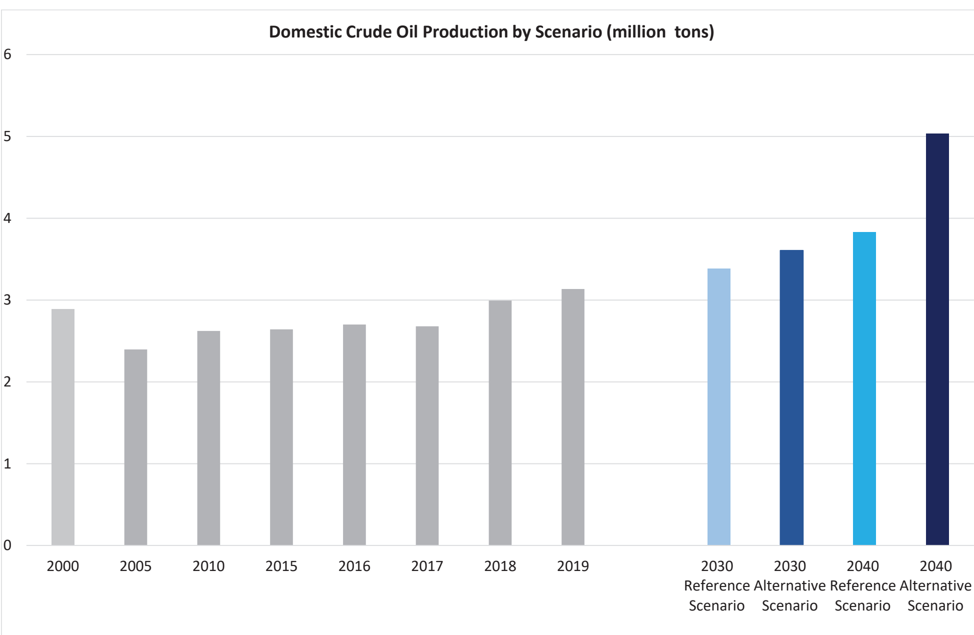
Technology and Localization: Turkey is prioritizing localization in sourcing E&P equipment and software. Turkey realized 32 projects in 2019, up from 19 E&P localization projects in 2018, increasing TPAO tenders from 5% localization to 14%. This upward trend is expected to increase.

TPAO, guided by policies to use innovative methods and local sourcing, has already adopted a number of approaches including integrating artificial intelligence to some processes and enabling technical improvements for domestic suppliers. Technology priorities include increasing productivity with fracking the tight reservoirs, downhole heaters, water and carbon dioxide injection, and polymer gel and acid applications. Increased use of public-private partnership models is another strategy being employed to increase E&P localization. These also promise improved efficiency and productivity in oil upstream investments.

Oil Supply Outlook: Intensified upstream activities in Turkey's largely unexplored basins account for expectations of increased domestic crude production in both Scenarios. The Reference Scenario shows an average 1.1% annual increase in production until 2040 backed by ongoing efforts to ramp up production from existing sites vie enhanced efficiency and adding new production fields into the inventory. In the Reference Scenario, domestic crude production would meet 11-12% of total crude oil supply by 2040 depending on upgrades in existing refinery infrastructure. Further gains in the Alternative Scenario would increase this ratio to 17-18% compared to 12% in 2018. Supported by a more attractive upstream framework, technology advancements including secondary production and enhanced recovery methods, and accelerated offshore and unconventional plays, the Alternative Scenario estimates that domestic production would increase by two-thirds until 2040 (Figure 3.29).

This estimate includes a number of unknowns as reliable expectations of the larger gains necessary to significantly reduce Turkey's oil import dependency will depend on one or more major discoveries that are, inherently, uncertain, especially considering the negative economic environment that E&P activities are likely to have for some years to come. However, it should be kept in mind that any large offshore discovery would considerably change this outlook.

Figure 3.29 Domestic Crude Oil Production by Scenario (million tons)



Crude Oil Import Assessment: Turkey imports crude oil from a diverse number of regions and countries. Parallel to the demand portfolio for petroleum products, Turkey's refineries consume medium to light crude oil grades from proximate sources in the Middle East, Russia, Caucuses, and North Africa. Turkey imports roughly 91% of its crude requirements, while the remaining 9% is met by domestic crude production (57 kb/d in 2019). Turkey's crude imports in the past decade have varied between 400 kb/d and 500 kb/d depending on refinery utilization levels. Iran and Iraq have been the two largest crude suppliers to Turkey in the last decade until 2018. The two countries combined have supplied Turkey with 280 kb/d that is evenly split between them, (65% of Turkey's total crude imports) for an extended period. This supply structure was altered after 2018. As shown in Table 3.4, Turkey's crude oil imports were led by Russia and Iraq in 2019. Kazakhstan, Iran, Saudi Arabia, Nigeria and Libya were also important suppliers, each providing over 1 million tons of crude supplies.

Table 3.4 Turkey's Top 10 Source Countries for Crude Oil (2019, million tons)

Country	Crude Oil Imports
Russia	10.4
Iraq	9.5
Kazakhstan	3.2
Iran	2.1
Saudi Arabia	1.9
Nigeria	1.8
Libya	1.1
Turkmenistan	0.5
Azerbaijan	0.4
Colombia	0.1

The United States reinstated the sanctions on Iran's crude exports but, in November 2018, provided import waivers to selected countries, including Turkey. Later, during 2019, the waivers were suspended and no imports could be practically imported by any Turkish refiner considering the economic consequences of violating the sanctions. During 2019 imports from Iran dropped from 7.1 million tons in 2018 to 2.1 million tons. Iran has been one of the major oil producing countries in the world and Turkey's main crude oil sources before the latest U.S. sanctions. While Iran's crude oil exports have been highly variable due to sanctions, disputes and technical challenges in its upstream industry, these have not posed oil supply problems for Turkey as its source countries for crude oil are diversified. Nonetheless, Turkish refiners' crude oil acquisition costs were adversely affected by the sanctions.

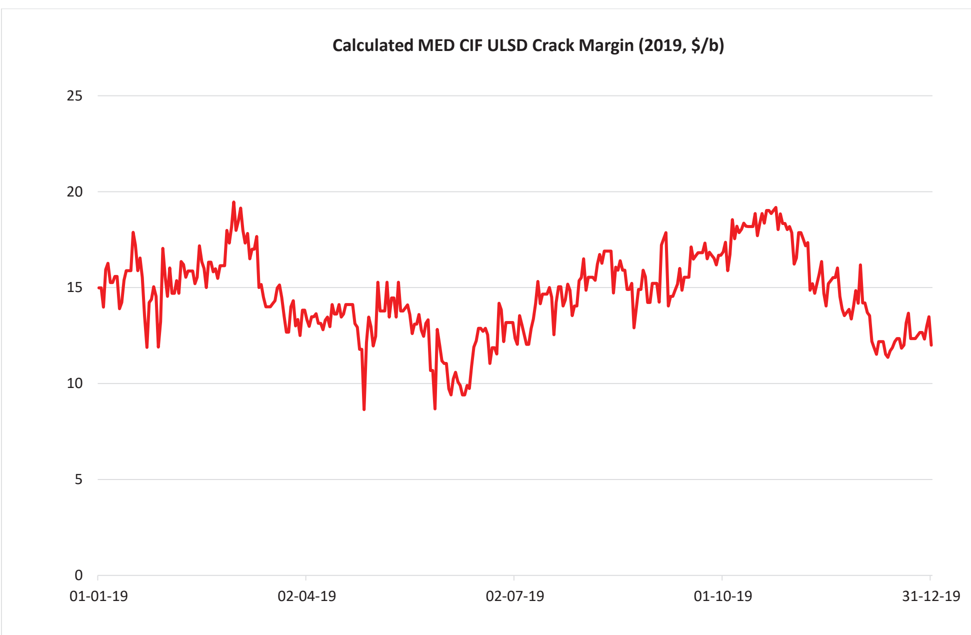
Turkey is also heavily dependent on diesel fuel imports to meet growing demand from the transport sector. The main diesel suppliers are Russia and India (Table 3.5). Combined, they provided 4.7 million tons of diesel fuel.

Table 3.5 Turkey's Top 5 Source Countries for Diesel Fuel (2019, million tons)

Country	Diesel Types Imports
Russia	2.7
India	2.0
Israel	1.0
Bulgaria	0.5
Greece	0.4

While the landed cost for Turkey's imported crude oil is not published, based on the data from EMRA and MED CIF, the Turkish refinery crack spread was $15/b in 2019 (Figure 3.30). Turkey's 2019 diesel fuel imports were 10.9 million tons, or 82.2 million b. These data suggest that $1.2 billion of foreign exchange could be saved if Turkey would produce all of its domestic diesel fuel consumption. This is a significant savings compared to our estimate of Turkey's total landed cost of imported crude oil ($13.9 billion).

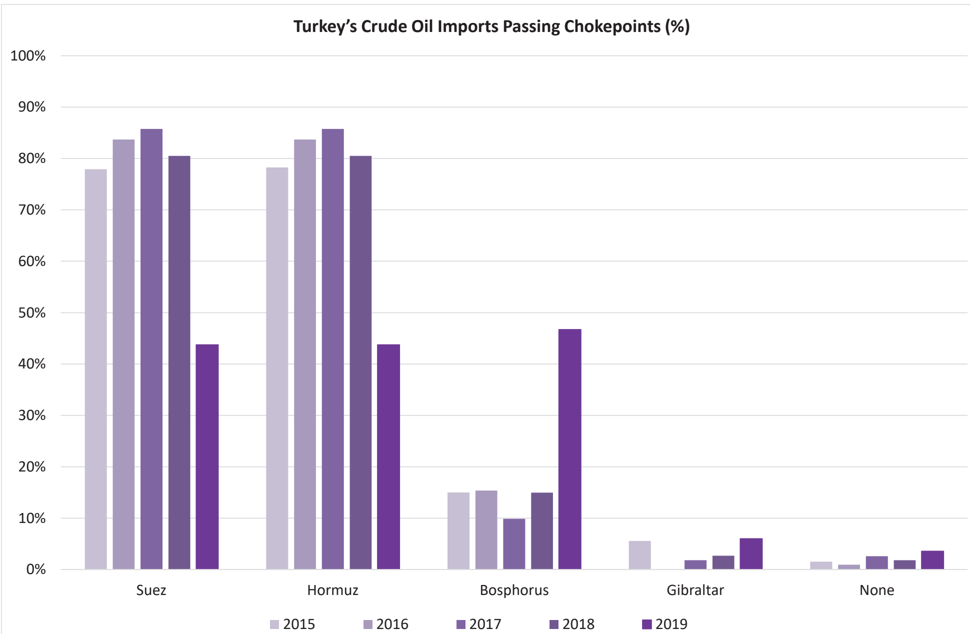
Figure 3.30 Calculated MED CIF ULSD[29] Crack Margin (2019, $/b)



29 ULSD is ultra-low sulfur diesel.

While Turkey has diversified crude oil suppliers, the trade routes are not. A significant share of Turkey's oil imports passes through the Hormuz Strait or the Suez Canal, two chokepoints that show up in multiple oil disruption scenarios. Concerns about the Hormuz Strait have drawn increased attention during 2019 with rising Middle East geopolitical tensions involving Iran (Figure 3.31).

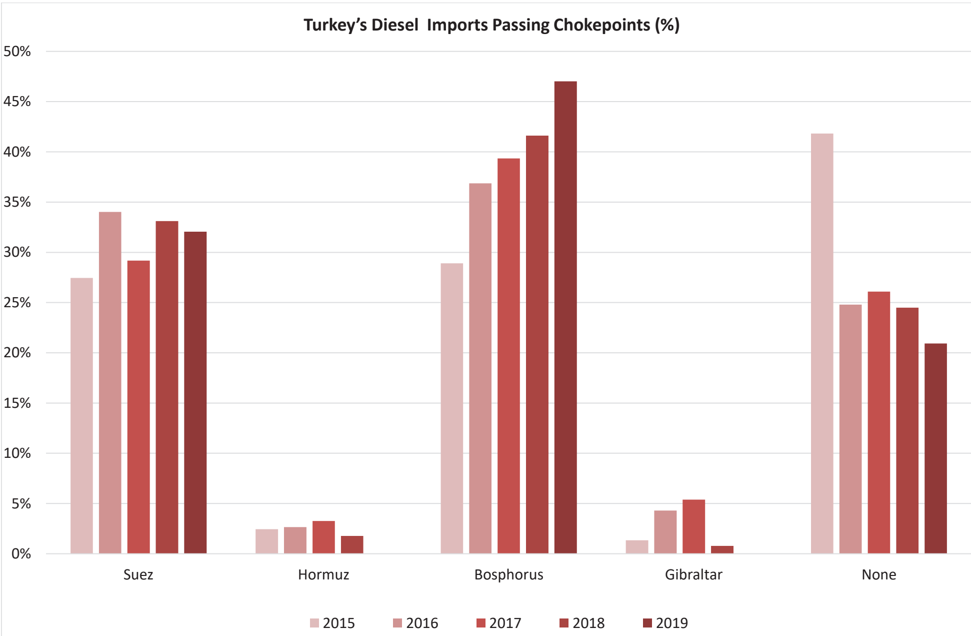
Figure 3.31 Turkey's Crude Oil Imports Passing Chokepoints (%)



Note: All imports from Russian Federation and Kazakhstan assumed to flow through the Bosphorus

The situation for total diesel fuel imports had been different. Turkey had a relatively secure trade route with more than 40% of the total supply arriving without passing through any chokepoints in 2015. However, this began to change with adding more imports arriving from Bosporus and Suez passages with increased volumes flowing from Russia and India. It is estimated that close to half of total diesel imports passed through the Turkish Straits (Figure 3.32). When crude and diesel imports are combined, the share of imports passing through the Turkish Straits has doubled from 22% in 2015 to 44% in 2019.

Figure 3.32 Turkey's Diesel Imports Passing Chokepoints (%)



Note: All imports from Russian Federation and Kazakhstan assumed to flow through the Bosphorus

Oil Trade Choke Points: The Turkish Straits is one of the most important passageways for seaborne crude oil and products transportation. The Turkish Straits is the fifth largest bottleneck in the world following the Hormuz Strait, Malacca Strait, Suez Canal and Bab-el Mandeb. On average, 1.7 mb/d of crude oil passes through the Turkish Straits, corresponding to 4% of all seaborne oil trade (Table 3.6). This is comprised primarily of Russian Urals and Kazakh CPC blend that are headed to global markets. Both grades are crucial for Mediterranean refineries making them particularly dependent on the performance of the Turkish Straits.

Table 3.6. Total Seaborne Crude Oil Trade and Share of Crude Oil Passing Turkish Straits

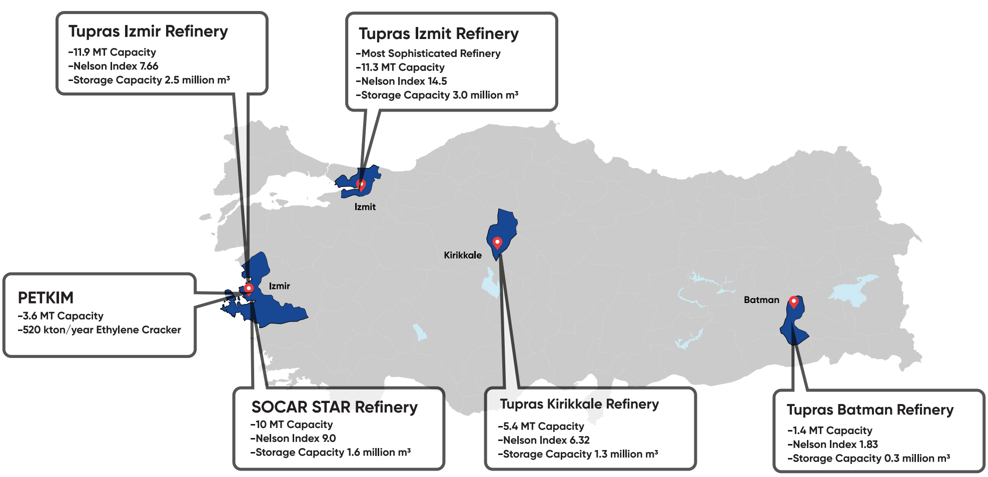
	Total World Seaborne (mb/d)	Turkish Straits (mb/d)	Share in Global Seaborne
2018	45.9	1.7	3.7%
2017	39.0	1.7	4.3%
2016	40.8	1.7	4.2%
2015	37.6	1.7	4.5%

Recently, there have been slight declines as less Russian crude oil is being loaded in Russian Black Sea ports perhaps reflecting increasing congestion in the Turkish Straits. Nonetheless, Russia's goals to export more Urals to India and other Asian destinations would be best served by transit through the Turkish Straits and Suez Canal. Suezmax class vessels are the most economic vessels to use through the Turkish straits and the Suez Canal. However, they face more delays in the Straits as they require harbor pilot support and they must sail in limited spaces. Additionally, laden vessels in Suezmax class have the least priority in crossing the Turkish Straits due to legal, safety and security restrictions, a major reason for additional delays and demurrage costs for Russian Urals cargoes. These shipment issues are most important for refineries in Greece and Italy that require heavy volumes of Urals and CPC blend.

3.3.4 Refinery Issues

Refining Capacity and Configuration: Turkey's total refining capacity is over 800 kb/d, split between 5 refineries and 2 companies (Figure 3.33, 3.34). TÜPRAŞ, which, up until 2018 was Turkey's sole refining company, owns 4 refineries with a total nameplate capacity of 600 kb/d. TÜPRAŞ' refineries produced 28.1 million tons of products in 2019 with total capacity of 30 million tons. TÜPRAŞ' product yields were comprised of 17% jet/kerosene and 4% LPG, while the naphtha and gasoline yields were at 1% and 20%, respectively. Diesel was 36%, fuel oil 9%, bitumen 8%, coke 3% and other products 2%.

Figure 3.33 Map of Turkey's Refineries



TÜPRAŞ, the former state-operated company, is now entirely privately owned; 51% by Energy Investment Inc. (77% of which is owned by Koç Holding) with the remainder publicly traded. Its 4 refineries are the İzmit, İzmir, Kırıkkale and Batman refineries. TÜPRAŞ benefits from integrated system optimization with its high complexity, procurement and logistics flexibility. In 2019, TÜPRAŞ purchased crude oil from 8 countries producing 15 different types and gravities of crude oil ranging between 20 and 47 API.

- The 228 kb/d İzmit refinery, near Istanbul and the Bosphorus, is the most complex refinery in Turkey with a Nelson Complexity Index of 14.5.
- The 240 kb/d İzmir refinery located at Aliağa on the Aegean coast is Turkey's largest refinery, but is not as complex as the İzmit refinery, with a Nelson Complexity index of 7.7.
- Kırıkkale Refinery is much smaller at 110 kb/d and located in central Turkey near Ankara. The refinery has a Nelson Complexity index of 6.3, ranking third among TÜPRAŞ refineries.
- Batman refinery, located in eastern Turkey, with 28 kb/d capacity, is the smallest refinery in Turkey and the least complex with a Nelson Complexity index of 1.8.

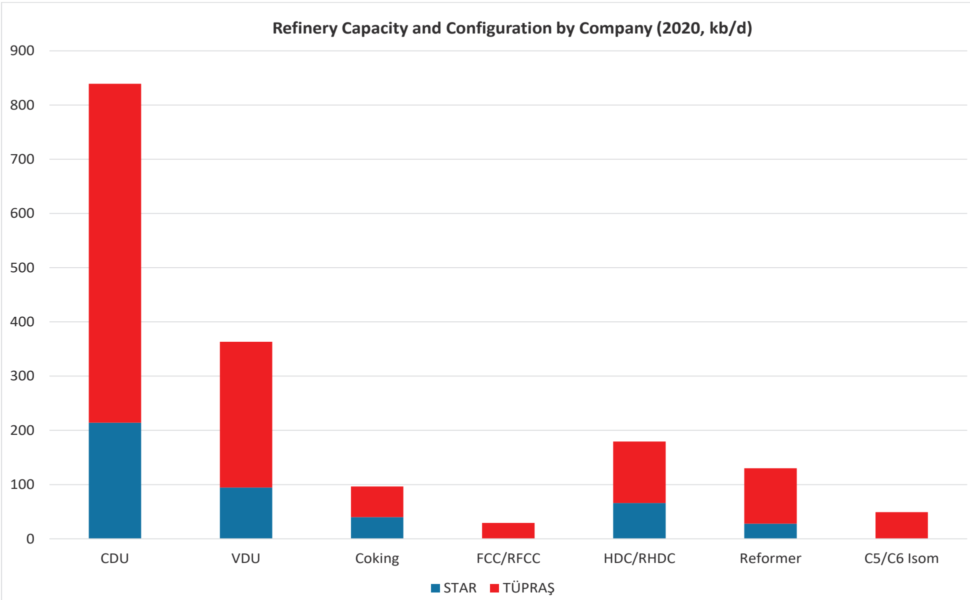
These four refineries hold a 9,000 m^3/d coker and hydrocrackers totaling 18,032 m^3/d, as well as a small FCC (4,650 m^3/d). Additionally, TÜPRAŞ holds 42,752 m^3/d VDU, 37,265 m^3/d Kero/Diesel (HDS), 7,804 m^3/d of isomeration, and 16,225 m^3/d unifier reformer capacity.

Another prominent refinery in Turkey is the STAR Refinery, which was commissioned in late 2018 by SOCAR and started full commercial operations in 2019. The STAR refinery is the second most complex refinery in Turkey. SOCAR Turkey holds 87% of the shares in the STAR Refinery. The refinery has about 10 million tons of capacity per year. The product yields were comprised of 3.4 million tons of diesel, 1.1 million tons of jet fuel, 0.8 million tons of naphtha and 0.1 million tons of LPG in 2019.

STAR Refinery's configuration includes a 40 kb/d coker and a 66 kb/d hydrocracker. Distillate treating capacity stands at around 100 kb/d. The STAR Refinery focuses on strategic products such as diesel, jet fuel and naphtha for addressing growing needs of the domestic oil industry. The refinery has an approximately 1.64 million m^3 of storage capacity with an ongoing expansion to 2.5 million m^3 and has the flexibility to process various types of crude oil between 28 and 36 API.

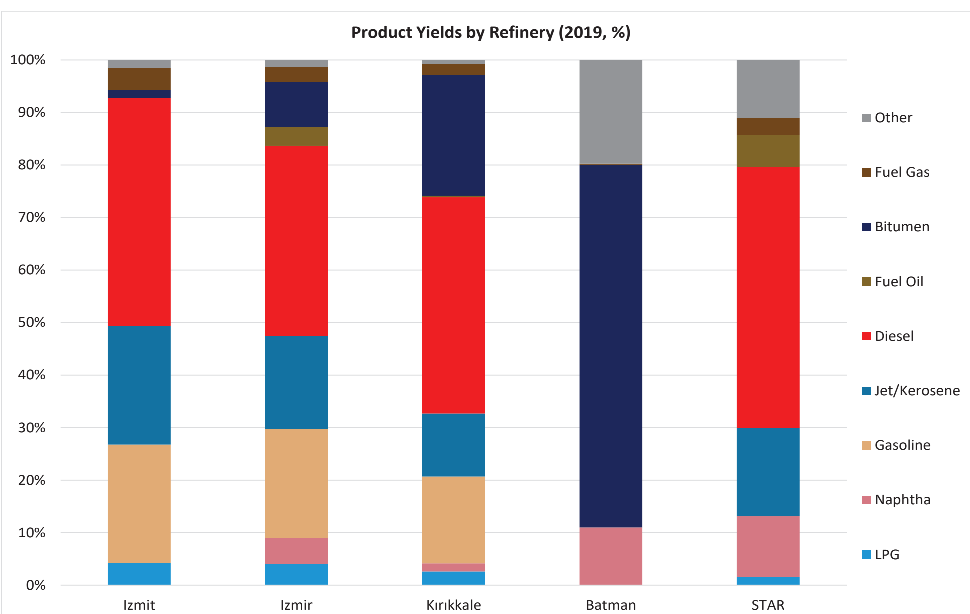
Product Slates: Turkey's refineries are able to provide all major oil products (Figure 3.35). Among TÜPRAŞ' refineries, İzmit is the one producing the highest middle distillate (70 %), gasoline (23%) and LPG (4%) yields. Corresponding to these high yields of valuable products, the İzmit refinery has the lowest yield of other products (0%) and a very low fuel oil yield (1.2%). The Batman refinery has the lowest fuel oil yield 1.4 million tons (4%) among TÜPRAŞ refineries. The Batman refinery also has the highest high-sulphur diesel yield. The STAR Refinery is geared to have yields of middle distillates and petrochemical feedstock (naphtha and reformate), but zero gasoline and low fuel oil output (6%). STAR Refinery's product yields is led by diesel (50%), jet fuel (17%) and naphtha (12%) (Figure 3.35).

Figure 3.34 Refinery Capacity and Configuration by Company (2020, kb/d)



Source: TÜPRAŞ, 2020; SOCAR; FGE
Note: STAR refinery data is for 2019.

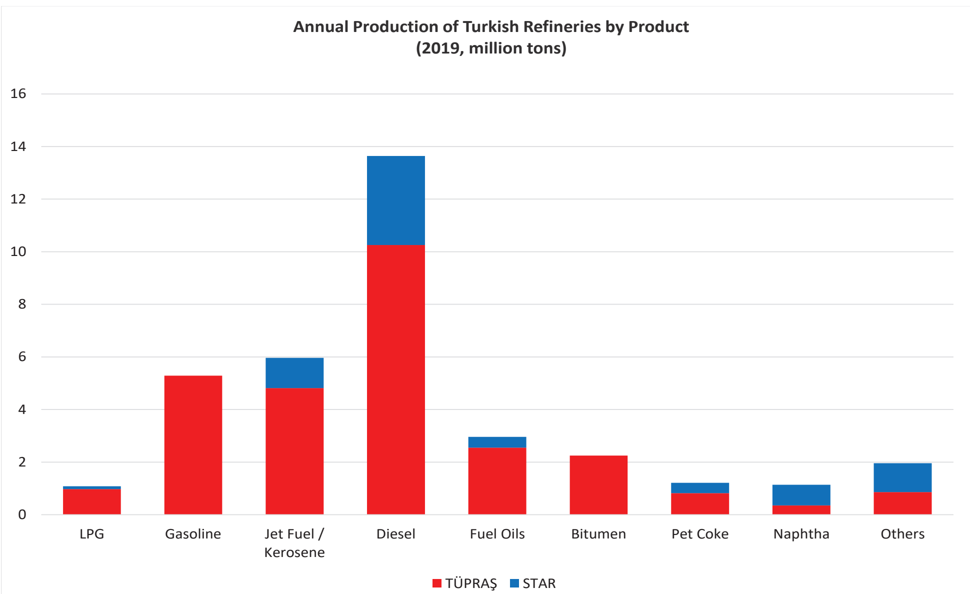
Figure 3.35 Product Yields by Refinery (2019)



Source: EMRA, 2020

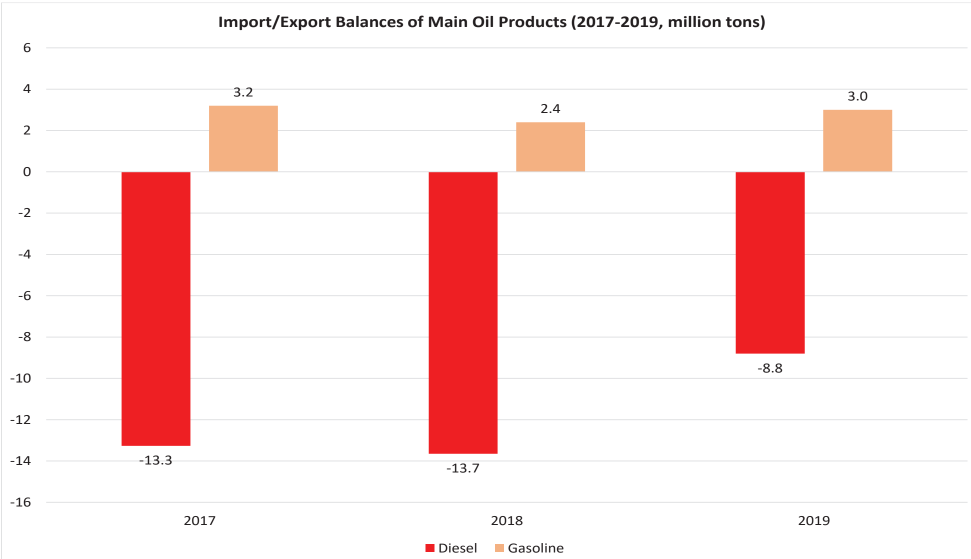
Turkey's total refinery capacity reached 40 million tons/yr. Four TÜPRAŞ refineries are able to produce 30 million tons and the STAR Refinery can deliver 10 million tons annually. In 2019, TÜPRAŞ refineries produced 5.3 million tons of gasoline followed by 4.8 million tons of jet fuel, 10.2 million tons of diesel fuel, 2.6 million tons of fuel oil, 1.0 million tons of LPG and 2.2 million tons of bitumen. The main product of the STAR refinery is low sulfur diesel producing 3.4 million tons in 2019. STAR also produced 1.1 million tons of jet fuel, 0.8 million tons of naphtha, and 0.1 million tons of LPG. Diesel fuel has been the major yield of Turkish refineries with a combined 2019 production of 13.6 million tons followed by jet fuel (5.9 million tons) and gasoline (5.3 million tons) (Figure 3.36).

Figure 3.36 Annual Production of Turkish Refineries by Product (2019, million tons)



Turkey has traditionally been short on LPG, naphtha and diesel fuel and long on gasoline. Even though Turkey is largely balanced on jet, kerosene and fuel oil, imports or exports of these products also occur. Turkey's refinery capacity and product slates result in net import requirements for two major fuels: diesel and LPG. Although the commissioning of STAR refinery lowered diesel imports from 13.6 million tons in 2018 to 8.7 million tons in 2019, diesel imports remain the major import item in the oil product balances of Turkey. Turkey's total jet fuel demand for domestic sales is lower than the current production capacity but is largely balanced with production including bunkers. However, this could change based on the expected growth of Turkey's aviation sector. Gasoline production capacity of 6.1 million tons (2020) is more than double of the domestic demand resulting in net exports of 3 million tons in 2019 (Figure 3.37).

Figure 3.37 Import/Export Balances of Main Oil Products (2017-2019, million tons)



Factors to Watch: The Turkish refinery sector has evolved substantially during the last decade. The NCI[30] of TÜPRAŞ' most sophisticated plant, the İzmit refinery, has nearly doubled since 2010 and reached to 14.5. Various residual upgrading projects have resulted in shifting yields to cleaner fuels away from heavy fuel oil. SOCAR's STAR refinery, another complex refinery, with an NCI of 9. As noted above, STAR produces practically no gasoline, as such, was designed to particularly serve Turkey's product needs. However, there are multiple challenges ahead for Turkey's refining system as the global refinery sector is very dynamic and competitive.

- **IMO Regulatory Change:** The International Maritime Organization's (IMO) has reduced, as 1 January 2020, the maximum sulfur limit in global marine fuel from 3.5% to 0.5%. This regulatory change caused a de-sulfurization of a large share of formerly compliant marine fuel (3.6 mb/d). There are options to continue using high sulfur fuel by installing scrubbers to instead remove the sulfur. Estimates are that 2.4 mb/d of the 3.6 mb/d of high sulfur material will be replaced. Even though Turkey's refineries have been increasing their complexity and reducing high sulfur fuel yields during the last years, this change has presented a challenge to desulfurizing their output of residual fuel oil. This is not helped by Turkey's structural diesel deficit as it makes it difficult to divert diesel fuel from the road market to the marine sector. Consequently, Turkey's refineries (TÜPRAŞ and STAR) may make additional investments to optimize their product mix in light of these changes.

30 The Nelson Complexity Index (NCI) of a refinery reflects what types of petroleum products can be produced. It is measured on a scale from 1 to 20 and the higher the value of the NCI, the more sophisticated and complex products the refinery can produce.

- **Crude Quality Changes:** Changes in global crude oil quality has become an ever more pressing issue for Turkish refineries during the last few years. With the recent U.S. sanctions on Iran and Venezuela and the continued growth of U.S. tight oil, there is a shift in the supply of medium/heavy sour crudes to lighter and sweeter grades. The effect of this change is evident from the global surplus of naphtha as the lighter crude slate has higher naphtha yields.

  However, the increased refinery complexity in Turkey makes it possible to process a diverse range of crudes. TÜPRAŞ' purchases vary between 19 API and 47 API and STAR' purchases vary between 28 API and 36 API. The majority of the crude coming into Turkey was sourced from Iran and Iraq. Now the majority of the crude oil has been sourced from the FSU region and Iraq but with no major changes related to crude quality.

- **Competition:** A persistent issue for Turkey's refineries is the rising refinery capacity East of Suez, specifically the Middle East and Asia. Product exports from these regions have grown substantially during the last decade and will continue to grow during the next years. For instance, in Asia, refinery capacity was projected to grow by 2.7 mb/d between 2019 and 2024. Most of this increase (1.7 mb/d) is expected by the end of 2021. In the Middle East, refinery capacity will rise by 1.8 mb/d between 2019 and 2024. However, Covid-19 outbreak would delay some of these investments.

  Notwithstanding increasing regional demand for petroleum products, their main target is not their domestic markets but export markets, especially nearby countries like Turkey. Almost all of these new refineries are complex, in most cases integrated with petrochemical plants and they are likely to be highly competitive.

  Turkey, with its structural product deficits, is a prime outlet for these exporters. A historical example is how India became a major diesel exporter to Turkey. Turkey has started importing diesel from India in 2010, when the country has shifted to 10 ppm diesel in January 2011. In a very short period, India replaced Russia as Turkey's major diesel supplier, as Russian diesel was high sulfur and India's complex refineries were able to deliver sufficient low sulfur diesel. Other suppliers such as Italy, Greece and Israel contributed by matching with these dynamics as well. IMO2020, as outlined above, will open another door for East of Suez export refineries.

  Another area where Turkey is structurally short is LPG. Turkey's LPG imports is now increasingly supplied by the United States. The United States came into the Turkish market in 2015 and is now replacing Russian market share. While still well short of Algerian LPG imports to Turkey, the U.S. share will likely grow in the coming years. The same could apply to petrochemical feedstocks as the United States is now one of the world's major ethylene exporters. As a result of its vast reserves of tight hydrocarbons in geologically favorable plays, and the United States highly-developed unconventional E&P industry, U.S. natural gas prices have reached remarkably low levels. It should be noted that the Covid-19 pandemic has caused world natural gas prices to decline to U.S. levels. Nonetheless, IICEC expects that this is a temporary situation and, as the world economy recovers, world gas prices will rise resulting again in U.S. gas prices being much lower than in other markets. Combined with the huge amount of natural gas processing and refineries processing more light tight oil, U.S. supplies of olefins and aromatics are increasing and their prices are decreasing. Consequently, U.S. petrochemical feedstocks are likely to be a continuing factor in the global petrochemical industry.

- **Refinery Investment Outlook:** Turkey has always been at the center of discussions around new refinery investments. Its proximity to European and African markets and the availability of different crude sources including pipeline infrastructure make a good case for a refinery. However, it is not easy to envisage an economic case for a refinery investment in the current global or regional oil market and infrastructure dynamics and there are multiple factors that speak against it.

  With the new STAR refinery, Turkey's refinery capacity reached 40 m tons/year (over 800 kb/d). While this figure is still lower than Turkey's total oil products demand of around 1 mb/d, the deficit is very specific: essentially it is diesel fuel (production covering 60% of consumption in 2019) and LPG. Compared to building new refineries to meet this demand and be faced with an excess of other products and an unattractive export market, combined with the ready import availability of diesel fuel and LPG, the economic case for new refinery investments is weak. Turkey's Mediterranean port and the end point of Kirkuk-Ceyhan and BTC pipelines, Ceyhan, has been considered as a suitable location for a new refinery. Crude availability from two pipelines, a deep-sea port suitable for VLCCs as well as the proximity to reach European and African markets have been considered as strong assets. However, the refinery world is changing rapidly. Integrated refinery plants face a slowdown in global oil demand growth. With European demand in decline due to a saturated market and strong climate change policies, European refineries are looking for new export markets including Turkey. Currently Turkish refineries compete with over 70 refineries in a broad region including the Mediterranean and Black Sea markets.

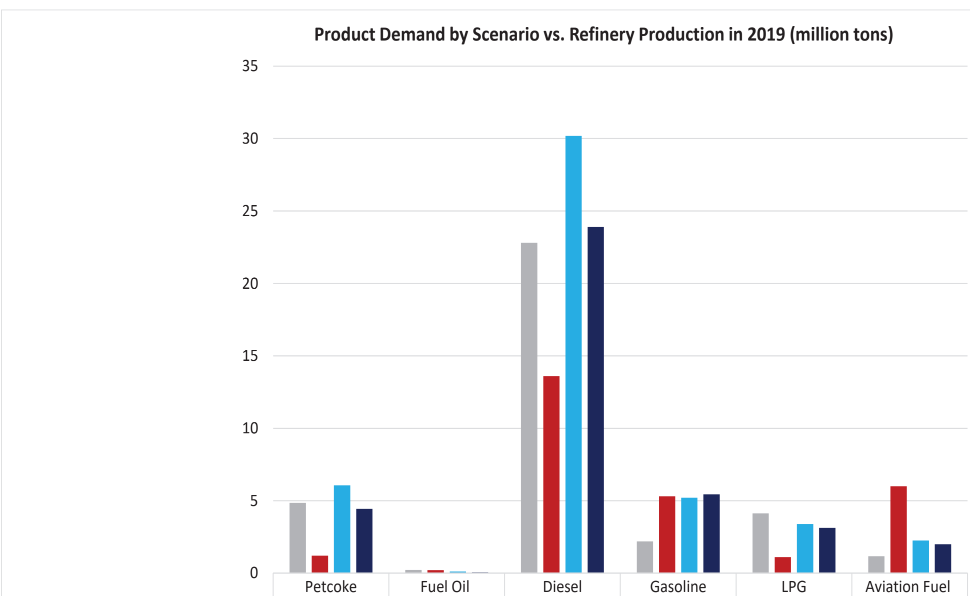
- **Outlook for Product Slates and Net Product Imports:** Despite additions to the refinery production base by the STAR refinery, the exposure of Turkey's oil economy to diesel imports will increase. While Turkish refineries produce an excess of gasoline over domestic demand, the value of these gasoline exports do not offset the corresponding cost of increased diesel imports. Changing product demands will have a significant impact on imports and exports (Figure 3.38), especially balancing the gasoline production and domestic demand and limiting the trade deficit in diesel imports in a growing transport energy economy. Shifting passenger car growth to a large extent to gasoline and hybrid vehicles can reduce this imbalance and reduce Turkey's net product import costs. As discussed in Chapter 2 (Transport), road fuel tax adjustments are an effective instrument to achieve a more balanced product slate and a reduced fuel import bill.

  The largest component of retail road-fuel prices in most countries, including Turkey, is the fuel tax. Again, as is common practice, in Turkey, different road fuels are taxed at different rates, with gasoline being taxed higher than diesel fuel. This partly reflects the reliance of the commercial sector on diesel vehicles.

In addition, for the Turkish automotive fleet, newer gasoline cars are sometimes more expensive luxury models. These vehicles don't provide the fuel efficiency achieved by smaller diesel vehicles. However, most gasoline vehicles purchased in Turkey are smaller, less expensive vehicles. The Turkish excise tax structure currently encourages the sale of cars with small turbocharged diesel engines. These engines provide high fuel efficiency, especially in urban driving conditions, as well as providing excellent low-end torque and overall performance. These smaller diesel engines play a strong role in contributing to reducing Turkey's oil consumption and oil import bill. Nonetheless, the global auto industry is producing more efficient gasoline cars and more gasoline hybrid vehicles that also have best-in-class fuel efficiency.

Tax policies that would facilitate the uptake of more efficient gasoline and gasoline hybrid vehicles could cause a higher share of road fuel to be met by gasoline. Combined with improvements in road vehicle efficiency and mode shifts to rail and marine, the expected increase of 7.4 million tons of diesel fuel in the Reference Scenario would be reduced to only 1.0 million tons in the Alternative Scenario. Dependence on LPG imports would decline by almost a quarter but remain significant (Figure 3.38). While new refinery investments could alter these balances, a significant expansion in Turkey's overall crude oil processing capacity is not expected because of the challenging economic fundamentals as articulated above.

Figure 3.38 Product Demand by Scenario vs. Refinery Production in 2019 (million tons)

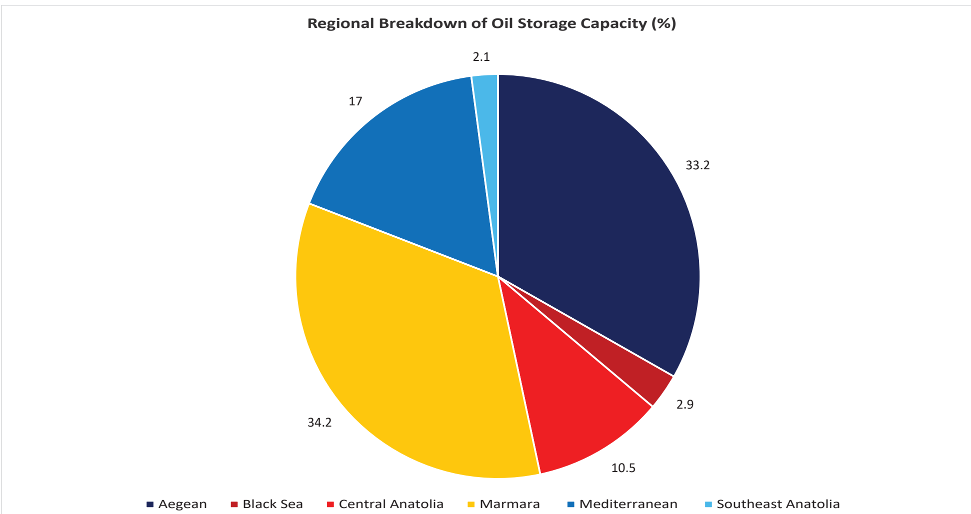


	Petcoke	Fuel Oil	Diesel	Gasoline	LPG	Aviation Fuel
2018 Demand	4.9	0.2	22.8	2.2	4.1	1.2
Refinery Production in 2019	1.2	0.2	13.6	5.3	1.1	6.0
2040 Reference Scenario Demand	6.1	0.1	30.2	5.2	3.4	2.2
2040 Alternative Scenario Demand	4.4	0.1	23.9	5.4	3.1	2.0

3.3.5 Port, Pipeline and Storage Needs

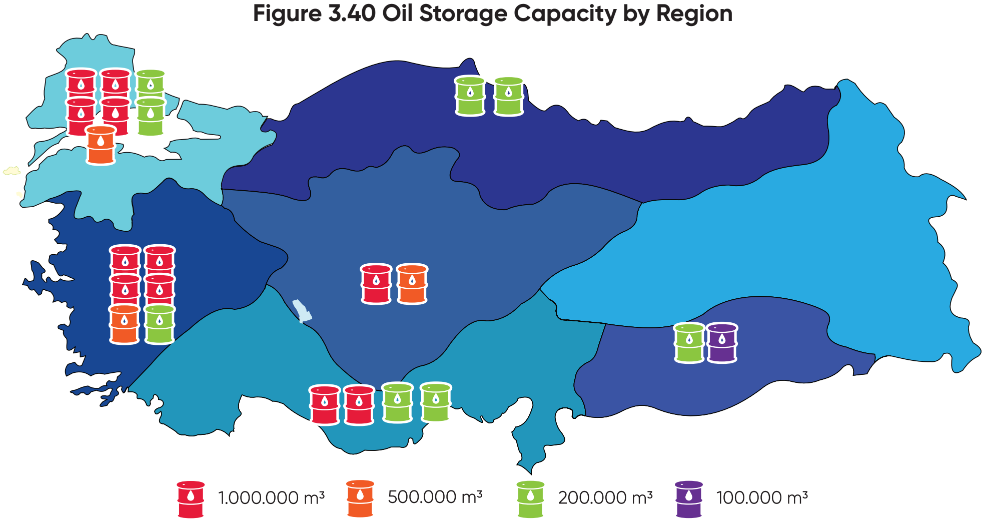
Oil Storage: Storage licenses are held by 95 storage facilities and 5 refineries with a total capacity of 14.4 million m³. Approximately two-thirds of the total is held by refineries. İzmir refinery holds the largest storage capacity of 3.0 million m³. Turkey's storage infrastructure is concentrated in the Western part of the country, with almost two-thirds of total storage capacity located in the Marmara and Aegean regions where the majority of Turkey's refineries and product demand are located (Figure 3.39, 3.40).

Figure 3.39 Regional Breakdown of Oil Storage Capacity (%)



Source: FGE

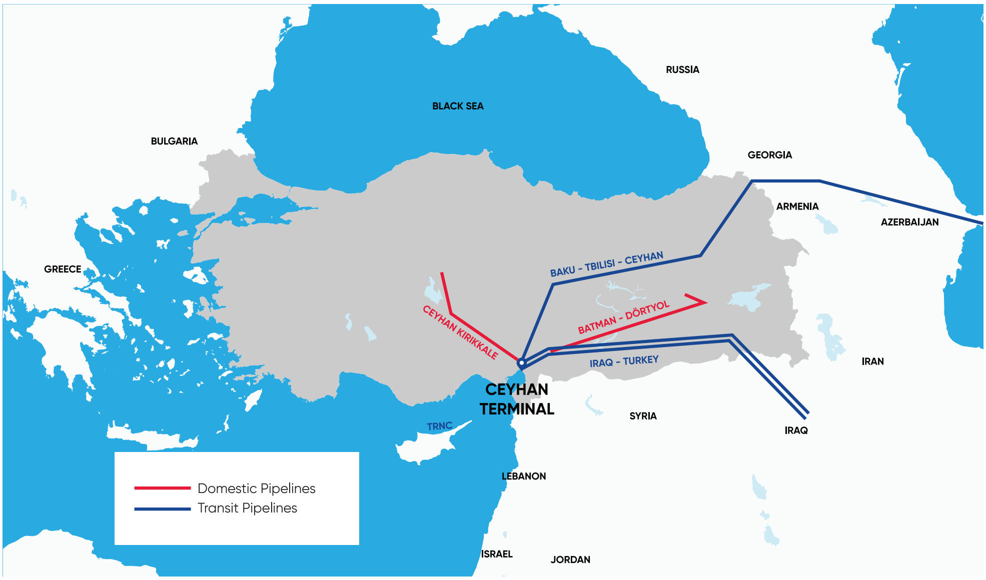
Figure 3.40 Oil Storage Capacity by Region



Source: FGE

Pipelines: Four crude oil pipelines exist in Turkey. Two pipelines carry crude to Turkey's Mediterranean port of Ceyhan, one to the port of Dörtyol (near Ceyhan) and the fourth one carries crude from Ceyhan to the inland Kırıkkale refinery (Figure 3.41).

Figure 3.41 Crude Oil Pipelines



Source: MENR, 2020

The Batman-Dörtyol pipeline carries domestically produced crude from Batman in eastern Turkey to the Mediterranean port of Dörtyol near Ceyhan. The pipeline has a throughput capacity of 70 kb/d. In 2018, roughly 55 kb/d of crude was transported through the pipeline including the volumes delivered to the Batman refinery. The Ceyhan-Kırıkkale pipeline carries crude from Ceyhan to the Kırıkkale refinery. The pipeline has a throughput capacity of 100 kb/d and in 2018 delivered 85 kb/d to the Kırıkkale refinery.

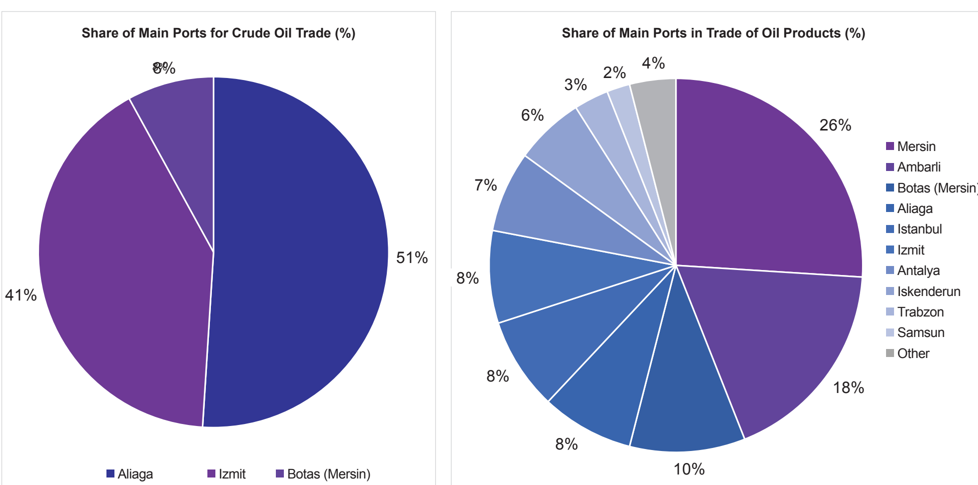
Turkey has two important oil transit pipelines. The Baku-Tbilisi-Ceyhan (BTC) pipeline transports crude from the Sangachal terminal near Baku on the shore of the Caspian Sea, through Azerbaijan, Georgia and Turkey to the Ceyhan terminal at the Turkish Mediterranean coast and has been operational since 2006. The Kirkuk-Ceyhan pipeline carries crude from northern Iraq to Turkey's Mediterranean port of Ceyhan. BTC Pipeline is 1,768 km long (1,076 km of which is within Turkey's border) and carries crude from Azeri-Chirag-Deepwater Gunashli oil field and condensate from the Shah Deniz field. In addition, crude oil from Turkmenistan continues to be delivered through the BTC pipeline. In October 2013, transportation of some volumes from the Tengiz oil field in Kazakhstan also resumed. BTC's throughput capacity is 1.2 mb/d, however, in 2018 throughput averaged roughly 680 kb/d. BP with 30.1% and Azerbaijan BTC with 25% are the pipeline's main stakeholders.

Nine other companies have different shares of the remaining 44.9% and overall 3.36 billion barrels of crude transported so far. The current flow is 600-700 thousand barrels per day including Kazakh and Turkmen crude oil. BOTAŞ International Limited is the operator of the stretch of the BTC pipeline that is in Turkey.

In the Kirkuk-Ceyhan pipeline system, originally two parallel pipelines ran from Kirkuk to Ceyhan with a maximum throughput capacity of 1.5 mb/d. The pipeline suffered severe damage within Iraq's borders and Iraq halted use of its main export route to Ceyhan in 2014 after ISIL forces swept through the region and badly damaged the pipeline. The Iraqi part of the system had been non-operational from March 2014 until November 2018, when the KRG announced that the pipeline had been upgraded and investment in new pumping stations had boosted its capacity to as high as 1 mb/d. With the 2017 arrival of Rosneft, the KRG also secured new oil exploration contracts. Despite these developments, the pipeline flows remain quite limited when compared to its total capacity. BOTAŞ is the owner and the operator of the pipeline that is in Turkey's territory.

Ports: Aliağa, İzmit and Mersin ports are the major spots for crude and petroleum product trade. Ambarlı Port, as one of the largest ports in the Marmara Region, stands as the second-largest spot in petroleum product trade following the Mersin port at the Mediterranean coast (Figure 3.42). There are 8 main ports along Turkey's coastline of 8,000 km that serve the oil market (Figure 3.43).

Figure 3.42 Share of Main Ports for Oil Trade (2018,%)



Source: FGE

Figure 3.43 Main Oil Ports

Source: FGE

Azeri BTC and Prospects for Ceyhan Oil Terminal: While dated Brent is typically used as an oil marker price in the North West Europe (NWE) market, two factors have put pressure on the Brent marker. First, North Sea oil production is declining so very little of the world's oil supply is actually Brent. In addition, there is more U.S. light oil being exported to Europe. This began after the United States lifted its crude oil export ban and continued to grow its tight oil production. Regional refineries are also importing more crude oil from the United States, West Africa, the Middle East and additional light oil sources like Azeri BTC loadings from the Ceyhan port of Turkey. Price assessment agencies have been working on some alternative methodologies to refine the Dated Brent price in order to better reflect actual oil grades being traded.

Increased exports of Azeri BTC to Europe is mainly due to the freight cost advantage and its security of supply. Azeri BTC has been added to the oil basket for the new Dated Brent methodology by one of the leading pricing agencies. This development also marks Ceyhan as a reliable source of crude oil. Ceyhan has become one of the major crude oil loading ports in the region. There are plans to increase the capacity of Ceyhan adding more Kazakh, and potentially Turkmen crude oil into the BTC pipeline. In the meantime, Azeri BTC loadings have increased due to the desirability of this crude grade in European, Asian and North American refineries. It has a cracking refinery gain of 4% and good gasoline and diesel cracking yields, at 27% and 30%, respectively. In addition, Azeri BTC is secure with low-risk production and transportation adding to Azeri BTC/Ceyhan port's positive role in international oil trade.

Figure 3.44 Key Spots for Oil Trade in the Region

Ceyhan would also have additional importance if Kirkuk loading disruptions had not reduced its volume. The future of the Kirkuk-Ceyhan pipeline is crucial for the importance and value-added of Ceyhan. Ceyhan loadings recently represent 2% of global seaborne trade and with increased Kirkuk loadings to Ceyhan, the port could be a reference point for high diesel yield crude grades especially for the European market. With Azeri BTC's rating as a benchmark crude oil, Ceyhan becomes the loading point for two of the highly globally demanded crude grades with an increasing role in regional and global trade (Table 3.7, Figure 3.44.)

Table 3.7 Share of Ceyhan Port Crude Oil Loadings in Total Seaborne Trade

	Total World Seaborne (mb)	Ceyhan Loadings (mb)	Share in Global Seaborne
2018	16,739	332.4	2.0%
2017	14,229	437.7	3.1%
2016	14,895	451.6	3.0%
2015	13,714	453.1	3.3%

3.4 IICEC Policy Recommendations

- **Overview**

The oil story is a transport story as the vast volume of petroleum products are used to fuel transport, particularly the valuable oil products: diesel fuel, gasoline and jet fuel. These are the fuels that refineries are in the business to produce. Everything else is byproducts that most refineries try to avoid and, as discussed above, Turkish refineries are very successful in maximizing the production of these high-value products. While, as discussed above, petroleum products are consumed in other economic sectors besides transport, significant reductions in Turkey's oil consumption require significant changes to Turkey's transport infrastructure and the choices made by Turkey's travelers and shippers. As noted in Chapter 2, there are strong headwinds against any rapid reduction of transport oil use. As a developing country, higher incomes will increase car ownership in Turkey. Against this trend the following changes are needed:

- moving travel to more efficient high occupancy modes, especially rail;
- increasing new vehicle fuel efficiency;
- retiring older inefficient and high polluting vehicles (especially trucks);
- supporting electric vehicles and recharging infrastructure; and
- reforming the urban transportation planning process to conduct data-driven assessments, for each urban area, of the best public transportation investments along with measures to restrain private automobile travel.

As these recommended policies were just discussed in Chapter 2, the remaining recommended oil sector policies aim to complement what's already been presented. In addition to reducing Turkey's overall oil consumption, these policies also aim to reduce the cost of Turkey's petroleum and petroleum product imports, improving Turkey's oil security and strengthening Turkey's economy.

- **Increasing Domestic Oil Production**

Turkey has made significant E&P progress in recent years. Nevertheless, the country is largely unexplored, both in onshore and offshore. The Petroleum Market Law provides important opportunities to increase investments and improve the overall efficiency of the sector. However, certain arrangements would be needed to attract the private sector and foreign capital into the upstream sector at increasing rates. Improvements in the permit and approval processes as well as developments in the information base can offer new opportunities to the market already supported by an attractive tax regime.

TPAO, as the leading actor in the sector, should continue to play a strong role focusing on increasing production and efficiency in existing fields. In line with Turkey's energy localization aspirations, more technology-oriented and innovative methods will be important for increased productivity and sustainability of Turkey's oil economy. Secondary production methods and enhanced oil recovery techniques, similar to global practice, should also be prioritized in line with the targets to improve overall productivity in the oil upstream industry. Supported with global and national technology advances, recent focus on offshore and unconventional plays offer prospects for increasing the share of domestic oil production. Nonetheless, absent highly uncertain major oil discoveries, and especially considering the likely negative economic factors in upstream activities worldwide for some years to come, Turkey should not be relying on increasing its domestic oil supply alone as a reliable pathway to reduced oil import dependence.

- **Seizing Demand Side Opportunities Across Sectors**

Fuel efficiency, fuel switching and use of high occupancy and less energy intensive modes of travel are the most important policies to achieve a more efficient, secure and sustainable energy economy. These policies are more crucial for economies with strong dependence on oil imports like Turkey. Fuel savings measures as defined in the National Energy Efficiency Action Plan can also provide major gains in reducing oil consumption in buildings and industry. In addition, these two sectors have been reducing oil use with gasification and electrification. Energy efficiency will remain important in agriculture which satisfies two-thirds of its energy needs from oil although further electrification measures could also reduce oil use (see Chapter 5, Other Sectors and Fuels).

Improving efficiency and fuel switching in transport is more challenging and will require further policy efforts and technology improvements. All aspects must be emphasized especially achieving better fuel efficiency across all vehicle fleets, greater modal shifts to less oil intensive transport modes, and expanded use of public transportation as was discussed in Chapter 2 (Transport). Lowering the dependence on oil imports depends almost entirely on achieving lowered oil demand growth in the transport sector. This serves critical objectives of the Turkish energy economy including supply security, a lowered energy import bill and improved environmental performance.

- **Developing the Petrochemicals Industry**

Petrochemicals are increasingly becoming one of the main drivers of global oil consumption. With its strategic importance in feeding several economic sectors and other industries, petrochemicals infrastructure is set to remain a key investment theme in many regions. Emerging alternatives in viable feedstock options, currently oversupplied feedstock markets, oil prices and refinery integrations are among the key factors affecting the future of the petrochemicals industry.

Given a growing domestic market and significant trade deficit, petrochemicals stand as a strategic industry for Turkey. This view is reflected in recent industry initiatives to expand Turkey's petrochemical capacities. An effective petrochemical strategy requires enhancing Turkey's poly-based production capabilities. The spreads for naphtha and ethanol formed by Turkey has become an important event. However, increased dependence on naphtha means that it is also open to volatility in oil prices. In shaping future investments, feedstocks other than naphtha can also be considered. For example, the current gas glut regionally and globally can provide opportunities for use of natural gas as a competitive feedstock. In thermoplastics and other value-added products, an incentive mechanism can be activated to reduce Turkey's large trade deficit. Competing with ethane-based crackers in the U.S. and the cheap energy cost in the Middle East is another strategic consideration in expanding the petrochemicals base in a sustainable manner.

- **Improving the Gasoline vs. Diesel Fuel Balance**

Despite the addition of the STAR Refinery with a product slate that matches with current needs of Turkey's domestic oil industry, Turkey remains largely short in diesel fuel. Importing more diesel fuel adds to Turkey's already high oil import bill despite Turkey's exports of excess gasoline production.

Diesel fuel demand is set to grow higher than any other petroleum product in transport absent any strategies allowing for larger shifts to other fuels. Expanding freight shipments will drive diesel fuel consumption but higher diesel fuel consumption can also come from the continued growth of diesel-powered passenger cars. This is encouraged by the relative taxes on diesel fuel and gasoline. Gasoline fuel efficiency is improving as a result of global technological improvements such as lean-burn technologies. Furthermore, hybrid electric vehicles provide excellent fuel efficiency in congested urban environments and these are typically produced, for economic reasons, with a gasoline engine.

Lowering diesel imports and changing Turkey's gasoline-diesel fuel balance back to gasoline would help alleviate Turkey's petroleum product import dependency and reduce Turkey's overall energy import bill. Considering that most commercial vehicles, notably trucks and tractors, will continue to consume diesel fuel, a socially acceptable solution would be around a redesign in fuel and vehicle tax regimes for passenger cars. Special taxation regimes could also be considered specifically to urban private passenger travel and linked to strategies to incentivize efficient public transport and reduce air pollution in densely populated areas.

- **Improving Oil Supply Security**

In an increasingly interconnected global market, no country is immune to oil supply shocks or disruptions. Oil price shocks from supply interruptions would cause a worldwide economic contraction. Decades of relevant research on this topic make clear that oil price spikes cause economic dislocations through relatively well-understood mechanisms (Difiglio, 2014).

It is true that oil's share of the global energy economy has been on a decline and losing ground due to light-duty vehicle saturation in many countries, increasing efficiency and climate change measures as well as the emergence of cleaner alternative fuels for transport. Although oil demand growth may be slowing and then stall over the next decade and we may see a plateau of relatively stable demand within the next two decades, oil consumption will remain as an important economic factor for the foreseeable future. Oil security concerns do not disappear despite projections of lowering oil demand growth (IEA, 2019d).

As discussed above, a sharp increase in oil prices as a result of an oil supply disruption has an adverse effect on all industrial economies not only in the immediate aftermath of the price shock but also well after oil prices have receded. Owing to continued instability in some oil exporting countries and terrorism, underlying oil security concerns could re-emerge if world oil markets return to balance.

The main defense against any large supply shortfall is to quickly release strategic petroleum reserves to fully replace lost oil supplies as quickly as possible to reassure markets. Consequently, maintaining global strategic oil stocks remains a priority. Ensuring and coordinating strategic oil stocks is a major responsibility of the International Energy Agency (IEA). Turkey has established a stockholding regime as an IEA Member country. Turkey should continue to strongly support the IEA's activities in this regard and be skeptical of any proposals to reduce strategic oil stocks in light of today's oversupplied oil market. Considering Turkey's reliance not only on imported crude oil but also imported diesel fuel, substituting a share of the crude oil stocks with petroleum products would add further improvements to Turkey's oil security.

Advancing the midstream infrastructure in line with a growing oil economy is another key consideration for Turkey to provide a more secure and sustainable outlook for the oil sector. Although Turkey has achieved a diversified oil import portfolio over the decades, it is largely reliant on a few choke points. Therefore, further diversification including source regions and the trade routes would contribute to improved oil and broader energy security in a dynamic global oil market economy.

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CHAPTER 4:
NATURAL GAS

Summary

- Natural gas represents about 30% of Turkey's total primary energy supplies and 23% of final energy demand. Consumption of natural gas tripled in the past two decades. This growth increased the share of natural gas in Turkey's final energy demand from 7% to over 20% during the same period, reflecting increased gas use in all key sectors. The share of natural gas is now second only to oil (driving transport demand) and greater than electricity (20%), coal (12%) and renewables (8%).
- Turkey currently supplies 99% of its natural gas needs from imports but the recent gas finding in the Black Sea (with 405 bcm OGIP) will alter this balance with prospects for plausible new additions to the resource base in the coming years. IICEC estimates that at least 10 bcm/yr. annual production will result from the Tuna-1 location (a conservative estimate based on current information).
- Further discoveries in these geologically attractive Black Sea areas, backed by ongoing efforts and supported by expanded drilling, that may include an expansion of the current drillship fleet, can increase the resource base and potential gas production that can be realized.
- In the Alternative Scenario, around half of total annual demand in 2040 is met by domestic production compared to 25% in the Reference Scenario and only 1 % in 2019. These assumptions are developed, in particular, to reflect the impact of the most recent findings and the opportunities to lower Turkey's energy import bill with the more-than-worthwhile efforts to find additional large fields.
- It is well possible that major discoveries in other areas, besides the Black Sea, for example in the Eastern Mediterranean, could further decrease Turkey's reliance on natural gas imports. Enhancing domestic production will require sustained technology oriented investments in the offshore and extending into unconventional plays and coal-bed-methane (CBM).
- Turkey's security of gas supply has improved with enhanced network flexibility including more LNG, storage and pipeline withdrawal capacities, a strongly diversified range of suppliers especially with increasing LNG volumes, and having high LNG import capacities to deal with any disruptions in supply. With only modest growth in the consumption of natural gas projected for the next two decades (61.5 bcm/yr. in the Reference Scenario and 55.0 bcm/yr. in the Alternative Scenario compared to 45.2 bcm/yr. in 2019), natural gas security is set to remain strong.
- These positive structural changes go hand in hand with the current dynamics in the global gas market: rising supplies of LNG, increased emphasis on short-term and spot supplies, and contract pricing based on gas-to-gas competition. Use of long-term fixed contracts with destination clauses and other flexibility impediments has declined.

- Turkey is already a key player in the new global LNG market. LNG now meets one-third of Turkey's demand, and spot LNG, a substantial share of this, is contributing to supply flexibility.
- Unlike the oil sector, where the emphasis is on using less oil (Chapter 3), the use of gas is encouraged since gas is a healthier and lower GHG-emitting fuel than the fuels it is replacing (coal and oil) apart from in the power sector, where IICEC's Alternative Policy Scenario projects a significant decrease in gas use as a result of high renewables dispatch, increased nuclear generation and lower demand growth from increased efficiency.
- The IICEC Alternative Scenario shows more residential and commercial energy needs being served by natural gas than in its Reference Scenario (43% of building energy demand). Natural gas increases its share in meeting industrial energy demand from 30% in 2019 to 35% in 2040 in the Alternative Scenario (Chapter 5). Contribution of natural gas to total final energy demand grows from 23% in 2019 to 24% in the Reference Scenario and 28% in the Alternative Scenario by 2040.
- A substantial share of Turkey's long term import contracts signed in the 1990s and 2000s are approaching their termination dates between 2020 and 2022. Such contracts account for 15.9 bcm/yr. (or about one-third of Turkey's supplies). Renegotiating these contracts on better terms and letting some of them expire entirely could have a favorable impact on Turkey's trade balance by lowering average gas import costs.
- Such renegotiations would be in line with global trends where consumers are achieving more favorable terms on gas contracts for shorter time periods and also relying more on spot gas, taking advantage of an over-supplied world gas market. With only modest gas demand growth out to 2040 (under IICEC's Alternative Scenario), there is an important window of opportunity for Turkey to enjoy more flexible and competitive supplies reflecting gas-to-gas pricing towards that other markets have gravitated towards.
- Turkey has taken the regulatory steps to establish an organized natural gas trading platform including day-ahead, intra-day and weekly components. A futures market with physical deliveries is in preparation to become operational in late 2021. These markets, with a diverse set of products, can transform the Turkish natural gas market into a more competitive structure that is essential for a more efficient and broader energy economy.
- These developments also provide an opportunity to have the private sector play a greater role as a counterparty to natural gas import contracts if it can rely on cost-reflective pricing in Turkey's wholesale and retail markets.
- Similar to the experience in the European market, Turkish gas prices would become more closely linked to European hub pricing and, as the Turkish trading hub evolved, would gravitate to the Turkish hub price. More liquid spot and futures markets, under the OTSP, would serve as a platform to divert supply volumes directly to a well-functioning and competitive market.

4.1 Global Developments

Natural gas is a dynamic fuel playing a more significant role in recent years as a widely used and traded energy commodity. It is indeed the only fossil fuel whose share of the energy mix is estimated to rise over the coming decades according to several projections. This progress has reflected expanded access among producers and consumers, especially because of the growth of LNG trade, as well as more competitive gas pricing and less restrictive gas contracts. Natural gas offers ready environmental benefits when used *in lieu* of other hydrocarbon fuels as it burns much more cleanly and the capital equipment for using gas, for example in the power sector, is relatively inexpensive. The EU has reformed its energy regulations to make European gas trade more competitive and also, by emphasizing competition, putting consumers on a more level playing field with suppliers (IICEC, 2019). In the power sector, natural gas can complement intermittent renewable energy as natural gas plants, having relatively low capital costs and flexible operating parameters, can most easily operate in a load-following mode and potentially be economically viable with low capacity factors. For use in residential, commercial and public buildings, natural gas provides substantial environmental and cost advantages over coal and oil and can be an important way to reduce the health consequences of providing heat and cooking in many parts of the world. World gas reserves are abundant and are not expected to limit the growth potential that natural gas can have in the world's energy economy after renewable energy.

4.1.1 Demand Drivers and Trends

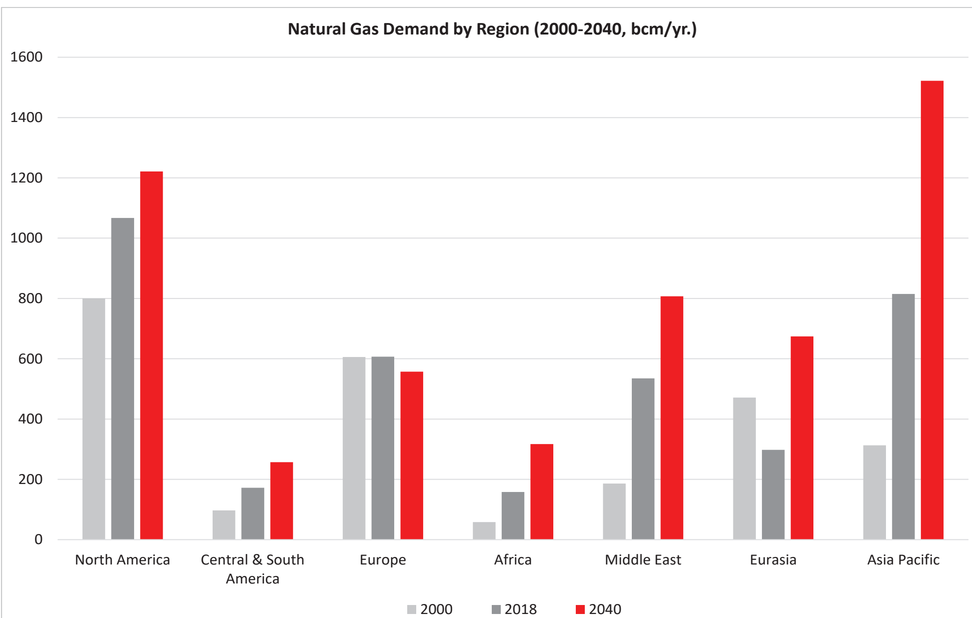
Global gas consumption increased from 2.5 trillion cubic meters per year (tcm/yr.) in 2000 to 4.0 tcm/yr. by the end of 2018 (a 56% increase). This increase accounted for half the total growth in global primary energy demand during the same period (IEA, 2019a). Since 2000, about 80% of the gas demand growth has been realized in North America, Europe, Asia Pacific and the Middle East (Figure 4.1). With large unconventional domestic resources to supplement its declining production of conventional gas, the United States is the world's largest natural gas producer and is the world's largest consumer at 879 bcm/yr. (EIA, 2020a). Natural gas offered a quick and cost effective option to shut down U.S. coal plants with high greenhouse gas and other emissions. While not offering the very low reductions of renewable energy, natural gas was readily welcomed as a "transition fuel" in the fight against GHG emissions.

European gas demand, after many years of strong growth, is now reaching a saturation level. Gas consumption in Europe is predicted to decline to 557 bcm/yr. in 2040 from 607 bcm/yr. in 2018 (Figure 4.1). Improved energy efficiency measures, declining cost of and increasing use of renewables, and the economic pressure on gas-fired generators are among the major reasons for softening gas demand growth. However, despite the projected slowdown in future gas demand, the role of natural gas in Europe's energy economy was expected to remain strong with a well-integrated gas market structure, a diversified LNG market, and good storage infrastructure (IEA, 2019a). However, the European Green Deal, announced by the European Commission in December 2019 might change this picture.

It confirms the bloc's target for climate neutrality by 2050. In addition, its energy system integration strategy, unveiled in July 2020, aims to progressively replace natural gas with renewable gases such as biogases or hydrogen allowing only some diminished long-term role for natural gas.

In Africa, demand for natural gas is on the rise, as it is for all other fuels, stimulated mainly by economic growth, growing population, electrification, and development of the large-scale gas resources discovered over the last decade. Although the majority of production is exported, increased investments in domestic infrastructure have fueled demand across industries as well as for household cooking. Gas demand is anticipated to double by 2040, increasing from 158 bcm/yr. in 2018 to 317 bcm/yr. (Figure 4.1).

Figure 4.1 Natural Gas Demand by Region, (2000-2040, bcm/yr.)



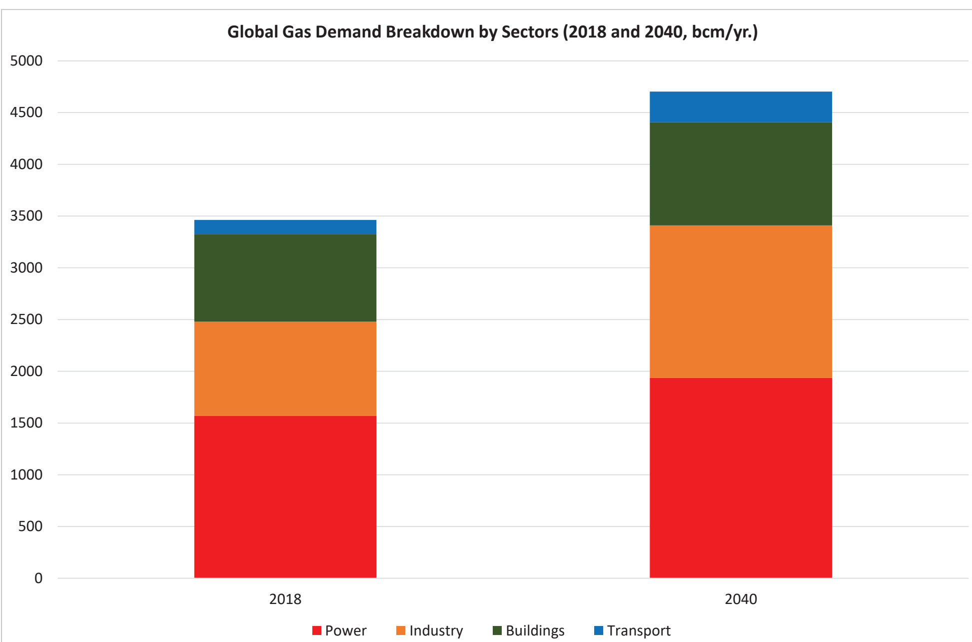
Source: IEA, 2019

China can be expected to increase its future gas consumption due to economic growth and a policy agenda to reduce residential and industrial coal use. Substituting gas for coal will be a strong tool in China's drive to improve its poor air quality in many parts of the country. The share of natural gas in its total energy supply remains low compared to other advanced energy economies and accounts for only 13%. Gas meets 7% of total industrial energy demand and 12% of residential heating demand. China's natural gas demand is expected to more than double over the next two decades, growing from 282 bcm/yr. in 2018 to 655 bcm/yr. in 2040. This would be more than the rest of developing Asia's combined growth (IEA, 2019a).

India is another growing energy economy but the prospects for natural gas demand remain limited compared to other Asian countries. Projected growth in electricity demand is expected to be met by use of a combination of renewables and coal, while natural gas is largely confined to a balancing power role. Due to supply constraints, affordability issues and insufficient infrastructure, India's demand for gas remains low compared to its total energy use. Nevertheless, Indian gas consumption is expected to triple by 2040 reaching 200 bcm/yr. mainly driven by cooking, water heating and CNG for transport. Overall, in Southeast Asia, despite the expected growth of coal and renewables, natural gas consumption is anticipated to grow from 163 bcm/yr. in 2018 to 295 bcm/yr. by 2040. Because of strong energy demand growth, Southeast Asia would switch from a net exporter to a net importer of natural gas by 2040 (IEA, 2019a).

Globally, while the growth of gas is not expected to replicate its growth during the last two decades, it, nonetheless, is projected to grow by 1.4%/yr. from 2018 up to 2040 and increase to 5.4 tcm/yr. (IEA, 2019a). Gas is increasingly used in various industrial sectors such as steel, petrochemicals, textiles, food processing, glass and ceramics. Gas demand by industry accounts for 62% of global projected growth until 2040 (Figure 4.2). Most of this development will be realized in developing and industrializing economies, mainly India, China and the Middle East.

Figure 4.2 Global Gas Demand Breakdown by Sectors (2018-2040, bcm/yr.)



Source: IEA, 2019

Demand for power generation from natural gas differs among regions. Globally, it is expected to increase from 1.6 tcm/yr. (2018) to 1.9 tcm/yr. (2040), a 23% increase (Figure 4.2). Natural gas plants become the second fastest growing power technology, after renewable power plants, and will increase the gas share of power generation from fossil fuels from 35% in 2018 to 45% in 2040. In addition, power plant efficiency improvements would decrease fuel use per kWh by 11% in 2040 compared to current plants (IEA, 2019a).

The power sector has been the main field for rivalry between coal and gas. Using already existing power infrastructures to afford the same energy services with lower emissions has mainly been possible by switching from coal to gas. Since 2010, it is estimated that 500 million tons of CO_2 emissions have been prevented owing to coal to gas switching and two-thirds of these emission savings have been realized in the power sector. In comparison to oil combustion natural gas results in 20% less CO_2 emission and 40% less CO_2 emission than coal for each unit of energy output. The United States has achieved the largest CO_2 savings from the coal to gas switch, motivated as much by economics as the country's climate policies. The rise of shale gas has decreased natural gas prices, making electricity produced from natural gas the least expensive power in the United States along with wind power in States that have good wind regimes.

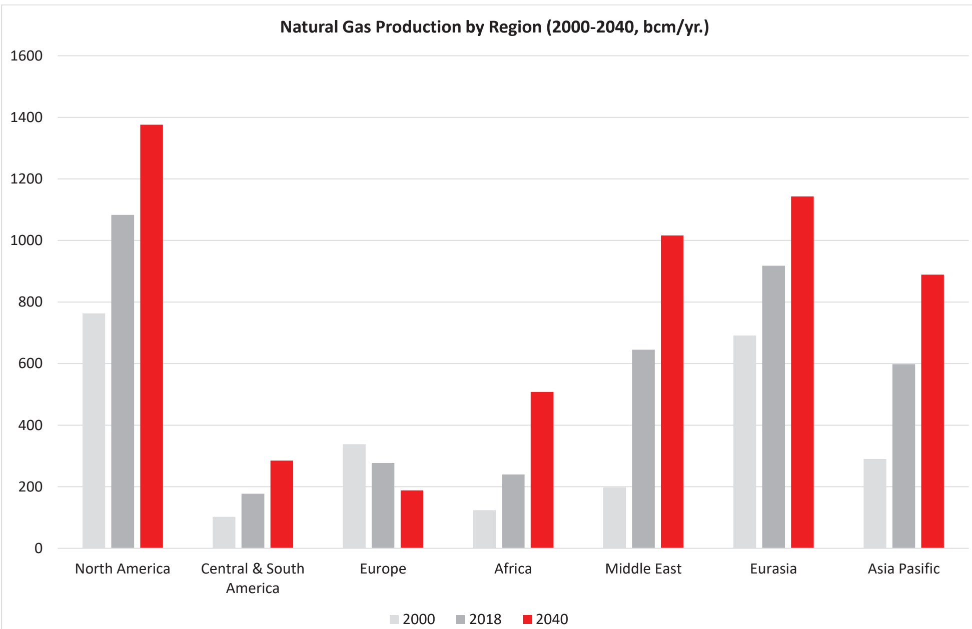
Both Europe and Japan are expected to experience a peak in gas use for power generation before the mid-2020s. In Europe, the gap left by diminishing nuclear and coal capacity is expected to be filled largely by enhanced gas use. However, as renewables continue to grow, gas demand growth is anticipated to slow down. In Japan, the return to service of nuclear plants and utilization of increased renewable capacity will slow Japanese gas consumption. Natural gas will have a more difficult time challenging coal in China or India. Its share in power generation is expected to remain flat at 10% until 2040, absent the unexpected availability of inexpensive gas (IEA, 2019a).

Building energy services accounted for 846 bcm/yr. gas demand in 2018 (22% of total global gas demand). Natural gas is increasingly used as a heating fuel. 18% of the net increase in natural gas demand until 2040 is expected in the building sector, requiring an additional 152 bcm/yr. of gas by 2040 (Figure 4.2). Demand in transport is expected to increase from 140 bcm/yr. in 2018 to 300 bcm/yr. by 2040. This is stimulated mainly by increased use of CNG for road travel in India, China and the Middle East. LNG use will also be on the uptake in marine shipping stimulated somewhat by recent IMO regulations limiting use of high-sulfur fuel oil. Despite these gains, natural gas will not be a major global transport fuel in a sector dominated by petroleum fuels and, in the longer run, electrification. Other gas users include other energy conversion and transportation industries such as refineries and pipeline operations.

4.1.2 Production

Global gas production increased from 2.5 tcm/yr. in 2000 to 4.0 tcm/yr. in 2019 and is expected to reach 5.4 tcm/yr. by 2040, more than doubling in forty years. New technologies to produce gas reserves that were previously not economically recoverable, technological advancements in deep offshore production and investments in mid-stream and downstream infrastructure have enabled this recent surge of world-wide natural gas production (IEA, 2019a) (BP, 2020). North America is projected to have the leading share in natural gas production growth, accounting for 31% of forecasted global production growth to 2040. In several other regions including Russia, Caspian, Middle East, Asia Pacific, Africa, and Central-South America, production growth is also anticipated to continue. Europe is the only region where gas production is forecast to decline up to 2040 (Figure 4.3) (IEA, 2019a).

Figure 4.3 Natural Gas Production by Region (2000-2040, bcm/yr.)



Source: IEA, 2019

The United States is the world's largest producer of natural gas, with 920 bcm/yr. in 2019. (BP, 2020) or 23.1% of global gas production and by 2025 is projected to become the second-largest gas exporter after Russia. U.S. production depends on shale gas as U.S. natural gas production had been in a declining phase before tight gas production technology was commercialized. As mentioned above, major regasification investments were being made just prior to the commercialization of shale gas technology in anticipation that the U.S. would need significant LNG imports. Continued growth of U.S. gas production can readily draw on the Marcellus and Utica shale plays, each holding 40% of the country's total shale gas resources. Recently, these two plays were growing by 200 bcm/yr. By 2040, U.S. gas production was expected to reach 1.1 tcm/yr., a 30% increase from recent levels contributing to North American production reaching 1.4 tcm/yr. (Figure 4.3). Of course, with all projections made prior to the Covid-19 pandemic, even out to 2040, they might require downward adjustment to reflect current low prices and deferments of investments.

Russia is the second-largest natural gas producer with output of 679 bcm in 2019 (17% of the global total). Russia is also the world's largest gas exporter. LNG exports have increased with the Yamal and Arctic LNG projects while production growth in Eastern Siberia feeds pipeline exports to China via the Power of Siberia pipeline. By 2040, gas production is anticipated to increase to 853 bcm/yr., or 20% above current levels (IEA, 2019a) (BP, 2020).

Europe is in a declining phase of natural gas production, notably because of the termination of production at the Netherlands Groningen field. Norwegian North Sea production also faces a decline by 21% from a high of 121 bcm in 2018 to 95 bcm in 2040. Continued declines are expected, by 35% out to 2040, reducing recent production of 250 bcm/yr. to less than 190 bcm/yr. by 2040 (Figure 4.3).

African natural gas production is expected to increase from 236 bcm/yr. in 2018 to 508 bcm/yr. in 2040 (Figure 4.3). This growth will be mainly driven by exports rather than local demand as African gas exporters aim to increase their share of the LNG market. It is expected that African exports will increase by 40% from 2025 to 2040 (IEA, 2019a) (BP, 2020).

Australia is experiencing a decline in gas production in some of its mature basins, causing some near-term challenges in preserving supplies for both domestic consumption growth and LNG exports. Natural gas production of 118 bcm in 2018 is estimated to increase to 199 bcm in 2040. The projected growth in gas production significantly relies upon further investments supported by federal hydrocarbon policies.

4.1.3 Global Gas Market, Trade and Pricing

Natural gas trading has become much more competitive in recent years as a result of several factors, including increasing volumes of LNG traded outside of long-term contracts free from destination clauses – either on the spot market or through contracts lasting two year or less - and the investments made in consuming countries in regasification terminals. In addition, the enthusiasm to compete in the LNG export business, especially after the Fukushima nuclear accident (2011) and the resultant surge in Asian LNG prices, has led supply to become ample, but worldwide economic conditions have not been as accommodating as might have been hoped. Consequently, the market had shifted into a period of oversupply even before the Covid-19 pandemic. In addition to changing fundamentals favoring consumers, regulatory changes, especially in Europe have caused a decline in certain anti-competitive practices, the most important of which has been the banning of the destination clause. The destination clause restricts a natural gas customer from re-exporting the gas it receives from a supplier ensuring that this gas cannot go back into the market to compete against additional exports from that supplier. There is no economic rationale for this practice and it obviously produces a sub-optimal allocation of economic resources. In addition to European Commission legal requirements, the destination clause suffered a major blow in the LNG market when U.S. LNG contracts were offered without the destination clause. One reason for this was that U.S. LNG exporters were selling a liquefaction service, and were not concerned, as national entities would be, to sell their country's natural gas. U.S. LNG exporters simply purchased gas on behalf of their LNG customers charging them Henry Hub prices plus a commission.

Global LNG trade has grown because of a rapid expansion of export capacities, heavily in North America and Australia, and a diversification of supply sources. The share of LNG in global gas trade increased from 31% in 2008 to 45% by 2019, more than doubling in trade volumes. In 2019, global LNG imports reached 485 bcm, with an annual increase of 54 bcm, the strongest growth rate experienced since 2010 (Figure 4.4). In 2019, 21 countries exported LNG and 42 countries imported LNG. Over the last decade alone, the number of companies receiving regasified LNG has surged from 40 to 100. In the last two years, an additional 15 new LNG buyers have emerged as a reflection of the increasing supply, lower cost and accessibility of LNG (GIIGNL, 2020).

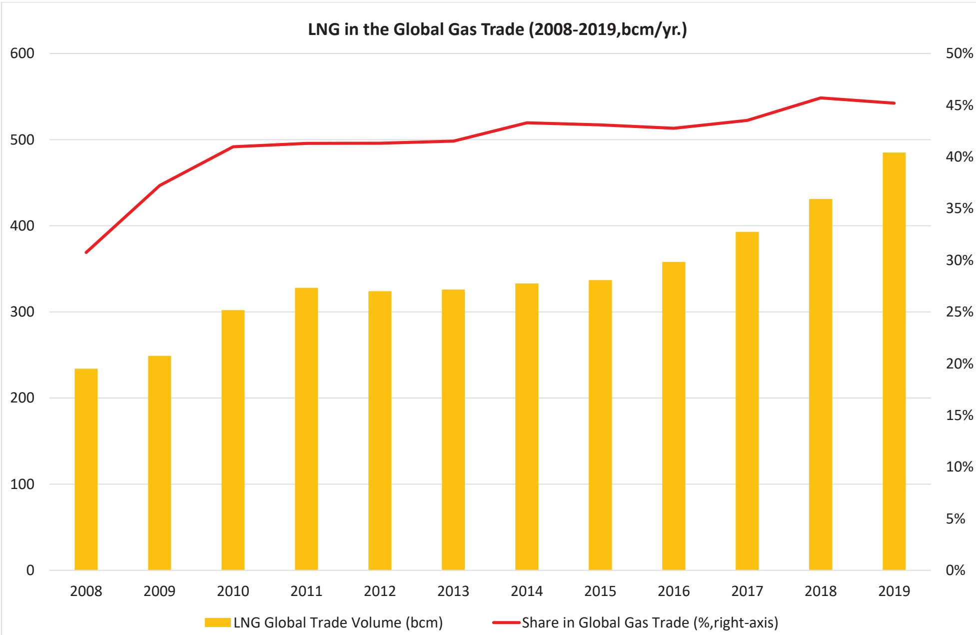
Asian LNG imports increased by 3.2% in 2019 to 335 bcm. There has been a decline in imports among the traditional LNG importers, namely Japan, South Korea and Taiwan. For instance, LNG imports declined in Japan by 6.8% in 2019 compared to the previous year but Japan is still the leading importing country with a 22% global market share (105 bcm/yr.) (IGU, 2020). Japanese LNG import trends are highly dependent on their schedule for putting their nuclear reactor fleet back online.

All LNG importing countries in Europe increased imports in 2019. The growth in net LNG imports reached 120 bcm with an increase of 48 bcm in 2019. The largest three importers that year were France (23 bcm), Spain (22 bcm) and the United Kingdom (18 bcm) (EU Commission, 2019).

Qatar managed to remain the top LNG exporter, with 22% of global exports, at 106 bcm in 2019. Qatar was followed by Australia with an annual increase of 13%, exporting 103 bcm in 2019. The United States added 18 bcm in 2019 to reach 47.5 bcm becoming the third largest LNG exporter. Russia is now the fourth leading exporter of LNG with 40 bcm/yr. after both Yamal LNG and Vysotsk LNG became operational (IGU, 2020). Algeria managed to recover some of its export decline in 2018. Egypt added 3 bcm more exports in 2019, as offshore production ramped up (EU Commission, 2019).

In an increasingly more crowded marketplace, LNG contracts are becoming more diverse and the terms of gas trade between buyers and sellers are also changing. The combination of a growing spot market with more destination flexibility is accelerating as the market opens to new buyers including portfolio traders. The growth of destination-flexible, hub-priced LNG exports with newly emerging LNG exporter countries have facilitated a change towards a more liquid and integrated global gas market and enabled short-term optimization of LNG volumes based on supply and demand prospects and arbitrage opportunities. Within the next decade, 50% of all existing LNG contracts, accounting for 200 bcm/yr. of LNG, are due to expire (IGU, 2019). With buyers being in a much stronger position than they were in previous contract negotiations, buyers are likely to want more competitive pricing terms (indexing prices to relevant gas hubs), will want shorter-term contracts than before and will probably refuse to sign contracts with destination clauses, absent compensating concessions on the part of the supplier.

Figure 4.4 LNG in the Global Gas Trade (2008-2019, bcm/yr.)[31]



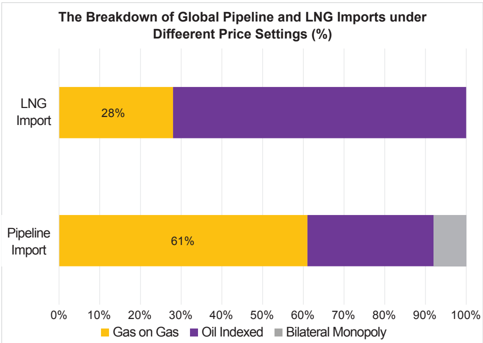
Source: BP, 2020

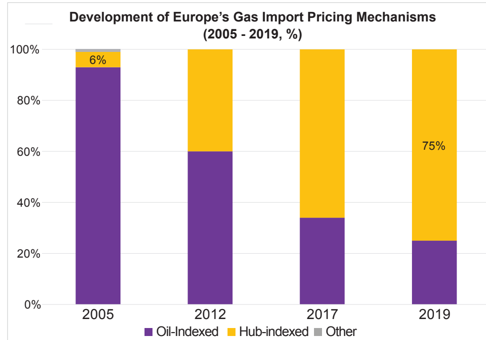
Pipeline and LNG trading contract settings are divided in three categories, namely oil indexation, where price is linked to crude oil or oil products, gas-on-gas competition (hub pricing), and bilateral monopoly agreements. Long-term oil-indexed pricing dates back to the 1960s and is still used as a pricing method in many regions. However, its use is declining and it represented 31% of all pipeline imports and 72% of all LNG imports in 2018. Gas-on-gas accounts for the majority of all pipeline imports (61%). The bilateral monopoly[32] , where price terms are determined by bilateral agreements between a large seller and a large buyer, had the balance of 8%, accounting for 59 bcm in 2018. The European gas imports have showed a remarkable evolution towards hub-indexation over the past decade. (Figure 4.5) (IGU, 2019; IEA, 2020a).

[31] Please note that bcm/yr. figures are not exactly comparable among different data sources, for example, among BP, the IEA and Turkish data as the assumed kcal of natural gas per cubic meter are slightly different.

[32] The price is determined by bilateral discussions and agreements between a large seller and a large buyer, with the price being fixed for a period of time. There may be a written contract in place but often the arrangement is at the government or state owned company level.

Figure 4.5 The Breakdown of Global and European Pipeline and LNG Imports under Different Price Settings (%)





Source: IGU, 2019; IEA, 2020

With hub pricing becoming more prevalent in an increasingly oversupplied market, the history and progress towards hub pricing has been uneven. While the U.S. market has always been based on hub pricing, the European gas market has had both oil indexed and gas-on-gas competition contracts. However, Europe is one of the regions where the most significant changes in price formation mechanisms have taken place. There has been a broadly continuous move from oil indexation to gas-on-gas price structures. From 2005 to 2019, the share of gas-on-gas based contracts in Europe increased from 6% to 75%. Oil indexation only represents 24% of gas trade in 2018 (IGU, 2019). The Asian market used to be dominated by oil-linked contracts but started to realize the benefits of short term spot markets and is also moving its contracts towards hub-linked prices.

Another significant trend is a move towards spot trading and trading on a shorter term basis compared to legacy contracts of twenty or thirty years. These are being replaced by short term contracts and many buyers are less reliant on having contracts due to the emergence of a liquid spot market for gas. Of course, contracts do provide insurance against unforeseen disruptions that could risk natural gas supply security so there is likely to be a continued role for natural gas contracts but they will tend to be of shorter duration, have hub-linked prices and not have anti-competitive features such as destination clauses.

By the end of 2019, 34% of global LNG volumes were traded on a spot or on a short-term basis. The expansion of spot LNG was mainly enforced by the ramp-up of flexible volumes from the United States and Australia. The United States has become the number one provider of flexible LNG supply with 20% of the spot and short-term volumes, followed by Australia and Qatar with 17% and 5% of global market shares, respectively (GIIGNL, 2020). However, spot gas prices declined to record lows in 2019 and have decreased further on the back of ample LNG supplies with the significant demand destruction caused by the Covid-19 pandemic. The LNG industry faces an economic struggle, along with many others, as it will be hamstrung by sluggish demand and poor economic growth until broader economic problems are addressed. Even when the industrialized world emerges from the restrictions required to defeat the Covid-19 pandemic, the lingering economic consequences on the developing world may last longer. For LNG suppliers, this would be of concern as this is the market where its future demand growth lies.

While, as noted above, there has been a trend away from destination clauses, the majority of conventional long-term LNG contracts still contain them. Under destination clauses, gas buyers are restrained from reselling LNG cargoes outside of a designated market. Therefore, the destination clauses confine importers from reselling gas once purchased and cargoes cannot be diverted to higher-priced markets. The restriction of the destination clause becomes transparently uneconomic and disruptive in LNG trade due to the nature of LNG transport. It is expensive to liquefy natural gas and regasify LNG. If, under contract, a buyer is due to receive a cargo of LNG it does not need, it is of obvious net global economic benefit to divert the tanker to a destination that wants the cargo while it en route. This prevents the costs of liquefaction and regasification from being wasted. For gas imported from pipelines, the impact of destination clauses become less restrictive especially if that gas moves into a gas supply system that is served by multiple suppliers making the effective enforcement of the destination clause more difficult since the molecules of CH_4 do not carry flags of national origin with them as they traverse through a common storage and distribution network. Nonetheless, pipeline contracts have also begun to move away from containing destination clauses. Destination clauses in pipeline and LNG contracts are also on the decline because of legal prohibitions that have been established in the EU and certain countries (EU Commission, 2017).

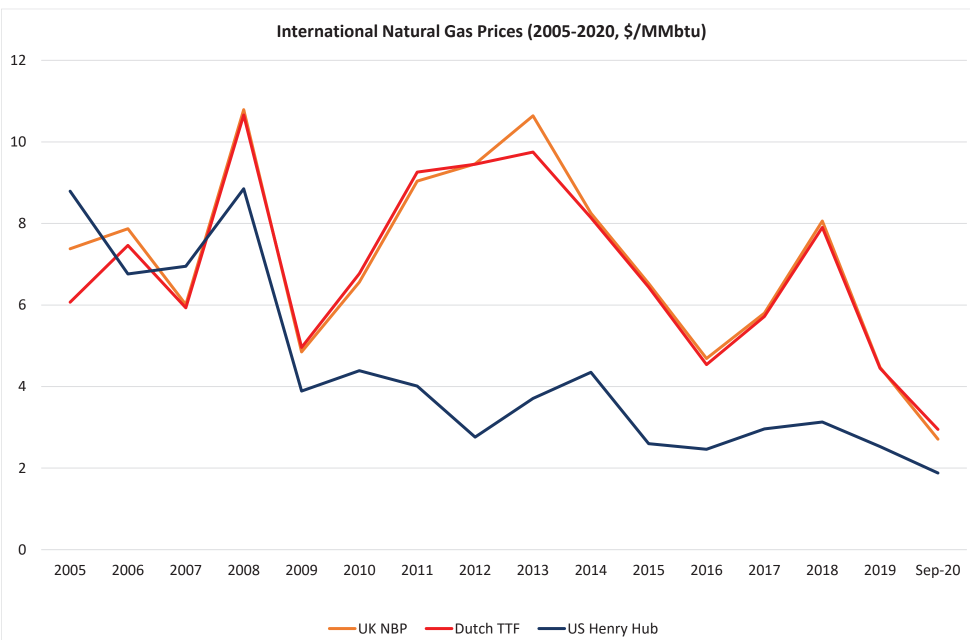
As spot gas pricing expands worldwide, gas-on-gas priced trading volumes have gained. The commodity markets where these price discoveries occur attract trading among a wide range of participants including industrial users, utility companies, power generators, LNG suppliers and oil and gas producers. However, the most important participants in these markets are the non-commercial traders, who include speculators, as they provide the liquidity necessary to avoid price volatility that would occur if trades were only being transacted by commercial traders in behalf of parties or by parties that want to actually supply gas or take physical delivery of gas.[33] In Europe, at the Dutch Title Transfer Facility (TTF) and the United Kingdom National Balancing Point (UK NBP), market participants have been trading a variety of spot gas products. In particular, the increase in traded volumes at the Dutch TTF has been noteworthy, with a great rise in activity since 2014 and the hub now accounting for 67% of the total hub traded volumes in the EU in 2019 (OIES, 2019 & 2020). The TTF has become a mature risk management hub not only for the Netherlands but also for all of Europe. The TTF is, by far, the most liquid, most traded hub, with the greatest number of participants among all the European traded gas hubs.

[33] Banks and trading companies do not exclusively engage in trades to hedge commercial transactions or to speculate on the future movement of commodity prices in behalf of their clients. Consequently, an individual trader does not always engage in commercial or non-commercial trading. The point remains, however, that there are not enough transactions whose purpose is to hedge actual gas sales or purchases to have a well-functioning commodity exchange without the much larger number of counterparties that, among other things, are alert to the opportunity to make profits by buying when prices appear to drop below market or selling when they appear to be higher. This liquidity (the large number of counterparties) does not guarantee price stability, especially when fundamentals abruptly change, but without it, prices would be much more volatile.

Global gas prices had declined significantly through 2019 because of a global gas supply glut, market flexibility benefits and mild winter conditions. In addition to the impacts of these, as noted above, a large hit to global gas prices started to occur from the first quarter of 2020 due to the widespread international response related to the Covid-19 pandemic. As a result of this weak demand and nearly collapsing export orders, gas prices at global hubs have hit a 3-year-low.

The U.S. Henry Hub has been acting as the major apparatus for gas-on-gas pricing since its establishment as a trading hub in 1990 and has become a benchmark as a global gas price reference and as a model for a physical and financial gas hub. Henry Hub front-month prices averaged $2.66 per MMBtu in 2019 and declined to $1.88 per MMBtu in September 2020. Spot prices at the Dutch TTF fell to their ten-year low in 2019. The Dutch TTF's front-month averaged $4.98/MMBtu in 2019 and declined to as low as $2.95/MMBtu in September 2020 as a result of the impact of the Covid-19 outbreak (Figure 4.6). The UK NBP spot price dropped by 23% on a year-on-year basis in 2019. The NBP front-month contract average hit its lowest level in 10 years, $3.15/MMBtu in 2019 and dropped further to $2.71/MMBtu in September 2020.

Figure 4.6 International Natural Gas Prices (2005-2020, $/MMBtu)



Source: EIA, 2020; BP, 2020

A two-decade-long robust global expansion for natural gas trade has come to a halt as coronavirus outbreaks put a brake on the global gas business. The losses these have all caused go well beyond the Middle East, Europe, America and Asia Pacific, damaging gas trading from Australia to the U.S. Given that the magnitude of impact remains unprecedented, this would likely become the largest recorded annual decline in the natural gas industry. The loss in residential and commercial consumption and decline in gas-fired power generation with lower power demand and increasing share of renewables have all weighed on natural gas consumption. Gas consumption is anticipated to diminish in every sector and region of the world through 2020. Global gas demand is likely to drop as much as 150 bcm in 2020, a 4% reduction compared to 2019. 60% of the drop is expected in power generation and other energy conversion sectors. 20% of the global gas demand decline is projected in the residential and commercial sectors and another 20% decline is expected in the industrial sector (IEA, 2020b).

Supply chains are being interrupted during the pandemic and have caused work force shortages and delayed construction of approved projects in gas exporting countries. Investment decisions have been either postponed or canceled in countries such as Australia, Mozambique and the United States. As noted for the oil market in Chapter 3, where the demand destruction of Covid-19 has caused similar economic havoc to the industry, construction delays and decline in final investment decisions could be a challenge once demand starts to recover. However, the capacity increase as a result of continuous investments over the past few years combined with the impact of slower gas demand growth post-2020 is anticipated to limit the risk of a tighter LNG market until the mid-2020s. The utilization rate of liquefaction facilities is expected to lower to 90% from over 95% in 2019 and remain at about that level through 2025 (IEA, 2020b).

4.2 Turkey's Natural Gas Policies

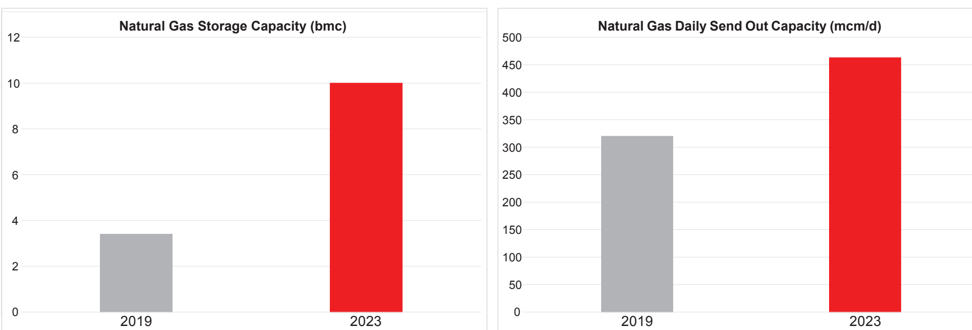
The key policy documents considered in the TEO include the 11th Development Plan issued by the Presidency of Turkey in July 2019 and the Strategic Plans of the Ministry of Energy and Natural Resources. Each of these documents focuses on plans and goals towards 2023. The National Energy Efficiency Action Plan also defines strategies for a more efficient natural gas sector. TEO scenarios also take into consideration key legislation in place or under consideration.

Due to high dependence on imports (99%) to satisfy Turkey's natural gas demand, enhancing supply security with route and source diversification has been the main policy priority for the natural gas sector. By 2023, Turkey targets an increase of its current underground storage capacity from 3.4 bcm to 10 bcm and its send-out capacity from 313 million m^3/day (mcm/d) in 2019 to 463 mcm/d with expansions of existing storage, new FSRU investments and increased LNG inflow capacities (Figure 4.7). If these expansions are realized, storage capacity would correspond to about 20% of the anticipated annual demand, up from zero before 2007 and less than 10% in 2019.

The distribution network already covers all of Turkey's 81 provinces and BOTAŞ aims to increase the number of settlements with access to gas to 585 by 2023 from 550 in 2020. Turkey's policy documents mention the gains to be achieved by demand side management and the start of pilot projects in this area.

Regarding domestic production, Turkey was not rich in known gas resources until the recent Black Sea discovery and production has met about 1% of annual domestic demand over the past decade. Turkey produced around only 17 bcm natural gas production in total since 1976. Turkish policies targeted a 4 bcm cumulative production increase by the state companies from 2019 to 2023. The recent discovery in the Black Sea with the announced original gas in place over 400 bcm will significantly increase the outlook for domestic gas production while reducing Turkey's anticipated natural gas imports.

Figure 4.7 Natural Gas Policy 2023 Objectives for Underground Storage and Total Daily Send-out Capacity (bcm and mcm/d)



Source: MENR, 2020

Turkey's gas policies also emphasize "an active involvement in regional projects for diversification of supplies and routes and for enhancing Turkey's role in natural gas balances in the region" including "increased interconnection capacities with the SEE region to facilitate regional gas trading including bi-directional physical flows."

Turkey is one of the first countries in Europe setting a gas market liberalization target with the Natural Gas Market Law 4646 dated 2001. Although the Law envisages a fully liberalized market structure, there are shortcomings with regard to implementation due to the legacy of existing gas contracting structures and reluctance of the foreign suppliers to release the contracts into the private sector. Turkey's natural gas market liberalization will continue to lag behind what was announced in the early 2000s and also what has been achieved so far in the power market[34]. This is understandable given BOTAŞ' take-or-pay obligations for most of Turkey's gas supply. However, recent policy documents also include goals to achieve competitive market reforms and cost-reflective pricing.

[34] However, weekly products for the natural gas was launched before the power market.

To be more specific, Turkey established an Organized Wholesale Natural Gas Sales Market (OTSP) allowing users of natural gas transmission systems to trade and to eliminate their imbalances on the basis of a continuous trade. Operations started on September 1, 2018. With the commissioning of OTSP, Turkey became the first country in its region to open a stock exchange that can perform daily natural gas trading.

About one-third of Turkey's long term import contracts accounting for 16 bcm/yr. (over one-third of current annual demand) will reach their termination dates by the end of 2021. Decisions on whether to extend these and other contracts that will be expiring after 2021 will have a large impact on whether Turkey can be "achieving a more flexible and competitive supply structure and import contracts in line with recent global developments in natural gas trade" as articulated as a key goal of Turkish natural gas policy.

4.3 IICEC Overview, Scenarios and Analyses

4.3.1 Introduction

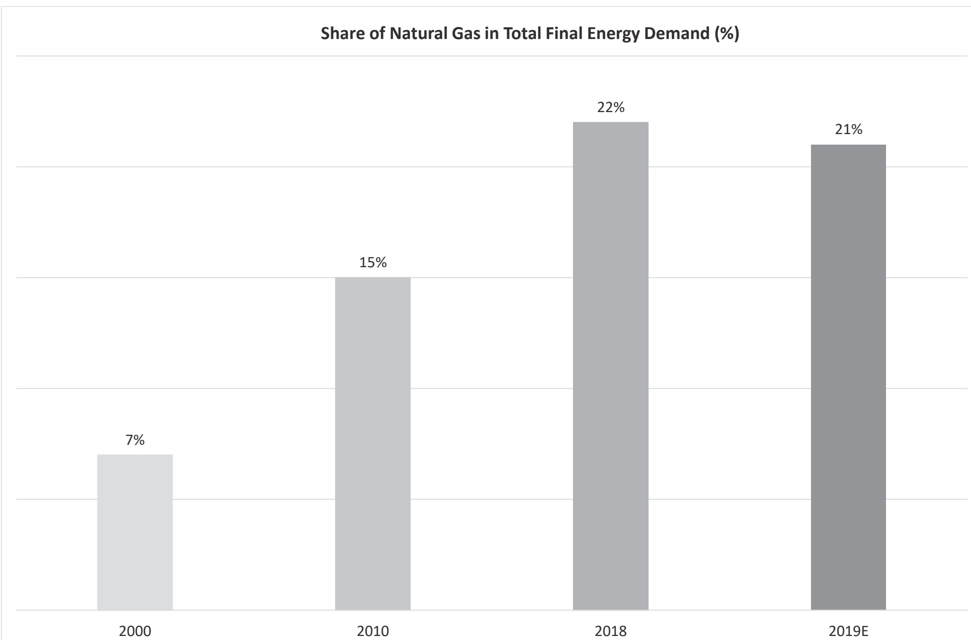
Demand: Natural gas represents about 30% of Turkey's total primary energy supplies and 22% of final energy demand. Consumption of natural gas tripled in the past two decades increasing from 15.1 bcm in 2000 to 45.1 bcm in 2019. This increased the share of natural gas in Turkey's final energy demand from 7% to over 20% during the same period (Figure 4.8). Turkey's increased gas use was broadly based reflecting increased gas use in buildings, industry and power generation. The share of natural gas is second only to oil and greater than electricity (20%), coal (12%) and renewables (8%). Natural gas has become the leading fuel in households and industry and second only after electricity in meeting commercial and public buildings energy demand. The gains in Turkey's natural gas use have contributed to better environmental performance reducing both air pollution and Turkey's carbon footprint.

Power generation has been one of the major drivers of increasing natural gas penetration. Turkey has increased natural gas installed power capacity by more than three-times, from 7 GW[35] in 2000 to 25.6 GW in 2019. During the second half of this period, the share of natural gas in power generation accounted for half of total power generation in dry years. The natural gas fleet also played an important role in achieving electricity supply security and flexibility. Gas use in the power sector peaked at over 24 bcm in 2014 and accounted for more than half of gas demand that year. However, this has started to change as a result of Turkey's policy objectives targeting a reduced role for natural gas in power generation to reduce imported fuel costs while increasingly focusing on the promotion of renewable power generation. Driven by this policy and due to reduced power demand growth, the increased uptake of renewables and altering gas and power price dynamics, natural gas's contribution to electricity production decreased from almost half in 2010 to 18% in 2019. Gas demand for power generation decreased from 21.1 bcm in 2011 to 11.2 bcm in 2019. The power sector now represents a quarter of total gas demand in Turkey, about half of its role

[35] Including dual-fueled capacity also able to burn liquid fuels.

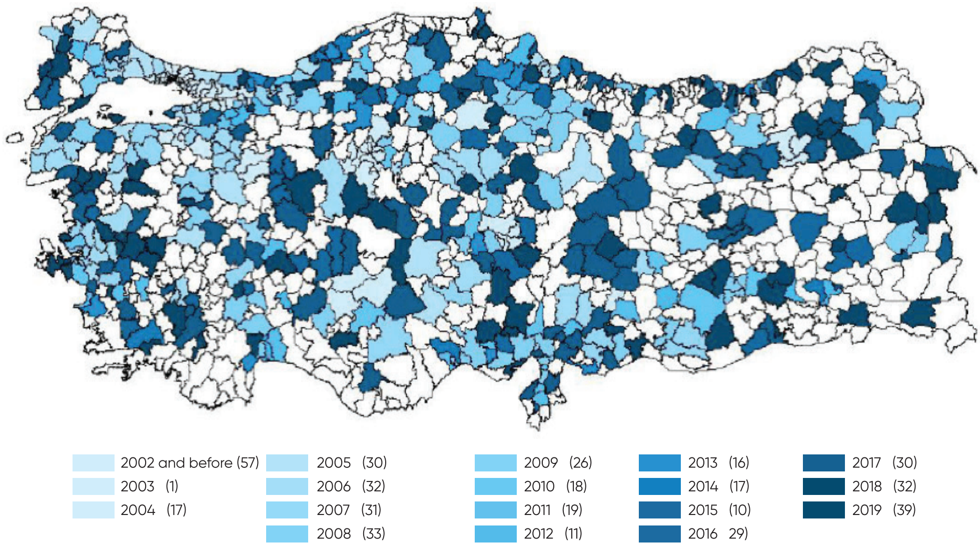
in some past years. This trend has continued during the first half of 2020 with gas plants' contribution to the power mix dropping to below 20% due to reduced power demand as a result of the economic consequences of the Covid-19 pandemic. As discussed in Chapter 1 (Power Sector) the declining role of natural gas in Turkey's power sector is likely to be a long-term trend but, nonetheless, an efficient gas fleet is likely to be needed to maintain power system flexibility and supply security towards 2040. As discussed below, this will be amplified by Turkey's well developed natural gas supply infrastructure and increased diversification of natural gas supplies, especially from spot LNG and high regasification and storage reserve capacity that can be employed when needed.

Figure 4.8 Share of Natural Gas in Total Final Energy Demand (%)



The residential sector has been the fastest growing source of gas use over the past two decades. In 2000 only 6 cities had natural gas services. Now, the gas distribution network is available in every one of Turkey's 81 provinces, serving 550 residential settlements (Figure 4.9). Turkey continues to extend gas access to areas that still do not have it. The population with access to natural gas grew from 36.8 million in 2010 to 66.5 million by the end of 2019 and now corresponds to 80% of the Turkish population. Residential gas consumption increased from less than 3 bcm in 2000 to 14.3 bcm in 2019. Now, about half of household energy demand is met by natural gas, accounting for one-third of total gas demand. Increased access to gas has significantly reduced the coal and oil that had been used for heating services.

Figure 4.9 Turkey's Gasification Progress Map



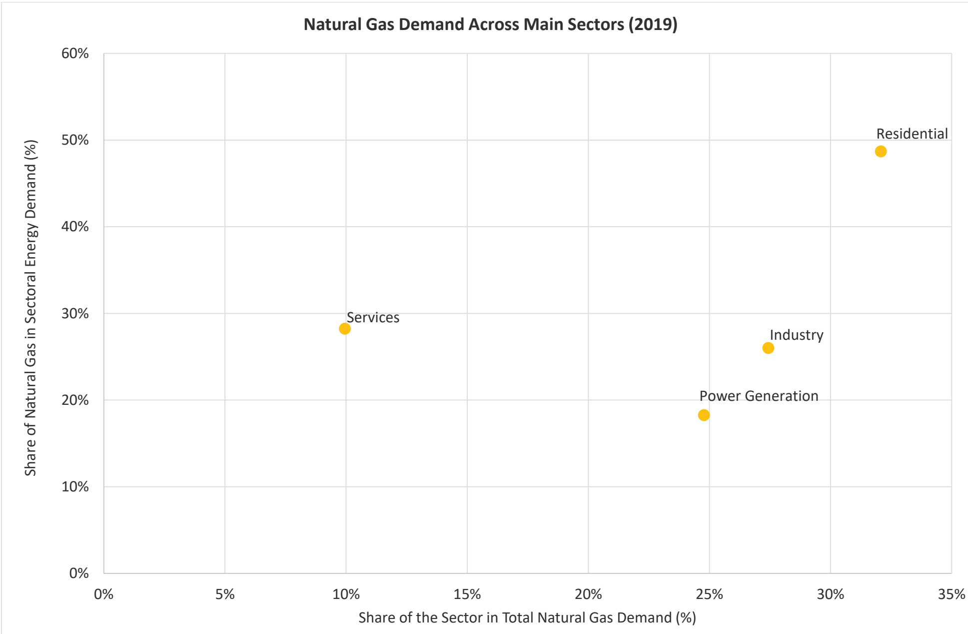
Source: GAZBİR, 2020

Non-residential buildings is another sector experiencing continuous growth over the past two decades mainly driven by expanding cities and consumption in public and commercial buildings including governmental buildings, hospitals, shopping malls and universities. The gas demand of these increased from less than 1 bcm in 2000 to 4.6 bcm in 2019. Likewise, industrial gas demand has rapidly increased from 1.9 bcm in 2000 to 12.4 bcm in 2019. Since 2012, industrial gas demand has fluctuated between 11.5 bcm/yr. and 14 bcm/yr. reflecting changing industrial outputs and other factors.

Figure 4.10 shows the importance of natural gas in each sector. Besides, as already mentioned, gas providing one-half of residential energy needs, it provides 30% of commercial building energy demand, 27 % of industry energy demand and 20% of power generation (as noted above, gas is in a declining role due to the rise of renewable energy and other factors). These four sectors represent 94% of total gas demand. The remaining uses include refineries (1.8 bcm, or 5%), pipeline energy (0.3 bcm), road transportation (0.1 bcm) and blast furnaces (0.1 bcm).

The TEO Reference and Alternative Scenarios reflect a growing natural gas sector supported by Turkey's sound infrastructure, expanding population and growing economy enabling gas to replace other fossil fuels, especially in the residential sector. In commercial buildings and several industries, further increases in gas demand are also foreseen causing additional decreases of oil and coal use. Power generation is the only sector to experience sluggish gas growth in the Reference Scenario and a major decline in the Alternative Scenario due to reasons discussed in Chapter 1 (Power Sector).

Figure 4.10 Natural Gas Demand Across Main Sectors (2019)

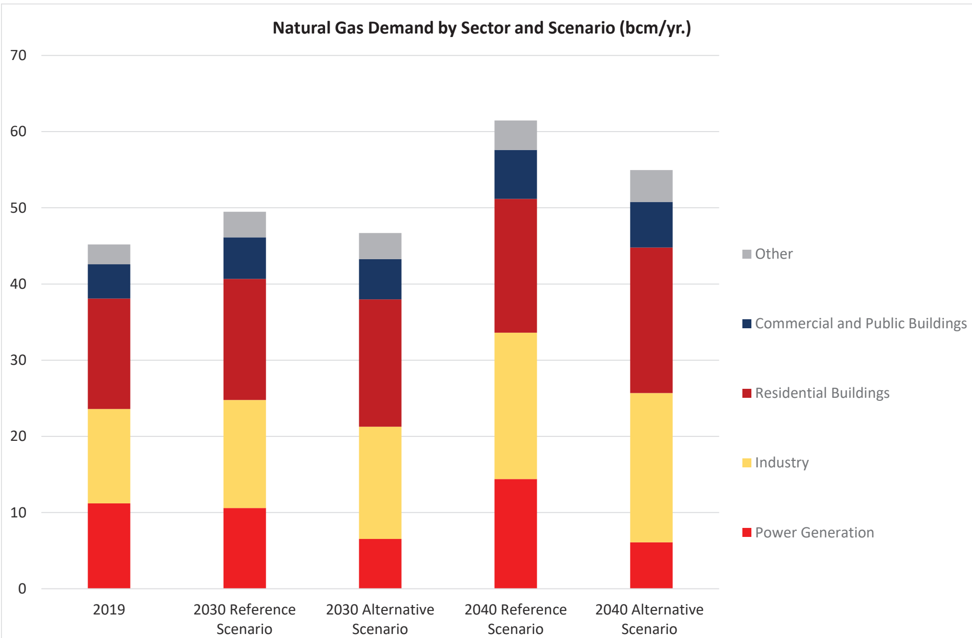


As natural gas growth becomes concentrated in the residential, commercial and industrial sectors, efficient combustion of gas for heating becomes more important for achieving a more environmentally sustainable energy economy. The Reference Scenario reflects the current trends and progress based on a set of energy efficiency policy initiatives and investments defined in the targets provided by government documents. The Alternative Scenario adds more ambitious and longer term policy priorities and investment choices that require a variety of additional fuel switching and efficiency measures.

In the Reference Scenario, natural gas demand increases by 1.5%/yr., resulting in 16 bcm more demand in 2040 (36% cumulative growth) compared to 2019. The projected annual growth is significantly less than the three times increase experienced during the past twenty years. The largest growth in absolute terms takes place in the industrial segment with 6.8 bcm (55%) as a result of switching from coal and oil products (42% of the total increase). Residential demand increases by 3.1 bcm (21%) driven by increasing energy demand in households and further gasification opportunities to replace other fossil fuels. This is partially offset by a growing efficiency gain that reaches 15% by 2040. 81% of the population will be using gas by 2040 (an additional 10% than currently).

In 2040, demand from the power sector is forecast to be 3.2 bcm higher than 2019 but 3.8 bcm lower than 2018 (reflecting differences in overall electricity demand and hydrology between 2019 and 2018). Service sector demand is 1.9 bcm higher than 2019 as a result of ongoing urbanization, strong socio-economic fundamentals and the appeal of using natural gas for more commercial building energy needs (Figure 4.11). While the estimated increase in natural gas as a road fuel is large (about five times), the 0.5 bcm increase is still a very small share of the total gas demand increase (3%).

Figure 4.11 Natural Gas Demand by Sector and Scenario (bcm/yr.)



In the Alternative Scenario, natural gas demand increases by 22% from 2019 to 2040. The demand in 2040 is 15% less than in the Reference Scenario as a result of demand reductions in all sectors except for households and transportation. The largest growth in absolute terms takes place again in the industrial segment (7.2 bcm), driven by further shifts away from coal and oil products to natural gas and partially offset by additional energy efficiency. The Alternative Scenario anticipates about 2% more industrial gas demand compared to the Reference Scenario by 2040. The residential sector shows the second largest growth in absolute terms (4.6 bcm) and is 1.5 bcm (9%) higher than in the Reference Scenario (Figure 4.11). This is a result of 4.2 million more subscribers and an additional efficiency gain of 5% expected by 2040[36]. In the Alternative Scenario, 94% of total population is expected to be actively utilizing natural gas (compared to 63% in 2019). The residential sector will increase its share in total gas demand in both scenarios from 32% at present to over 35% by 2040 (Table 4.1.).

[36] Most of these subscribers are expected to have lower average consumption and this factor is accounted for in the TEO projections.

Summing up, the Reference and Alternative Scenarios show a mixed picture of natural gas use. The Alternative Scenario shows increased use of natural gas end-use equipment in the residential and other buildings as well as industrial sectors at the expense of other equipment fueled by oil or coal. This increased reliance on natural gas is largely offset by increased combustion efficiency. In the power sector, we see a different picture where the differences between the Reference and Alternative Scenarios are greatest. In the Alternative Scenario, gas used for power sharply decreases due to the higher uptake of renewable energy, increased end-use efficiency and other factors discussed in Chapter 1 (Power Sector).

Apart from the changes in the Alternative Scenario's power sector, the most important factor reducing natural gas use between the Reference and Alternative Scenario is improved energy efficiency. Reducing the import bill stemming from increasing gas demand will be a persistent energy policy objective for Turkey, making additional efforts on natural gas combustion efficiency a national priority. As will be discussed below (4.3.4. Achieving More Flexible and Competitive Supplies), reducing Turkey's gas import bill is not just about reducing its natural gas imports but also about improving its terms of trade, a prospect that appears to be particularly important considering the recent discoveries, recent trends in the global gas market, Turkey's diversification of supplies, expanded infrastructure, and slower demand growth.

Table 4.1 Summary of Natural Gas Demand by Scenarios

Scenarios			**Reference Scenario**		**Alternative Scenario**	
bcm	**2000**	**2019**	**2030**	**2040**	**2030**	**2040**
Total Gas Demand	15.1	45.2	49.5	61.5	46.7	55.0
of which						
Residential		14.5	15.9	17.6	16.7	19.1
Services	3.2*	4.5	5.5	6.4	5.3	6.0
Industry	1.9	12.4	14.2	19.2	14.7	19.6
Power	9.5	11.2	10.6	14.4	6.5	6.1
Other	0.4	2.6	3.4	3.9	3.4	4.2
Share of Residential Sector in Natural Gas Demand (%)	<20%	32%	32%	29%	36%	35%

Note: * includes residential demand

Supply: Gas production in Turkey has historically been limited compared to rapidly growing demand. Annual production peaked around 1 bcm/yr. in 2008 but entered a declining trend until 2017. Output has increased to 480 mcm in 2019 from 360 mcm in 2017. But this represented only 1% of Turkey's demand. The remaining recoverable resources were standing at 3.3 bcm by the end of 2019 correspond to about 7 years at current production levels. Turkey has been improving its inventory of resources and taking steps to develop both conventional and unconventional gas plays. This is one of the main localization and energy security related policy objectives defined in the NEMP to reduce import volumes and bill while further enforcing supply security. Part of this strategy involves exploiting Turkey's undiscovered gas and oil resources. To accomplish this, Turkey purchased 3 drilling ships, named Fatih, Yavuz and Kanuni. They started in 2017 carrying out 9 deep sea offshore drillings, 8 in the Mediterranean and 1 in the Black Sea with the goal to carry out 26 deep sea offshore drillings by 2023.

As a result of these valuable efforts, Turkey realized a large discovery in the Black Sea by Fatih in the Sakarya field, Tuna-I location. The original gas in place (OGIP) of this field was announced at 405 bcm. It represents a milestone for the Turkish energy sector. Although further activities and studies will be needed to determine the recoverable reserve amount yielding an annual production planning curve, this finding will significantly alter Turkey's long lasting heavy dependence on natural gas imports. The most preliminary production estimate from this field is 10-15 bcm/yr. Therefore, this find alone could provide an average of 20% to 30% of Turkey's projected gas demand. While, of course, Turkey will likely remain an importer of natural gas, it is possible, probably likely, that further discoveries will add to Turkey's OGIP leading to more domestic production and further reductions of imported gas.

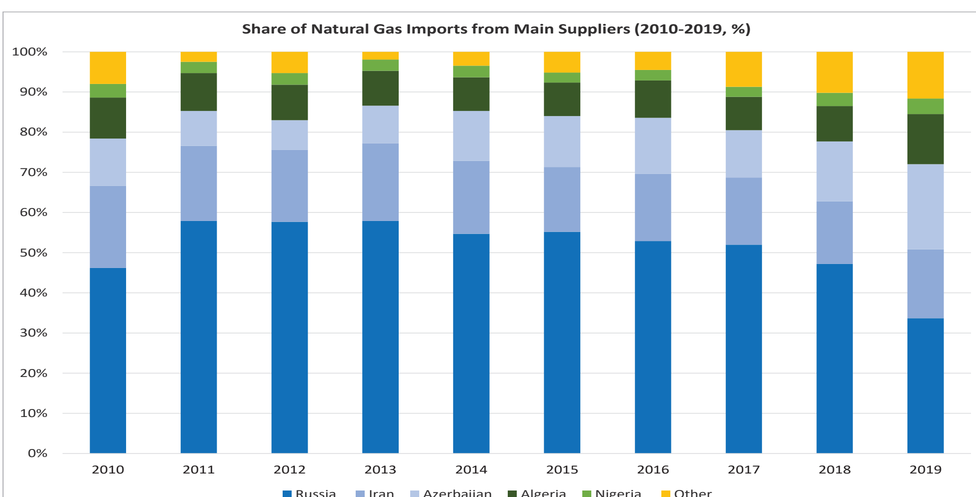
Turkey is currently importing gas in pipelines and as LNG. As discussed above, trends in the global gas market combined with a number of Turkey's gas trends, policy objectives and prospects for significant increases in Turkey's domestic supplies will improve its natural gas supply security. The gas trends in Turkey include an improved natural gas transmission and distribution network with fewer bottlenecks, reduced dependence on gas in the power sector, especially in the IICEC Alternative Scenario, multiple regasification entry points and increased natural gas storage.

In recent years, Turkey continued to diversify its gas supply portfolio and reduced the share of natural gas from the largest source (Russia) from 17.6 bcm in 2010 (46%) to 15.1 bcm (34%) in 2019. Turkey procured 21% of total annual imports from Azerbaijan and 17% from Iran. Two other large sources are LNG from Algeria and Nigeria (Figure 4.12). Gas imports from these five countries are based on long term contracts. Recently, Turkey has been ramping up LNG imports reaching to 12.8 bcm in 2019 up from 8.8 bcm in 2010. 2019 LNG imports corresponded to 27% of total annual gas imports, a historic high for Turkey. Another big step has been increasing the share of imports of spot LNG. Compared to a structure fully based on long term imports in early 2000s, Turkey procured 5% and 12% of total imports based on spot purchases in 2018 and 2019 respectively.

This appears to be rapidly changing as spot LNG is now being imported from more than 5 different countries[37] and contributed to 30% of total imports in the first 5 months of 2020. The share and amount of

LNG imports have accelerated despite the drop in Turkey's total natural gas imports in recent years. This is in line with global developments that favor spot and short term-arrangements in a globally oversupplied gas market with enhanced interconnectedness among regions supported by extended storage and LNG capacities. This has been largely possible thanks to the Turkish Organized Wholesale Natural Gas Sales Market (OTSP), that began operations in 2018 as well as the legislation and infrastructure allowing spot pipe gas imports. In this way, Turkey enjoyed the benefits of spot LNG by making instant purchases when global natural gas prices were low. This trend partly reflects the Covid-19 crash in natural gas prices and the favorable position of natural gas customers. However, the benefits of spot trade can be maintained in the longer term for Turkey. Even when natural gas prices rise due to a world-wide return to more normal gas demand levels, an increasingly diversified and competitive national natural gas market will still be able to exploit the opportunities that spot gas sales provide, especially with the well-developed natural gas infrastructure such as Turkey has achieved. In addition, as Turkey's domestic production increases, the adverse consequences of higher natural gas prices on Turkey's economy is mitigated in two ways. First, gas import levels are lower reducing the increase in Turkey's natural gas import bill caused by higher prices and, second, national profits from producing natural gas are higher. The country's annual energy bill creates a huge trade deficit of which fossil fuel imports accounts for a considerable amount. The share of natural gas in Turkey's total energy bill in 2019 is around $12 billion (almost 30%).

Figure 4.12 Share of Natural Gas Imports from Main Suppliers (2010-2019, %)



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[37] Including Cameroon, Egypt, Equator Guinea, Norway, Spain, Trinidad and Tobago, the United States.

Turkey's natural gas supply structure can be transformed thanks to this more flexible and competitive setting. A significant share of the existing contracts corresponding to over one-third of current annual demand, 16 bcm/yr., will expire by the end of 2021. By end-2025, an additional 20 bcm/yr. of the existing contract portfolio will also expire. The Turkish gas market is now over supplied with existing contract volumes (about 60 bcm/yr.) being well above the current "normal" annual demand level (45.2 bcm/yr. in 2019).

While Covid-19 related measures are lowering gas demand in the power sector during 2020, IICEC expects a longer term trend of reduced power sector gas use. In addition, several factors will improve Turkey's negotiating position as existing long term supply contracts expire. These include sluggish gas use, the likelihood that the LNG market will remain well supplied after Covid-19 countermeasures are no longer required, Turkey's high flexibility to distribute gas from LNG imports and strong prospects for significant domestic production that would reduce gas import requirements and prospects of using natural gas recently discovered in the Sakarya field. The benefits of the recent uptake of Turkey's E&P activities will begin to bear fruit in this decade and increase over the longer term having a potentially very large effect of reducing Turkey's gas import bill and associated economic and geopolitical benefits. This will be taken up in more detail in Section 4.3.4 (Achieving More Flexible and Competitive Supplies).

Infrastructure: A secure, reliable and modern gas transmission and distribution system is the backbone of a growing natural gas economy. At present, Turkey's gas transmission network comprises over 18 thousand km of high-pressure pipelines, with a total daily supply capacity of 357 mcm (well above peak daily demand of 245 mcm in 2019).

With two recently completed large gas pipelines, TANAP and TurkStream, and new regasification facilities, the entry capacity for imports grew from 213 mcm/day in 2017 to over 300 mcm/day today[38]. There are six international pipeline import points, four LNG entry points (with a fifth being added), two domestic entry points from underground storage facilities, and three entry points from production fields. Turkey has been expanding its gas import infrastructure (Figure 4.13).

Total daily inflows would further increase by planned new FSRU terminals and underground storage facility (UGS) expansions. These developments have been instrumental to achieve gas supply security and flexibility especially over the past 3 years. Turkey is able to meet current peak demand levels with sufficient contingency including satisfying the N-1 criteria[39] .

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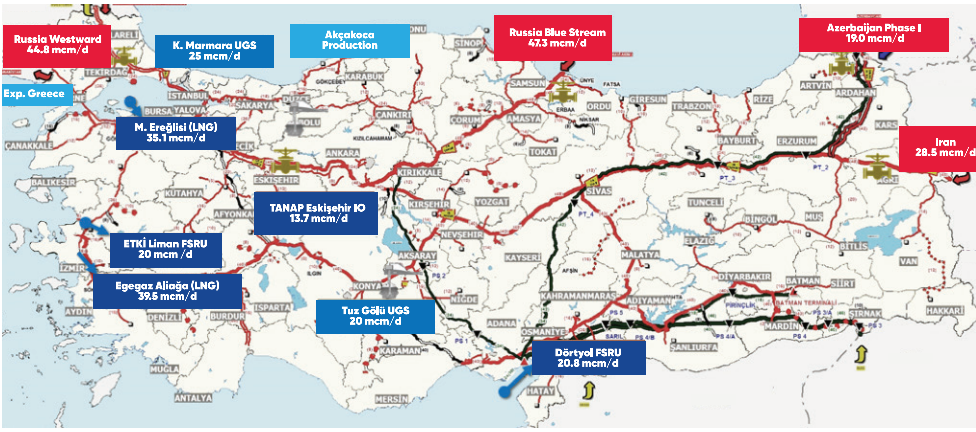
[38] This figure includes Malkoçlar, which is currently reserved but not used by Gazprom. (See Section 4.3.5).

[39] The N-1 condition is satisfied if the total supplies or inflows into a system are able to meet peak demand in case of a loss of the largest supply volume or the entry point.

Figure 4.13 Gas Transmission Network and Entry Points



Source: BOTAŞ; IICEC data

Turkey has established an extensive natural gas transportation system and stands as one of the largest natural gas markets in Europe. With an oversupplied structure, in terms of yearly contracted volumes and daily inflow capacities, a new phase may resume with lower demand growth prospects, more diversified sources of imports and increased domestic supplies. This new phase will help achieve Turkey's long awaited gas market reforms and focus development towards a more efficient and competitive natural gas market as discussed in Section 4.3.6 (Market Developments).

4.3.2 Demand

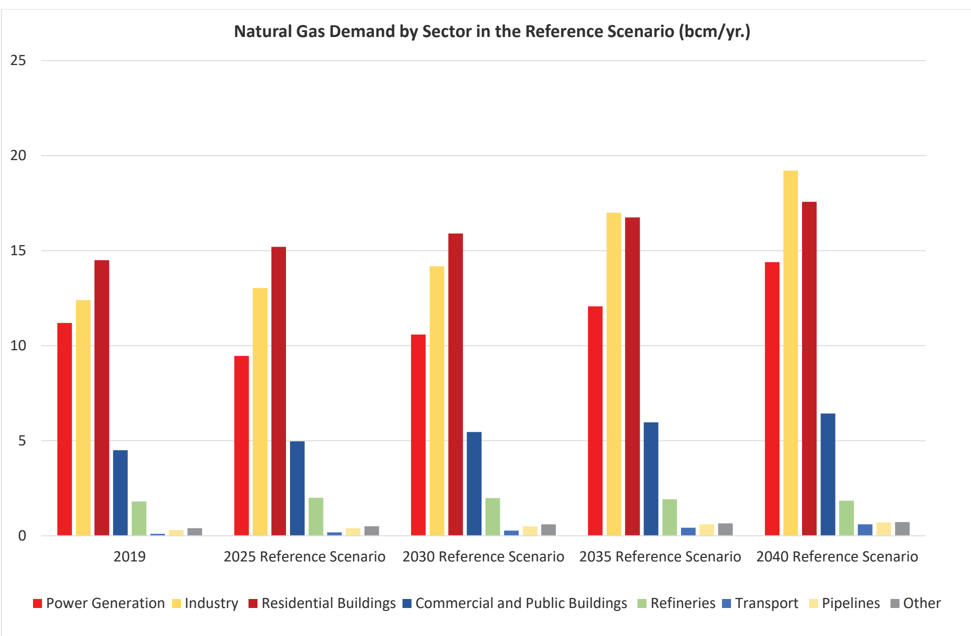
Both scenarios project a gas demand structure that is mostly driven by the buildings and industrial sectors. Due to reasons discussed in Chapter 1, natural gas to power reduces its share by 46% in the Alternative Scenario by 2040 compared to 2019. Industry will remain the largest gas consumer, followed by residential buildings. This is a result of further gasification opportunities in several industrial sectors to replace coal and petroleum fuels and benefit from natural gas in a more competitive market framework that is assumed for the Alternative Scenario.

Turkey's policies to expand the gas network has already paid off in achieving a more environmentally sustainable energy economy by enabling large shifts from coal and petroleum fuels. IICEC Scenarios show that this trend will continue increasing the role of natural gas in meeting residential energy demand. In addition to households, Turkey's commercial and public buildings are among the major users of natural gas and demand in these buildings will also increase. Population increase and ongoing urbanization will remain the key drivers for increasing natural gas consumption.

In both IICEC Scenarios, the increase in natural gas demand is moderated by estimated efficiency improvements. These improvements, supported by policy and technology measures, largely offset the growth of energy services that more gas-using end-use equipment provide to buildings and industry, particularly in the Alternative Scenario.

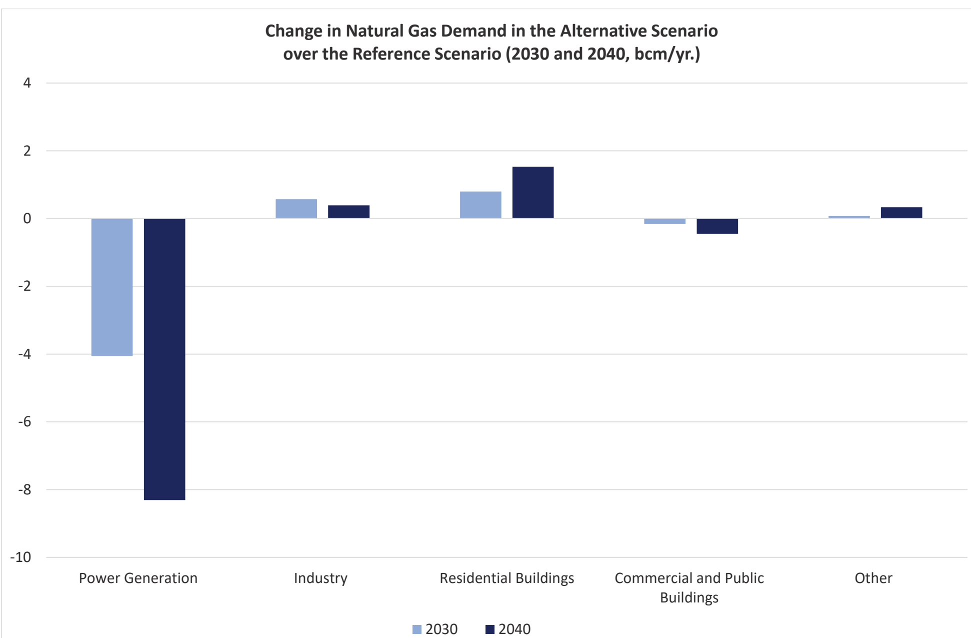
Figure 4.14 presents development of the natural gas demand by sector in the Reference Scenario. Total natural gas demand increases to 61.5 bcm in 2040 from 45.2 bcm in 2019 (35% increase). Industrial demand increases from 12.4 bcm/yr. to 19.2 bcm/yr. (55% increase). Residential buildings demand increases from 14.5 bcm/yr. to 17.6 bcm/yr. (21% increase). Demand in other buildings increases from 4.5 bcm/yr. to 6.4 bcm/yr. (43% increase). Power generation sector's demand increases by 3.2 bcm in 2040 over 2019 due to net capacity additions, as discussed in Chapter 1 (Power Sector). Buildings in total (residential, commercial and public buildings) continues to be the largest consumer of gas, and industry becomes the largest gas user segment around 2035, followed by residential buildings, as discussed in detail in Chapter 5 (Other Sectors and Fuels) (Figure 4.14).

Figure 4.14 Natural Gas Demand by Sector in the Reference Scenario (bcm/yr.)



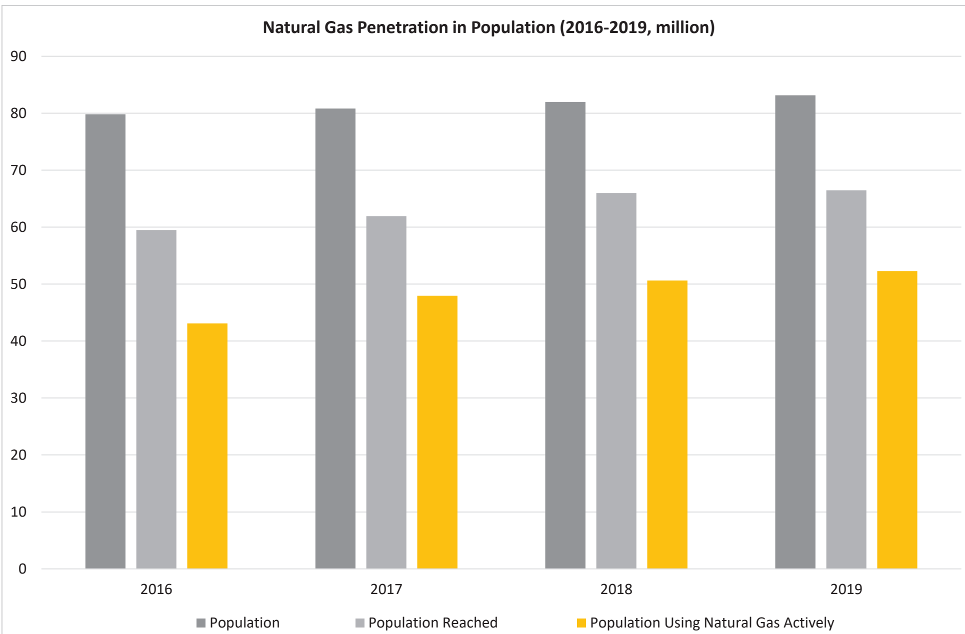
The Alternative Scenario reflects a more efficient, lower cost and competitive natural gas market development that takes advantage of gasification potential in buildings and across the industrial sectors. Increasing consumption as a result of further fuel shifts from coal and oil products are largely offset by an enhanced energy efficiency agenda supported by policy measures and technologies. The natural gas demand in the Alternative Scenario is 11% less than in the Reference Scenario by 2040. The largest difference compared to the Reference Scenario is a result of a more efficient and localized power sector that lowers the natural gas supply requirements for the power sector, as widely discussed in Chapter 1. The Alternative Scenario realizes 8.3 bcm/yr. less gas to power demand. Despite further shifts towards gas for industrial heating purposes, the industrial gas demand is only 0.4 bcm (or 2%) higher than the Reference Scenario in 2040 due to efficiency gains. Although further improvements yield in a more efficient residential buildings segment, gas demand is 1.5 bcm/yr. (or 9%) higher than in the Alternative Scenario as a result of further penetration of natural gas into a larger share of the total population. The demand in non-residential buildings is slightly lower than in the Reference Scenario yielding 0.5 bcm/yr. less demand in 2040 despite higher penetration of natural gas heating (Figure 4.15).

Figure 4.15 Change in Natural Gas Demand in the Alternative Scenario over the Reference Scenario (2030 and 2040, bcm/yr.)



Turkish energy policies favor increased use of natural gas in residential buildings. As a result of constantly increasing investments by BOTAŞ and distribution companies over the past decade, the population with access to natural gas increased to 66.5 million (80% of total population) by the end of 2019 from 75% in 2016. By the end of 2018, all 81 provinces have access to natural gas. However, active users represent 79% of the population having access to natural gas compared to 72% in 2016. 37% of the population with access to natural gas do not consume natural gas actively (Figure 4.16).

Figure 4.16 Natural Gas Penetration in Population (2016-2019, million)

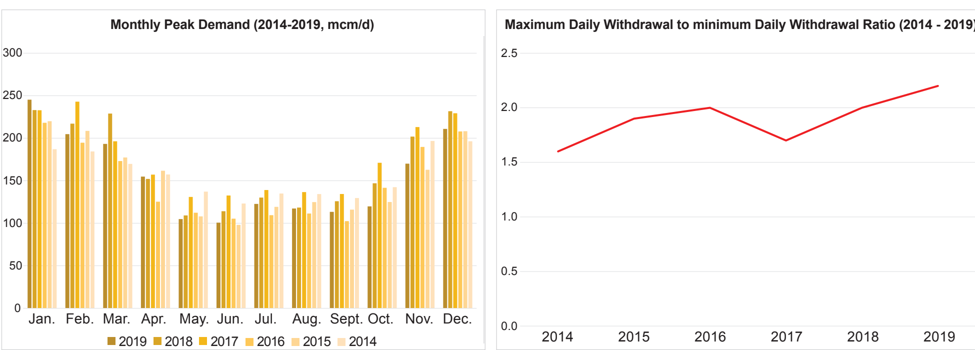


Source: GAZBİR, 2020

In the Reference Scenario, the demand from residential buildings increases by 3.1 bcm/yr., mainly driven by increasing population, urbanization and prosperity. Further gasification opportunities, by increasingly utilizing the current distribution infrastructure and extensions into new urban zones, increasingly replace other fossil fuels for heating purposes. 81% of the total population will be using gas by 2040 compared to 63% in 2019. Increasing gas use by fuel shifts is partly offset by a cumulative 22% efficiency gain by 2040 in terms of consumption per population actively using natural gas. Natural gas consumption per capita remains almost unchanged at 175 m^3/yr. In the Alternative Scenario, the residential buildings demand increases by 4.6 bcm/yr., or 1.5 bcm/yr. higher than in the Reference Scenario (2040). This is a result of additional 4.2 million subscribers and over 5% additional efficiency gain in terms of consumption per active population using gas. Further expansion of the grid to locations with much lower consumption points than the Reference Scenario also drives lower per household demand figures and reduces the cumulative demand increase. In the Alternative Scenario, 94% of the total population actively utilizes natural gas. The residential sector will remain the largest user of natural gas in the Turkish energy economy in both scenarios reaching over 35% contribution by 2040 compared to 32% in 2019. Demand from non-residential buildings also increase in both scenarios (1.9 bcm/yr. in the Reference Scenario and 1.5 bcm/yr. in the Alternative Scenario) as a result of an increasing services building stock in more urbanized demographics and partially offset by enhanced efficiency improvements.

Due to a large proportion of gas used for heating, Turkish gas demand varies strongly with the season and the weather. This results in almost two times more demand in the winter season compared to summer months (Figure 4.17). With increasing gasification in buildings, seasonality will remain a key characteristic of the Turkish natural gas system. This requires sustained actions to balance supply and demand throughout the grid, as discussed in Section 4.3.5. IICEC analyses, demonstrating this seasonality impact (Figure 4.18) also measured in terms of heating-degree-days (HDD)[40], indicate that residential gas demand is highly correlated to HDD developments.

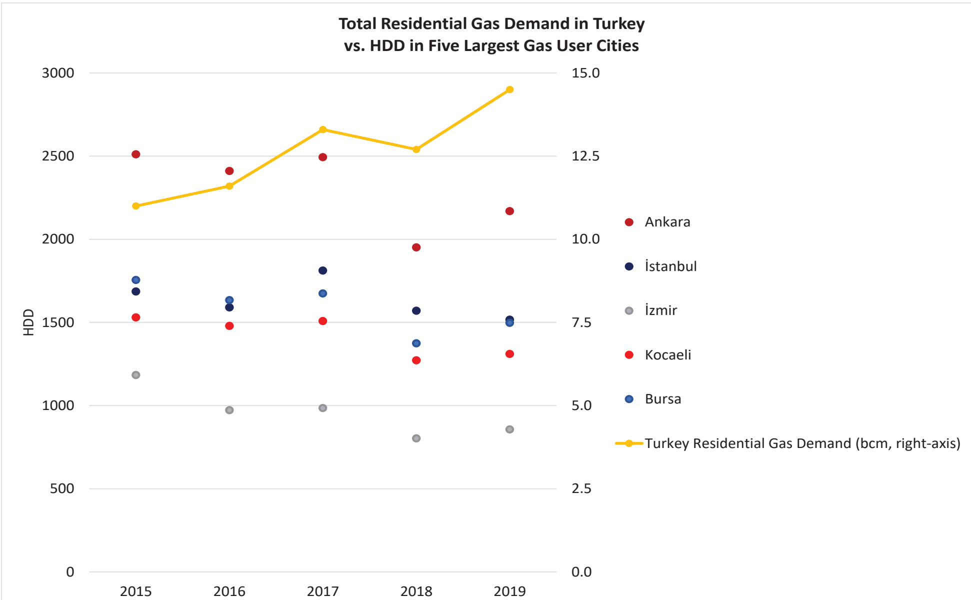
Figure 4.17 Seasonality in Natural Gas Demand (2014-2019)



Industry has become a major natural gas user over the past two decades. Natural gas met only 5% of total industrial energy demand compared to coal (45%) and oil products (22%) in 2000. However, natural gas use in Turkish industrial sectors accelerated in early 2000s. Increasing penetration of natural gas as a sustainable fuel alternative for industrial processes has been achieved by an extended infrastructure. Gas use largely substituted dirty and inefficient oil consumption across industrial sectors and reached over 20% of total industrial energy use in 2010. Oil use is now almost exclusively limited to the petcoke supplies into the cement industry, as discussed in Chapter 3 (Oil). Gasification of various industries has been in progress and increasingly replacing coal use (Figure 4.19). Currently, natural gas is the leading fuel to the industrial sector (26%) followed by coal (25%). This trend is in line with advanced energy economies and is improving the environmental performance of the Turkish energy economy.

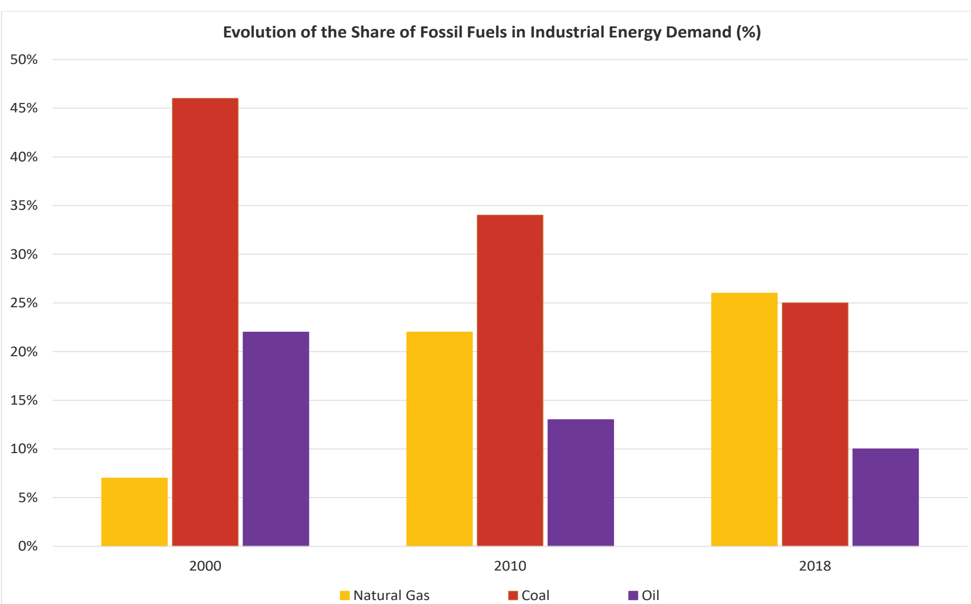
40 Heating-Degree-Day (HDD) is an effective indicator to measure heating requirements for buildings. In this analysis, HDD is equivalent to (18 °C - Tm) times number of days if Tm ≤ 15 °C and is zero if Tm > 15 °C where Tm is the daily mean temperature.

Figure 4.18 Total Residential Gas Demand in Turkey vs. HDD in Five Largest Gas User Cities (2015-2019)



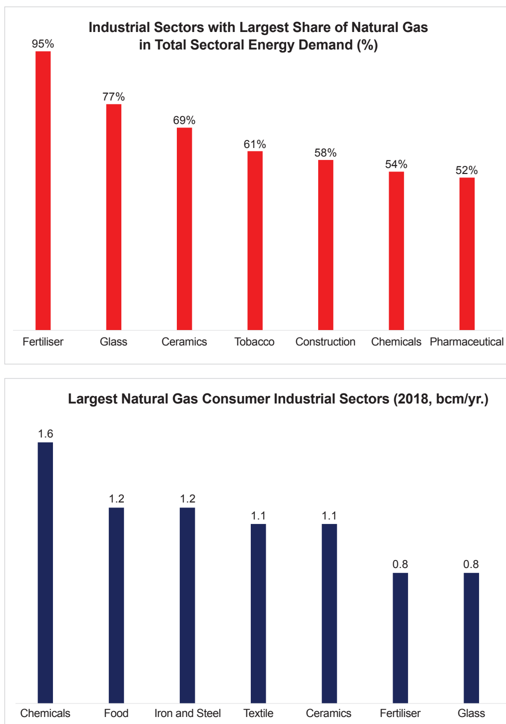
IICEC analysis based Turkish Meteorological Institute data, 2020

Figure 4.19 Evolution of the Share of Fossil Fuels in Industrial Energy Demand (%)



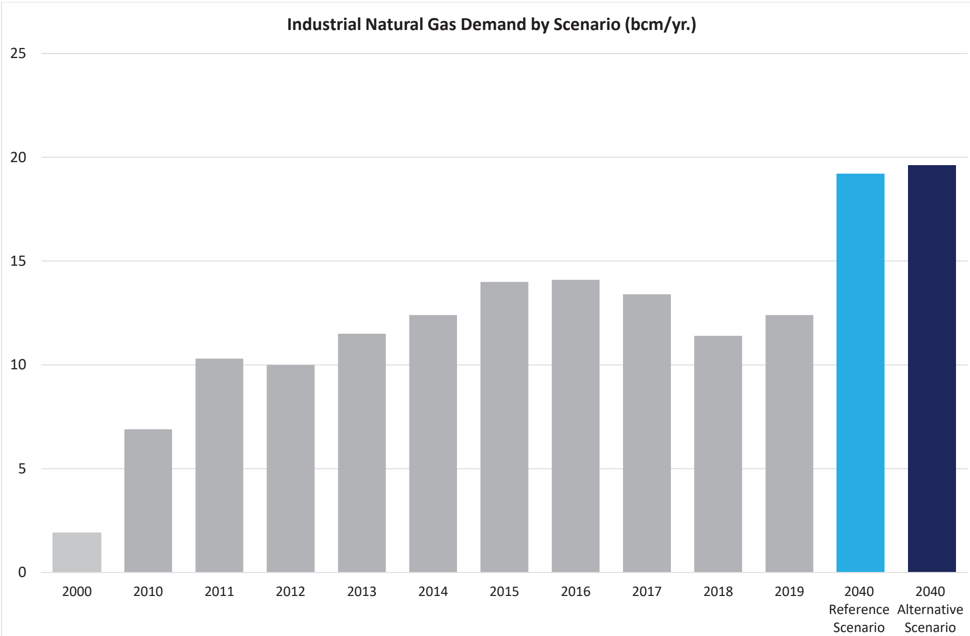
Chemicals is the largest natural gas user industry (1.6 bcm in 2018), followed by food (1.2 bcm/yr.), iron and steel (1.2 bcm/yr.), textile (1.1 bcm/yr.), ceramics (1.1 bcm/yr.), fertilizer (0.8 bcm/yr.) and glass (0.8 bcm/yr.). These sectors represented almost two-thirds of industrial gas consumption and one-sixth of Turkish natural gas demand in 2018. Natural gas is the leading fuel in several industries such as fertilizer, glass, ceramics and tobacco with 95%, 77%, 69% and 61% respectively. It also meets over half of total energy use in construction, chemicals and pharmaceuticals (Figure 4.20). Therefore, competitive and uninterrupted natural gas supplies will remain a key consideration for Turkish industries.

Figure 4.20 Natural Gas Use in Industrial Energy Consumption (2018, % and bcm/yr.)



Natural gas use in industry is mainly a function of industrial output. TEO projections, reflecting Turkey's economic growth prospects throughout 2040, demonstrate further gasification potential across industrial all sectors particularly supported by increasingly competitive and flexible natural gas supplies. In both scenarios, the largest demand growth in absolute terms take place in the industrial sector. In the Reference Scenario, the natural gas demand in the industrial segment increases by 6.8 bcm (or 55%) as a result of sustained switching from coal and oil products. The Alternative Scenario reflects further shifts away from other fossil fuels. As these fuel shifts are mostly offset by enhanced efficiency measures, the Alternative Scenario projects about 2% (0.4 bcm) more industrial gas demand compared to the Reference Scenario in 2040 (Figure 4.21).

Figure 4.21 Industrial Natural Gas Demand by Scenario (bcm/yr.)

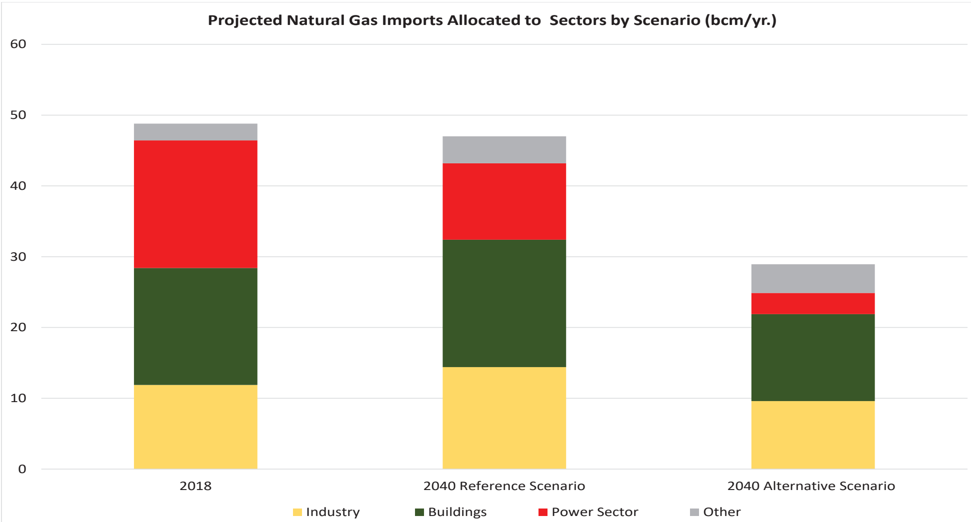


In both scenarios, a relatively sizable increase occurs in transportation with gas demand increasing from 0.1 bcm/yr. to 0.5 bcm/yr. in the Reference Scenario and further to 0.7 bcm/yr. in the Alternative Scenario (2040), as a result of increased uptake of CNG and LNG fueled HDVs, as discussed in Chapter 2 (Transport). Still, the share of transport in total gas demand remains marginal at 1% and 2% by 2040 in the Reference and Alternative Scenarios.

Natural gas accounts for the second largest energy import costs to Turkey after petroleum and petroleum products. Therefore, achieving reductions in natural gas demand across sectors and improved terms of trade should be among the most critical objectives for improving the energy trade deficit of Turkey.

The Alternative Scenario demonstrate that, with reduced growth in total gas demand mainly as a result of energy efficiency actions in buildings and industry and lowering demand for power generation together with increasing domestic production expectations as discussed in Section 4.3.3., the total import need for natural gas will substantially decrease (28.9 bcm in 2040 vs. 48.8 bcm in 2018 or 49% in 2040 vs. 99% in 2019). This is an important achievement for transforming the Turkish energy economy into a less import dependent structure (Figure 4.22.)

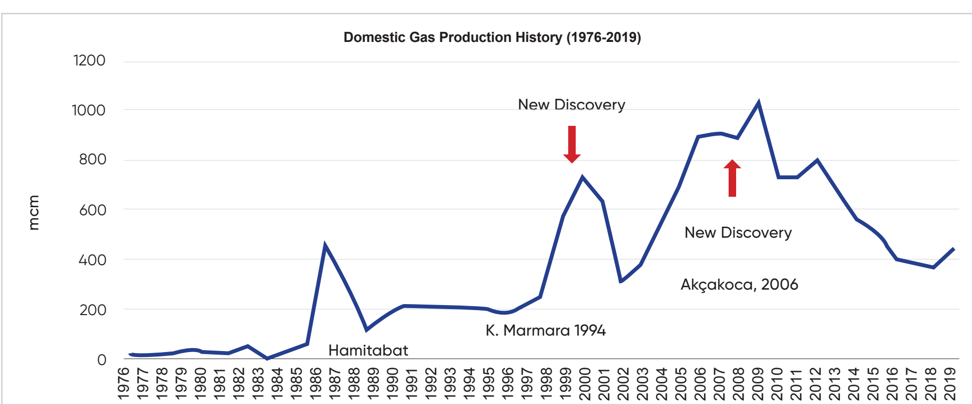
Figure 4.22 Projected Natural Gas Imports Allocated to Sectors by Scenario (bcm/yr.)



4.3.3 Production

Turkey has long been limited in known natural gas resources. Gas production started with the first significant discovery was realized at Hamitabat in 1976. Later discoveries were made at Kuzey Marmara in 1994 and Akçakoca in 2006. After each of these, production volumes again declined and Turkey did not achieve a stable annual production output until now (Figure 4.23). About 17 bcm cumulative production was achieved by the end of 2019, on average of 0.8 bcm/yr. since 1977. As a comparison Turkey's annual gas demand was 45.2 bcm/yr. in 2019.

Figure 4.23 Domestic Gas Production History (1976-2019)



Source: MAPEG

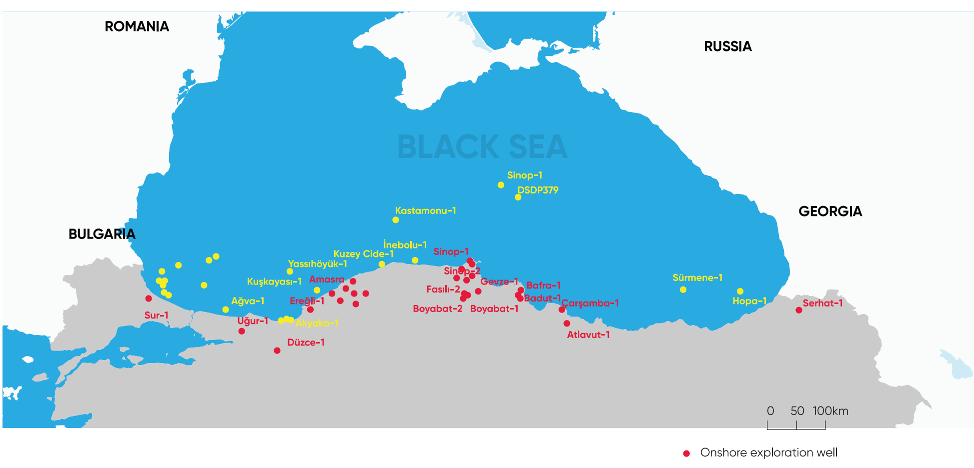
4.3.3.1 The Recent Discovery in the Black Sea

Turkey's offshore exploration efforts date back to the mid-1970s when the first projects commenced in the Marmara Sea. The activities have been intensified along the objectives of the National Energy and Mining Policy. TPAO has expanded its drill-ship fleet to undertake new wells, adding the technologically-sophisticated, new generation vessels *Fatih, Yavuz and Kanuni.*

Exploration activities in the Marmara Sea have accelerated since 2016 yielding over 3 thousand km² 3D seismic data. In the Black Sea, TPAO has evaluated over 142 thousand km² 2D seismic data and about 38 thousand km² 3D seismic data. In addition, 6 deep sea and 10 shallow sea exploration wells have been drilled. The Black Sea wells Akçakoca-3 and Akçakoca-4 were followed by 24 more wells in this vicinity. Likewise, in the Mediterranean Sea, seismic data collection has led to 15 exploration wells in the Gulf of Iskenderun and Mersin.

The Black Sea has been one of the main spots for drilling activities (Figure 4.24). Until 2020, several exploration wells in deep water have jointly drilled with TPAO in the Black Sea in cooperation with large companies[41]. TPAO also solely has drilled 2 exploration wells in the region. Twelve deep-sea wells had gas or oil shows. Around twenty shallow exploration wells were drilled by TPAO and others with sixteen of them having hydrocarbon shows. Most of the shallow water wells are located around Akçakoca, where the Akçakoca/Ayazlı gas fields were discovered.

Figure 4.24 Drilling Activities in Onshore and Offshore Wells in the Black Sea Region (as of June 2020)



The base map modified from Ross et al., 1978, by Palabıyık et. al., 2020

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[41] Including ARCO, BP, ExxonMobil, Shell, Chevron, Petrobras

The discovery in late August 2020 is the first large discovery of Turkey, achieved as a result of intensive efforts by the Ministry of Energy and Natural Resources and TPAO in the past few years. The ultra-deepwater Tuna-1 well discovered more than 100 meters of gas-bearing reservoirs in Pliocene and Miocene sands. TPAO has named the field Sakarya, reporting resources of 405 bcm of Original Gas in Place (OGIP)[42] of lean gas (high quality pure CH_4) in October 2020 (Figure 4.25). The drilling commenced on 20 July 2020. The location was selected using intense 2D and 3D seismic interpretations including sophisticated logging tools and test equipment used at the site. The planned depth of around 4,500 meters have been reached (2,115 meters of water depth plus 2,410 meters of drilling). Tested gas comes from Pliocene and Upper Miocene age sandstone beds which are the subsea alluvium fan deposits of the Danube River. The gas field is on the extension of Romanian offshore Domino gas field discovered by Petrom/Exxon Mobil JV in 2012 which has not been developed yet. The reserve is at approximately 1200-1400 m below the mud line. The pay zone (gas zone) is estimated at 100 m thickness. Two more pay zones were encountered before reaching the planned depth and the reserve figure was revised from 320 bcm to 405 bcm. More wells will be needed to achieve the proven reserve amount. These wells will be organized after the areal closure is assessed using 3D seismic data. The reserve evaluation depends on:

- Pay zone thickness,
- Area of closure,
- Formation pressure,
- Tested gas rate,
- Well head pressure,
- Formation porosity, permeability and other factors.

The Government expects to connect the first gas produced from this field to Turkey's pipeline distribution system by late 2023. This pathway requires further drilling of appraisal wells, establishment of floating platforms and construction of gas processing facilities and the pipeline to connect to the Turkish gas grid.

IICEC estimates that at least 10 bcm/yr. annual production will result from the Tuna-1 location (a conservative estimate based on current information). Further discoveries in these geologically attractive Black Sea areas, backed by ongoing efforts and supported by expanded drilling, that may include an expansion of the current drillship fleet, can increase the resource base and potential gas production that can be realized. The Government announced that new drilling activity will commence at Türkali-1 well, again in the Sakarya field. Further increases above the 10-15 bcm/yr. that could be realized from Tuna 1 and other wells could make more extensive cuts in Turkey's natural gas import needs and provide even more significant economic and geopolitical benefits.

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42 It is estimated at P50. The universal practice suggests that 70-80% of the Original Gas in Place (OGIP) is being producible.

Figure 4.25 Tuna-1 Location and the Exclusive Economic Zone of Turkey in the Black Sea

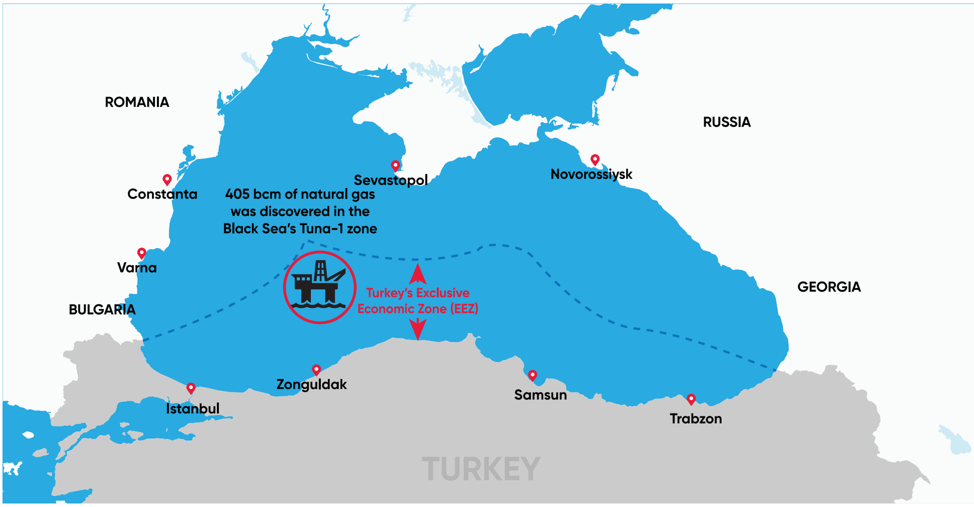
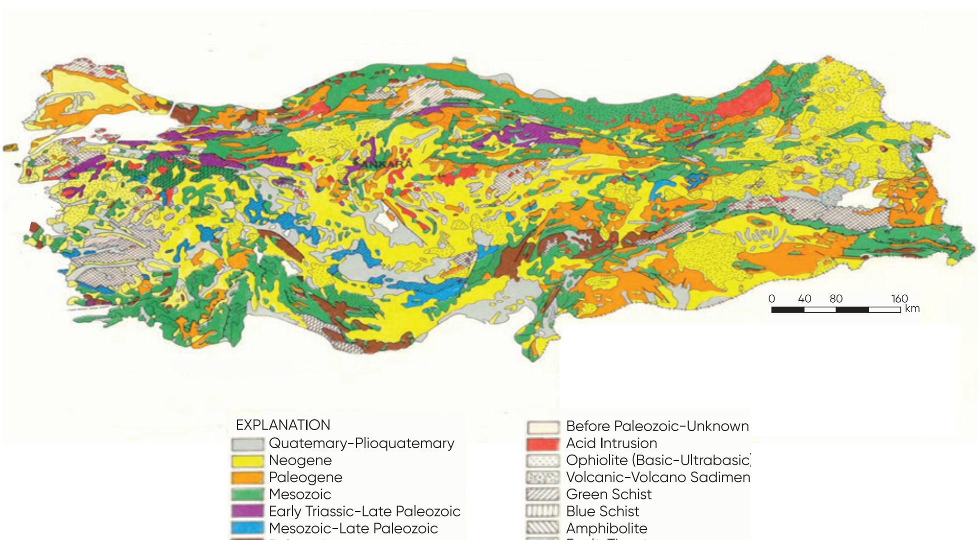


Figure 4.26 Turkey's Geology Map and Potential Unconventional Basins



Source: MTA, 2020

4.3.3.2 Eastern Mediterranean

Eastern Mediterranean is one of the current hotspots with intense exploration and production activity. Turkey has been active in the region as part of the strategies to enhance domestic production via increased offshore activities. A major discovery in the region can additionally decrease Turkey's reliance on foreign gas imports.

4.3.3.3 Unconventionals

Current activities in shale exploration aim to understand the production potential throughout the country. Exploration studies are ongoing in two basins: Thrace and South-Eastern Anatolia. Outside of North America, where the geology of shale plays is especially attractive and an extensive E&P infrastructure already existed, shale gas production has proved elusive. Whether Turkey possesses a favorable geology or not will only be known by increased application of advanced exploration technologies and the drilling of more wells. Turkey's geology indicates prospective regions for potential reserves, including other regions such as Central Anatolia and Western Black Sea (Figure 4.26).

Hydraulic fracturing has a long history in Turkey with the initial attempts in the Hamitabat tight sandstone formation in 1986. Further activities took place in the Silurian age Dadaş shale in the South-eastern Anatolia and in the Miocene-Oligocene age Mezardere shale in the Thrace.

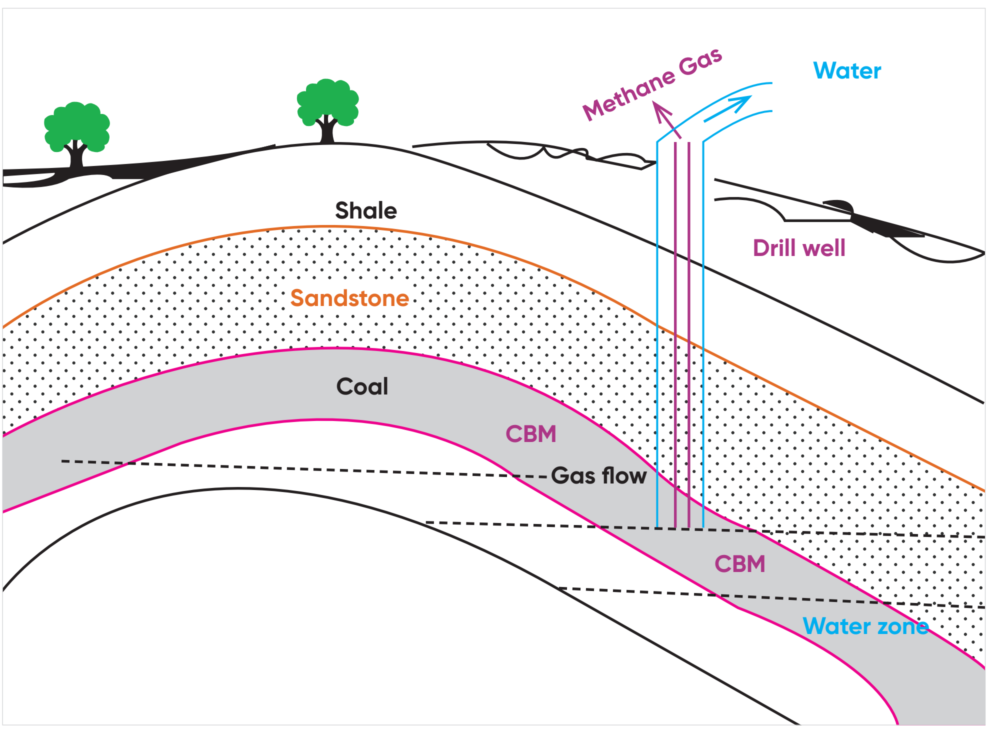
Table 4.2 High-Level Comparison of Dadaş and Barnett Shales

Parameters	Dadaş Shale	Barnett Shale
Surface Area Coverage	11,250 km^2	15,000 km^2
Formation age	L. Silurian, 416 million years	L. Carboniferous, 360 million years
TOC	0.5 – 5.5%	0.5 – 12%
Average Tmax °C	440-470	432-450
VRo %, maturation	0.6-1.2%	0.6-1.4%
Kerogen Type	II -III	II- III
Hot-shale thickness	50- 240m	30-250m
Porosity	1.5-3% (core) 0.5-6% (log)	4-6 % cores
Permeability	0.0139 – 0.0000143md core	0.001 – 0.000009md from cores
Avg. formation pressure	3500 psi	3700 psi
Reservoir pressure	3000-4000 psi	3000-5000 psi
Avg. formation temperature	3500 psi	3700 psi
Avg. formation depth	2200-3000m	2130-4000m

Source: EIA, 2015; IICEC database

First hydraulic fracturing in the Dadaş/Bedinan formation, east of Diyarbakır, was completed. Recently, Valuera and Equinor JV has drilled 3 deep unconventional wells (over 4,000 meters) in Keşan Formation in the Thrace basin in addition to several other wells in the last decade. Drilling of the Çeşmekolu-2/S well was completed at 4,750 meters in 2019 with hydraulic fracturing operation for 2020. Despite these various efforts, Turkey's unconventional basins remain largely unexplored. Current technology can help productive results if backed by adequate financing. The infrastructure oriented towards any unconventional play is far more complicated, thus necessitate sustained financial capabilities to start and expand the exploration and production aspirations. Dadaş Shale, in particular, possesses several similar characteristics with the Barnett Shale, one of the leading production bases in the United States[43] . These include the formation age as well as hot-shale thickness, porosity, permeability, and average formation pressure, temperature and depth (Table 4.2).

Figure 4.27 Schematic Geology of Natural Gas Resources



Reproduced from Zou, 2017.

[43] The Barnett Shale in Texas has been producing natural gas for more than a decade. Information from the Barnett Shale provided the initial technology stages for developing other shale plays in the United States.

4.3.3.4 Coal Bed Methane

Coal Bed Methane (CBM) is a hydrocarbon gas that is mainly composed of CH_4. It is generated and stored in coal beds in the adsorbed state. Coal is both the source rock and reservoir. CBM is a typical continuous gas deposit (Figure 4.27). CBM has similarities and differences from conventional natural gas. For example, the occurrence of CBM shows obvious zonation.

The first CBM assessment in Turkey was conducted in 1972 in the Kozlu Mine, Zonguldak (Western Black Sea region), but did not result in any gas production. According to the current Mining Law in Turkey, a mine with over 5m^3 gas per ton of coal should be producing gas. However, no CBM production has been performed yet. Western Anatolia lignite and Western Black Sea hard coal reserves would be candidates for a comprehensive CBM development program. Key technical success factors for a CBM project include many factors such as coal permeability, low ash content, high vitrinite, a high methane content and saturation percentage, adequate reservoir pressure in the coal layers, thermal maturity, reservoir thickness, hydrologic isolation, diffusivity, and a high gas flow rate.

4.3.3.5 Natural Gas Production in the TEO Scenarios

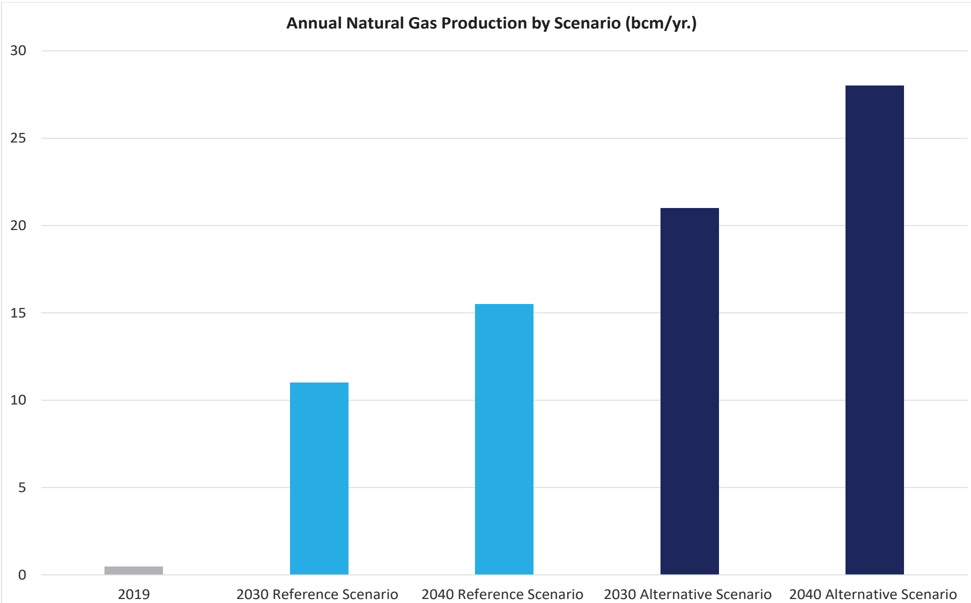
As discussed in Section 4.3.1, Turkey was able to meet only 1% of its total natural gas demand from domestic production in 2019. The recent discovery will contribute to reducing Turkey's total energy import bill given the substantial share of gas imports in Turkey's total energy imports and the projected demand increase in both scenarios.

The Reference Scenario shows annual production reaching 11.0 bcm/yr. until 2030 and further to 15.5 bcm/yr. with additional discoveries following the Tuna-1 location. The Alternative Scenario reflects a more optimistic exploration outcome mainly as a result of increased offshore exploration and a more intensified unconventional gas effort benefitting from best technology practices.

In the Alternative Scenario, around half of total annual demand in 2040 is met by domestic production compared to 25% in the Reference Scenario and only 1 % in 2019 (Figure 4.28). These assumptions are developed, in particular, to reflect the impact of the most recent findings and the opportunities to lower Turkey's energy import bill with the more-than-worthwhile efforts to find additional large fields.

It is well possible that major discoveries in other areas, besides the Black Sea, for example in the Eastern Mediterranean, could further decrease Turkey's reliance on natural gas imports, as discussed in 4.3.3.2, 4.3.3.3 and 4.3.3.4.

Figure 4.28 Annual Natural Gas Production Estimates by Scenario (bcm/yr.)



4.3.4 Achieving More Flexible and Competitive Supplies

Turkey started developing its natural gas industry in the late 1980s in order to fuel its economy while addressing urban pollution with relatively lower energy costs. BOTAŞ was chosen as the main tool in order to establish and develop gas infrastructure and also conclude gas sale and purchase agreements. BOTAŞ concluded several natural gas sale and purchase agreements with its counterparts in Russian Federation, Iran, Algeria, Nigeria, and Azerbaijan in the last three decades. The contracts reflected the practices of the natural gas market at that time including take-or-pay (ToP) obligations, oil indexed pricing and destination clauses restricting the resale of gas.

A substantial share of Turkey's long term import contracts signed in 1990s and 2000s are approaching their termination dates between 2020 and 2022 (see Table 4.3). Such contracts account for 15.9 bcm/yr., or about one-third of Turkey's supplies. Renegotiating these contracts on better terms and letting some of them expire entirely, could have a favorable impact on Turkey's balance of payments by lowering average gas import costs. Such renegotiations would be in line with global trends where consumers are getting more favorable terms on gas contracts for shorter time periods and also relying more on spot gas, taking advantage of an over-supplied world gas market. Imports of LNG accounted for a quarter of total imports in 2019 and have grown further in 2020. This is a trend that signals that BOTAŞ is taking benefit of its increasingly advantageous position as a gas customer. Also, as just discussed, besides Turkey's low gas consumption growth, significant new domestic supplies will likely have a large impact on the need for extending many existing gas import contracts.

Turkey has 16 long-term import contracts, including private sector contracts, at present. 14 of these are for the purchase of pipeline gas from Russia, Azerbaijan and Iran. The other two are LNG contracts from Algeria and Nigeria. With commencement of operation of the TurkStream line at the beginning of 2020, the delivery point of gas previously supplied via Malkoçlar on the Bulgarian border was changed to Kıyıköy on the Black Sea shore of Thrace. Existing long-term contracts sum up to 60.1 bcm/yr., well in excess of Turkey's current demand of about 45 bcm/yr. and with new Black Sea supplies, further in excess of Turkey's gas needs. BOTAŞ also had a shorter-term - three years – contract with Qatar for the import of 1.5 million tons (2 bcm) per year of LNG, which it may consider rolling over.

BOTAŞ' initial long-term purchase contracts included a destination clause. The destination clause prohibits the re-export of gas received under contract. This was a common feature in the international gas market when these contracts were signed. More recently, destination clauses have been quickly disappearing and, in some countries, for example the EU and Japan, they are prohibited by law. In the case of Turkey, they appear to be absent from new contracts signed by BOTAŞ and the private sector since around 2000. BOTAŞ was able to take advantage of the first Azerbaijani gas contract by executing an export agreement with DEPA of Greece in 2001. Re-exports under this contract began in November 2007 and Turkey has been meeting around one-thirds of Greek annual natural gas demand since then.

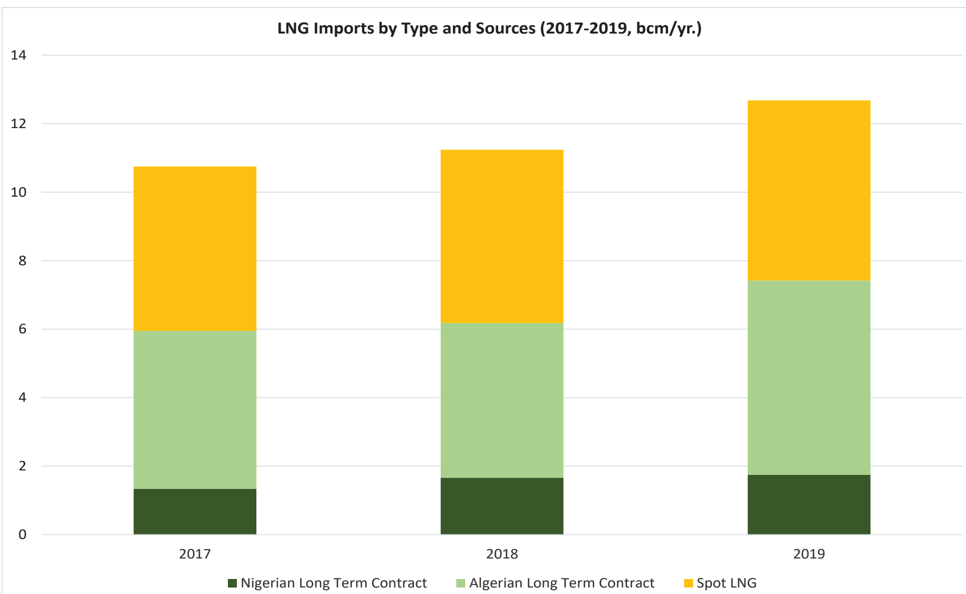
All of Turkey's gas import contracts are indexed to oil or oil product prices with a 6 to 9 months' lag. The cost of Turkey's imports of natural gas is thus correlated to global oil price developments, with a large exposure to the price volatility of the global oil market.

Table 4.3 Existing Natural Gas Import Contracts

Contract	Seller	Buyer	Delivery Point	ACQ bcm/yr. at 9000 kcal	Contract Term (years)	Start Year	Date of Expiry	Pricing
Azerbaijan, Shah Deniz 1	Azerbaijan Gas Supply Co. (AGSC)	BOTAŞ	Türkgözü	6.6	15	2007	30.4.2021	Indexation usually to oil product prices with 6-9 months lag
Nigeria	Nigeria LNG	BOTAŞ	LNG import terminals	1.3	22	1999	31.10.2021	
Russia - West route 1a	Gazprom, Russia	BOTAŞ	Malkoçlar to 2019, Kıyıköy from 2020	4	23*	1998	31.12.2021	
Russia - West route 1b	Gazprom, Russia	Four private companies		4	12--14	2007-2009	31.12.2021	
Algeria	Sonatrach, Algeria	BOTAŞ	LNG import terminals	4.4	20, plus 5+5	1994	31.10.2024	
Russia - Blue Stream	Gazprom, Russia	BOTAŞ	Durusu, Samsun	16	22	2003	31.12.2025	
Iran	NIGC	BOTAŞ	Gürbulak (Bargazan)	9.6	25	2001	30.7.2026	
Azerbaijan, Shah Deniz 2	AGSC	BOTAŞ	Eskişehir & Trakya	6	15	2018	30.6.2033	
Russia - West route 2	Gazprom, Russia	Four private companies	Malkoçlar to 2019, Kıyıköy from 2020	6	30	2013	2039-2042	
Azerbaijan (BIL)	AGSC	BOTAŞ International Limited	Türkgözü	0.15	33	2013	2046	

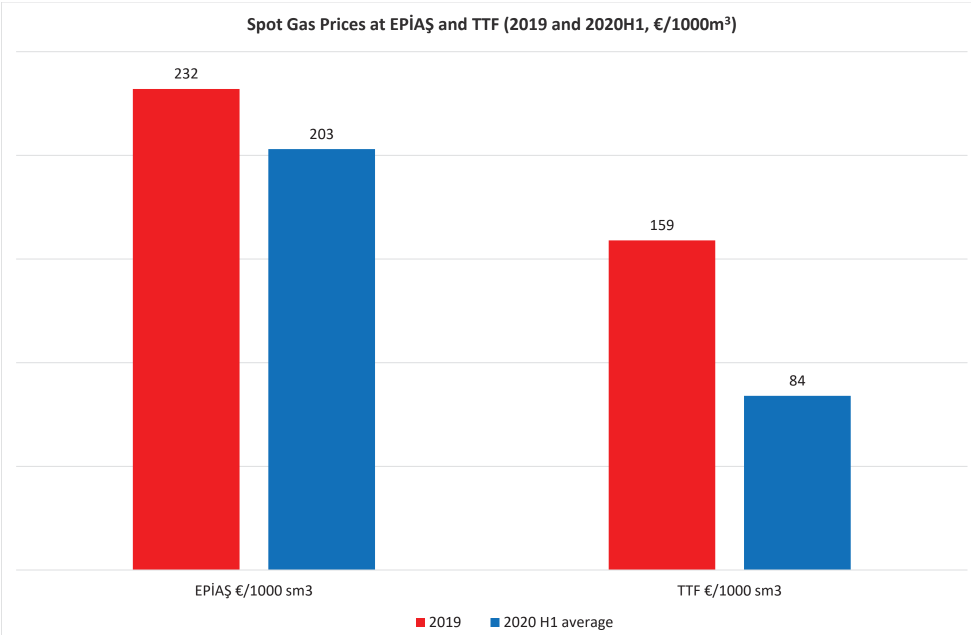
In 2019, imports of LNG accounted for 27% of imports of natural gas, up from 20% in 2017 (Figure 4.29). In the first half of 2020, their share jumped to another historic high, around 45%. During 2017-2019, spot LNG cargos represented 40-45% of LNG inflows to the Turkish regasification facilities. During the first half of 2020, this share increased to around two-thirds. Increasing imports of spot LNG have displaced more expensive pipeline imports into the Turkish gas market. Russian volumes decreased to 15 bcm/yr. in 2019 from about 29 bcm in 2017. Similarly, imports from Iran were reduced by 16% in this same period, not least because sabotage on the import line cut supplies for three months. The only increase of pipeline gas has been from Azerbaijan, following the commissioning of the TANAP pipeline in mid-2018 and the continuing ramping up of deliveries under BOTAŞ's second purchase contract with the Shah Deniz consortium.

Figure 4.29 LNG Imports by Type and Sources (2017-2019, bcm/yr.)



Despite all of Turkey's efforts to ensure a diversified gas supply, Turkish gas prices remain unlinked to price dynamics in Europe. Turkey's import costs are high compared to prices in European hubs where gas-to-gas competition is the fundamental dynamic. In an over-supplied market, it is a natural outcome that gas-to-gas competition causes lower prices. However, in Turkey in 2019, Daily Reference Prices at the OTSP averaged 46% higher than the average TTF price. During the first half of 2020, the differential rose, with the Daily Reference Price about 2.5 times the TTF average (Figure 4.30). Although the price differential with the TTF and other European hubs is expected to decline towards the end of 2020 as low oil prices work through into Turkey's contracted supplies, the anticipated differential is still significant. Existing import contracts limit adjustments in Turkey's terms of trade for natural gas.

Figure 4.30 Spot Gas Prices at EPİAŞ and TTF (2019 and 2020 H1,€/1000 m³)



All of Turkey's existing contracts have Take-or-Pay (ToP) limitations [44] that are estimated at above 40 bcm/yr. for 2020 and would normally limit a larger role for LNG import volumes to reduce Turkey's gas costs. However, this unfavorable situation could change as existing contracts approach their termination dates. Importers, in particular BOTAŞ, may decide to wait until the termination of their contracts, before importing shortfalls.

Three existing long term contracts with a total annual volume of about 16 bcm/yr. will expire by 2021. By 2026, an additional 20 bcm/yr. will also expire and that year a further 10 bcm/yr. will expire, reducing the existing contract base to about 12 bcm/yr. from 60.1 bcm in 2020 (Figure 4.31)[45]. As discussed in Section 4.3.2, natural gas demand has been declining since 2017 from about 55 bcm/yr. to 45.2 bcm/yr. in 2019.

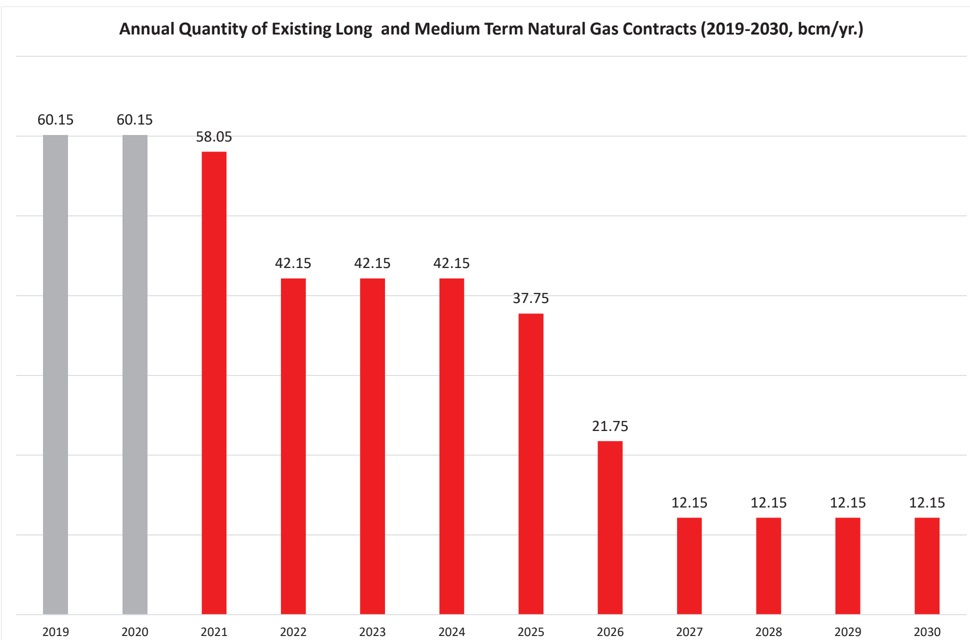
From 2022 onwards, re-establishing these ToP volumes anywhere near 40 bcm/yr. will no longer be required to ensure Turkey's gas supply. IICEC is not in a position to recommend a particular gas purchasing strategy except to note that ToP obligations should be gauged in relationship to Turkey's modest demand, especially considering the expected decline of natural gas use in the power sector, and the prospects for increasing domestic production.

[44] Contracts set a minimum contract quantity which the buyer should take. If the buyer falls short, he pays a share of the average cost of the gas shortfall and then has a period in which he may import this "make up gas", with a further payment for the unpaid share at the price when the gas is taken. The ToP ratios in existing pipeline contracts are usually 80-85% of annual contract quantities.

[45] Assuming the 2 bcm contract with Qatar is not renewed.

In addition, pricing should be linked to gas-to-gas hubs in line with global developments. With only modest gas demand growth out to 2040 (under IICEC's Alternative Scenario), there is an important window of opportunity for Turkey to enjoy more flexible and competitive supplies reflecting the gas-to-gas pricing towards which other markets have gravitated. These developments also provide an opportunity to have the private sector play a greater role as a counterparty to natural gas import contracts if it can rely on cost-reflective pricing in Turkey's wholesale and retail markets.

Figure 4.31 Annual Quantity of Existing Long and Medium Term Natural Gas Contracts (2019-2030, bcm/yr.)



Enhanced network capabilities over the past few years, as described in detail in Section 4.3.5, allow for meeting peak demand with supplies from BOTAŞ's multiple pipe-gas, LNG and storage injection points. IICEC observes that the availability of surplus capacity (around 30% over daily peak demand in 2019), especially the new LNG entry capacities, can enhance Turkey's negotiating power both for the future of existing contracts and in any new import arrangements. In an over-supplied domestic market outlook, Turkey is well positioned to benefit from current dynamics and trends in natural gas trading as well. However, it should be kept in mind traditional gas trading and pricing mechanisms have gone through a dramatic transformation. The onslaught of new LNG supply, especially from the US, Qatar and Russia (and Australia into the Asian markets), is challenging the legacy of oil indexation and the duration as the main pricing mechanism for gascontracts.

The market shows greater appetite to quickly transition from oil indexation towards gas-to-gas pricing. Oil indexation is becoming an archaic mechanism which will not survive, in the long run, against hub pricing. With the liberalization of the Turkish gas market and efficient operation of the Organized Wholesale Market (OTSP) allowing gas-on-gas direct competition, private sector companies, will engage in gas business and conclude sale and purchase agreements. As a result, private sector companies will make decisions about individual contracts and trade will happen where and when these companies see a market opportunity. These opportunities include enabling gas-to-gas competition similar to European hub developments that delinks the market pricing of natural gas from oil, more flexible spot and short term procurement arrangements and ToP obligations that match expected gas needs. Turkey's advanced gas transmission network, ample entry points, high regasification capacity and increased domestic production all support a flexible role for gas trading between Turkey and neighboring regions to balance Turkey's supply and demand and to lower net import costs.

Turkey can also promote a more liberalized gas market if it achieves more competitive terms of trade for its natural gas imports, providing a greater role for the private sector. Transforming Turkey's natural gas imports into a more flexible and competitive structure is essential if Turkey is to develop a more liberalized natural gas market and attract more competitive volumes to trade in Turkey's developing natural gas trading platforms, as will be discussed in Section 4.3.6.

In this context, the new concept of "spot pipeline" imports could prove transformational. Regulations published in 2019 allow BOTAŞ and other importers to request additional volumes from existing exporters of pipeline gas to Turkey. The highlights of these regulations are that EMRA will hold auctions for unused capacity on each import line[46]. At present, such unused capacity is limited to Malkoçlar (where a part of capacity is not booked by Gazprom) and to Kıyıköy (where EMRA may have still to resolve arrangements with Gazprom). However, from 2021, if expiring contracts are not extended, major opportunities could exist for use of this mechanism by private companies (provided they have a license for spot imports[47]) as well as by BOTAŞ. This could have two positive consequences:

- Ensuring lower prices for supplies from Gazprom and AGSC.
- Seeing the entry of new importers and a reduction of BOTAŞ's dominance of imports.

Bids will be ranked by the unit capacity rate offered by each bidder and awarded to the highest bidder or bidders. There is no reference to the price that the spot importer will pay to the gas supplier and, indeed, no reference to gas suppliers. No storage obligations for importers are specified. An early draft required 50% of sales be via the Organized Wholesale Market (OTSP). This has been removed, but a 20% requirement may later be introduced.

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[46] As set out in EMRA's Board Decision 8828 of September 12, 2019

[47] Existing licenses cover imports of LNG, CNG and pipeline gas

Successful implementation of these will require network cooperation agreements being signed with linking transmission systems operators. This does not seem to have yet happened. It will also require gas suppliers to consider the commercial implications of dealing with private sector companies rather than a trusted state-owned counterparty.

EMRA started holding auctions for unbooked capacity at the Malkoçlar entry point in 2020 and a recent auction was finalized. The auctions would enable a type of "price review" for expiring contracts, address the issue of potentially idle pipeline capacities and could result in new importers entering the market. Should this system develop, from the late 2020s it could be an important form of import to Turkey.

Turkey is thus on a pathway to achieve both supply security and a more competitive gas market, with improved terms of trade, continued diversity of gas suppliers, diversified entry points and import routes, increased storage capacity, increased domestic production, increased private sector participation and steps towards cost-reflective pricing. If this can be combined with policy shifts from stabilizing prices at predetermined levels to achieving longer term efficiency gains and cost reduction, social obligations when market prices rise can be fulfilled for a small part of residential consumers, who are vulnerable, without distorting prices in the market.

4.3.5 Infrastructure

Turkey's natural gas use began in 1976 with consumption of the limited indigenous gas production in a few industrial plants. Severe air pollution in big cities like İstanbul and Ankara, especially due to the use of coal in households for heating, was the main reason Turkey decided to switch these to natural gas. Turkey began natural gas imports from Russia in 1987. This was via the (then) Soviet Westward Line (interconnection with Bulgaria). An 842 km-length gas transmission line was constructed between the town of Malkoçlar on the Bulgarian border and the capital. Natural gas distribution started in Ankara in 1988. Other cities along this first transmission route (İstanbul, Kocaeli, Bursa and Eskisehir) followed after 1992. During the late 1990s and early 2000s, dense industry complexes along the first transmission line as well as new natural gas power plants facilitated the rapid growth of gas demand and led to interest in the establishment of an efficient and competitive gas market.

The gas transmission pipelines in Turkey are high-pressure pipelines, designed to operate at 75 bar. Under normal circumstances, a minimum pressure of 50 bar is maintained in major pipeline segments. BOTAŞ is the only license holder responsible for the operation of nationwide gas transmission lines. Although the Natural Gas Market Law[48] (NGML 4646) allows for licensing a merchant transmission grid inside Turkey, BOTAŞ remains the only company holding a transmission license and owns the existing transmission grid. In 2018, it completed the investments required to extend its network to all 81 provinces in the country.

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[48] This Law concerns with liberalization of the natural gas market and thus formation of a financially sound, stable, and transparent markets along with institution of an independent supervision and control mechanism so as to ensure supply of good-quality natural gas at competitive prices to consumers in a regular and environmentally sound manner under competitive conditions.

The total length of high-pressure lines has reached more than 18 thousand km. This grid is fed by six foreign transmission networks, two LNG terminals, two FSRU facilities, two underground storage facilities (USG) and three domestic production sites (Table 4.4). Nine compressor stations are in operation at present. BOTAŞ owns both UGS facilities and one of the existing LNG terminals. The other LNG terminal and one FSRU are owned by private players but their capacities are currently leased to BOTAŞ. A second FSRU is chartered and controlled by BOTAŞ, while a third FSRU, owned by BOTAŞ is due to start operation in Saros Bay located in the northern Aegean Sea by the end of 2020. LNG regasification facilities are also classified as storage facilities under the NGML provisions. Gas is handed over to the distribution companies at the inlet of the pressure reduction and metering stations that are directly connected to the high pressure grid.

There has been a rapid growth in daily entry capacity of the network during the past few years reaching about 319 mcm/d in 2019 up from 168 mcm/d in 2014. This sizeable capacity expansion is a result of the deployment of two FSRU units, a new underground gas storage facility in the Central Anatolia (Tuz Gölü UGS) and capacity expansions both in the existing two LNG Terminals and the Silivri UGS. With the ramping up of TANAP in 2019 and the start of Turk Stream in 2020, maximum daily withdrawal capacity of the system increased to 357 mcm/d, a doubling in 6 years (Table 4.4.). Total daily regasification capacity is now over 100 mcm, the second highest capacity in Europe after Spain. With deployment of the third FSRU unit and completion of capacity expansion projects in two existing UGS facilities, by the mid-2020s the network delivery capacity should exceed 400 mcm/d.

Blue Stream Gas Pipeline: Based on a 25-year contract signed between BOTAŞ and Gazexport in 1997, the pipeline was constructed between the Russian Federation under the Black Sea to Turkey. The Turkish part of the Blue Stream Project starts from Samsun and runs south to Ankara. The pipeline began operation in 2005, supplying gas under a contract for an annual 16 bcm/yr.

West Line Pipeline: BOTAŞ and SoyuzGazExport (now Gazprom Export) signed a 25-year contract in 1984. Natural gas imports started gradually from 1987 and reached 6 bcm/yr. in 1993. The West Line pipeline transits through the Ukraine, Romania and Bulgaria and enters Turkey at Malkoclar. The pipeline can carry 14 bcm/yr. As a result of the commencement of the TurkStream Pipeline, this pipeline is no longer expected to bring gas from Russia. However, having an established capacity, unbooked sections of this capacity may be used for enhanced trade in the region particularly via bidirectional flows.

The Baku-Tbilisi-Erzurum Natural Gas Pipeline (BTE): The BTE pipeline to supply natural gas produced from Azerbaijan's Caspian Sea Shah Deniz field to Turkey was realized under the Turkey-Azerbaijan Intergovernmental Agreement signed in 2001. The BTE pipeline is 980 km long and runs through the same corridor of the Baku-Tbilisi-Ceyhan Crude Oil Pipeline (BTC) transiting Georgia. Gas flow began in 2007 under a 15-year contract for 6.6 bcm/yr. between BOTAŞ and SOCAR.

Eastern Anatolian Natural Gas Main Transmission Line (Iran-Turkey): A contract was signed between Iran and Turkey in 1996 to supply about 10 bcm/yr. of natural gas. The Eastern Anatolian Natural Gas Main Transmission Line extends from Doğubeyazıt to Ankara via Erzurum. Gas flow began in 2001.

Trans Anatolian Natural Gas Pipeline (TANAP): In 2012, Turkey and Azerbaijan signed an agreement to construct a new pipeline that would carry Azeri gas to south-east Europe with offtake points in Turkey. TANAP is projected to carry 16 bcm/yr., of which 10 bcm/yr. will be transported to Europe and the remaining 6 bcm/yr. to be used by Turkey. BOTAŞ began off taking gas from TANAP at Eskişehir in mid-2018 and the first gas deliveries to Europe depend on the commissioning of the Trans-Adriatic Pipeline (TAP) due late 2020. Further details of the project are given below.

TurkStream Gas Pipeline: Agreement for construction of a new pipeline between Turkey and the Russian Federation was signed in 2016. This new pipeline, with a maximum capacity of 31.5 bcm/yr. consists of two lines each with a capacity of 15.75 bcm/yr., running from the Russian Federation through the Black Sea to the receiving terminal at Kıyıköy on the Black Sea coast of Turkey. One of the TurkStream's two lines is designated to replace the supply of Russian gas to Turkey via the Western Pipeline (Trans Balkan Line) allowing a direct access to Russian gas without transiting through other countries. The second TurkStream line carries Gazprom's exports via Turkey to Bulgaria and (from 2021), Serbia and Hungary. The first gas deliveries started in early 2020 both to Turkey and to Europe. Further details of the project are given below.

Silivri UGS: the Silivri UGS (underground storage), the first UGS project of Turkey, has been in operation since 2007. The facility makes use of two depleted natural gas offshore production fields located at the Northern Marmara. The field is owned and operated by BOTAŞ and has a current storage capacity is 2.84 bcm. The maximum withdrawal rate is 25 mcm/d.

Tuz Gölü UGS: Tuz Gölü UGS, operated by BOTAŞ, is a salt cavern whose first phase was commissioned in 2017. It is the largest gas storage facility at salt cavern foundations worldwide. Currently, the facility provides 0.6 bcm storage capacity and 20 mcm/d withdraw capacity. With the completion of a second development phase, the total working gas capacity will be 1 bcm with a daily injection capacity of 30 mcm and extraction capacity of 40 mcm.

BOTAŞ Marmara Ereğlisi LNG Terminal: This terminal is operated by BOTAŞ and serves mainly for the long term LNG purchase agreements of BOTAŞ with its Algerian and Nigerian suppliers. The terminal began operating in 1994 including three storage tanks, each with an LNG storage capacity of 85,000 m^3. The re-gasification capacity of the terminal is 8.2 bcm/yr. After several expansion works, its current send-out rate stands at 37 mcm/day and the terminal is capable of loading LNG on up to 75 trucks per day.

EGEGAZ Aliağa LNG Terminal: This terminal, located on the Aegean Sea shore at Aliağa, north of Izmir, is owned and operated by Ege Gaz, a private company. The terminal was constructed in 2003 and began operating in 2006. The Terminal has two storage tanks, each with an LNG storage capacity of 140,000 m^3. The re-gasification capacity of the terminal is 6 bcm/yr. Following expansion works in 2018, the regasification capacity is 14.6 bcm/yr., making it the biggest receiving terminal in Turkey. The first cargos were received in 2009. The terminal is used by BOTAŞ for its spot LNG purchases as well as cargos from its Algerian and Nigerian contracts.

Aliağa (ETKİ Liman) FSRU: Turkey's first FSRU (floating storage regasification unit) arrived in the Aliağa industrial area in 2016. The FSRU is operated by the private license holder ETKİ Liman, a subsidiary of the Turkish construction group Kolin. Since its arrival, the FSRU has received cargoes on a regular basis, particularly supporting Turkey's winter gas consumption. The Aliağa FSRU has a regasification capacity of 7.8 bcm/yr. and has 167 thousand m^3 cargo capacity. Half of the FSRU's capacity has currently been booked by BOTAŞ. The facility has reached a daily send-out capacity of 20 mcm/d.

Dörtyol FSRU: The Dörtyol port is situated close to the Ceyhan oil terminal in the Mediterranean Sea. *The MOL FSRU Challenger* arrived there in 2018. It was chartered from the Mitsui OSK lines (MOL) and is operated by BOTAŞ. In May 2020, BOTAŞ extended the initial charter. The Dörtyol FSRU has a regasification capacity of 7.3 bcm/yr. and has 263 thousand m^3 of LNG storage capacity. The facility has an initial maximum daily send-out capacity of 20 mcm.

In addition to these established entry capacities, several projects are under development to increase inflows into the Turkish transmission grid. A capacity expansion project in Silivri UGS is currently being implemented. The project involves a new gas processing facility and new offshore wells. Once completed, the UGS will reach 4.6 bcm storage capacity while the daily withdrawal capacity would become 75 mcm/d. This project is targeted to be completed by 2023. There is also another capacity expansion project for Tuz Gölü UGS. The contract was awarded in March 2019. With the projected completion of this investment by 2023, the storage capacity of the facility would increase to 5.4 bcm and the withdrawal capacity would be 80 mcm/d. The cost of these expansions are estimated at $1.2 billion. There are also a few private sector licensees for new UGS facilities in the vicinity of Tarsus city in the South as well as around the Tuz Gölü area with a total storage capacity of 5 bcm. Environmental Impact Assessments for these planned facilities have been completed. However, no investment decisions have been made.

A third FSRU Project to be located in Saros Bay (North East of Aegean Sea) by BOTAŞ is also ongoing with an initial capacity of 20 mcm/d. Recent interest from some private industry players to deploy additional FSRU projects indicate that Turkey would expand FSRU based entry-capacities further in this decade. These plans are motivated by the current outlook of global and regional gas trade and the flexibility and competitiveness opportunities provided via spot and short term LNG procurements.

Table 4.4 Maximum Daily Withdrawal Capacity Expansion Since 2014

Maximum Daily Withdrawal Capacity per Year (2014-2020, Sm^3/d)							
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Malkoçlar	51.4	51.4	51.4	51.4	51.4	51.4	44.8
Durusu	47.3	47.3	47.3	47.3	47.3	47.3	47.3
Marmara Ereğli	22.0	22.0	22.0	22.0	27.0	35.1	35.1
Türkgözü	19.0	19.0	19.0	19.0	19.0	21.1	19.0
Gürbulak	28.6	28.5	28.5	28.5	28.5	28.5	28.5
Egegaz		16.1	16.1	24.5	39.5	39.5	39.5
Değirmenköy, Silivri		20.0	20.0	20.0	25.0	25.0	25.0
Akçakoca TPAO		0.2	0.2	0.2	0.4	0.4	0.4
Temi Edirne		1.0	1.0	1.0	1.0	1.0	1.0
Etki FSRU				20.0	20.0	20.0	20.0
Dörtyol FSRU					20.0	20.8	20.8
Marsa Gelibolu					1.0	1.0	1.0
Tuz Gölü					20.0	20.0	20.0
TANAP, Eskişehir- average					2.8	8.2	13.7
Türkakım Kıyıköy							40.7
TOTAL	**168.3**	**205.5**	**205.5**	**233.9**	**300.0**	**319.2**	**356.7**

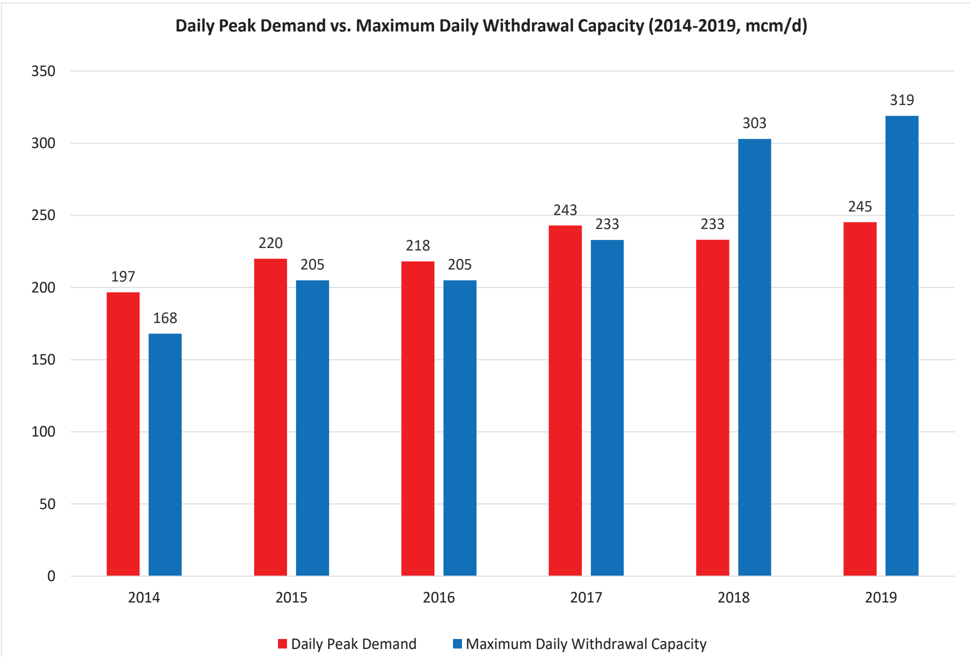
Source: BOTAŞ, 2020

Note: Figures for TANAP are average of first and second half capacities.

In the period 2010 to 2014, gas security had become a more serious issue for Turkey as the daily send-out capacities were short of rapidly increasing peak demand, particularly in cold winter periods. This situation sometimes required that gas supply to the power sector and some industrial facilities be curtailed. With the investments undertaken since 2018, these curtailments no longer occur. Neither are they expected to occur in the medium to long term. This is a major improvement in Turkey's energy security.

Currently, the reported daily maximum network injection capacity (Figure 4.32). The natural gas grid is able to accommodate a N-1 situation, that is should the largest single entry volume be lost (currently that at Durusu at 47.3 mcm/d). With a more sluggish demand outlook compared to the past decade and ongoing capacity expansions in the network, the grid is not expected to encounter a problem in meeting seasonal and daily peak demand. The grid is also not likely to encounter a capacity problem during dry seasons when hydro generation is limited and more output is required from Turkey's natural gas fleet: at these times heating demand is at its minimum. Nevertheless, planning, monitoring and management of Turkey's gas supply system remains essential to ensure sustained energy security and a well-balanced supply demand structure without major idle capacities in the system.

Figure 4.32 Daily Peak Demand vs. Maximum Daily Withdrawal Capacity (2014-2019, mcm/d)



The IICEC views that the network has already shown its ability to accommodate the volumes under pipeline gas contracts and effectively utilize the regasification capacities at LNG terminals and FSRUs. The network now benefits from more diversified supply points in the vicinity of major demand centers in the Marmara and Aegean regions. However, the loss of any major supply source needs to be assessed in terms of significant pressure drops in these regions where the industrial and power generation demand are also concentrated. This requires continued monitoring and planning and other grid management actions. Significant investments were realized during the past few years to develop additional capacity and improved redundancy for the compressor stations. Similar to all well-functioning gas grids, any bottlenecks for offtakes in particular locations need to be identified and addressed as part of the overall grid management system and are typically addressed with minor changes such as the addition of further loops.

The investment requirements of the network should be determined in accordance with potential increases in supply sources along with the projected increases in demand. The gas infrastructure sets the limitations for supply and demand regarding the physical flexibility of the system. Turkey's increasingly growing investments in recent years into an expanded gas infrastructure is also considered to be important for commercial flexibility. Nevertheless, given a large market compared to most European countries, and an increasingly shifting demand for gas away from the power sector to households and industry, Turkey's natural gas system has the potential for additional physical and commercial flexibility. This can be achieved by an efficient utilization of the asset base and with effective allocation of investments along the natural gas value chain.

Access to the grid is governed by the Grid Code, the "Network Operating Principles" (shortly referred as ŞİD in Turkish). This was prepared by BOTAŞ in consultation with market participants and, after approval by EMRA, published in the Official Gazette in September 2004. ŞİD lays down the general and detailed rules and principles governing the rights and obligations of the transporter and of shippers regarding the transmission service, including system entry, capacity allocation, system balancing, metering and the conditions and characteristics of the use of transmission system. Following amendments in 2018, BOTAŞ is required each year to prepare a 10-year network capacity report, a move in line with international practice. The first report was prepared in 2019.

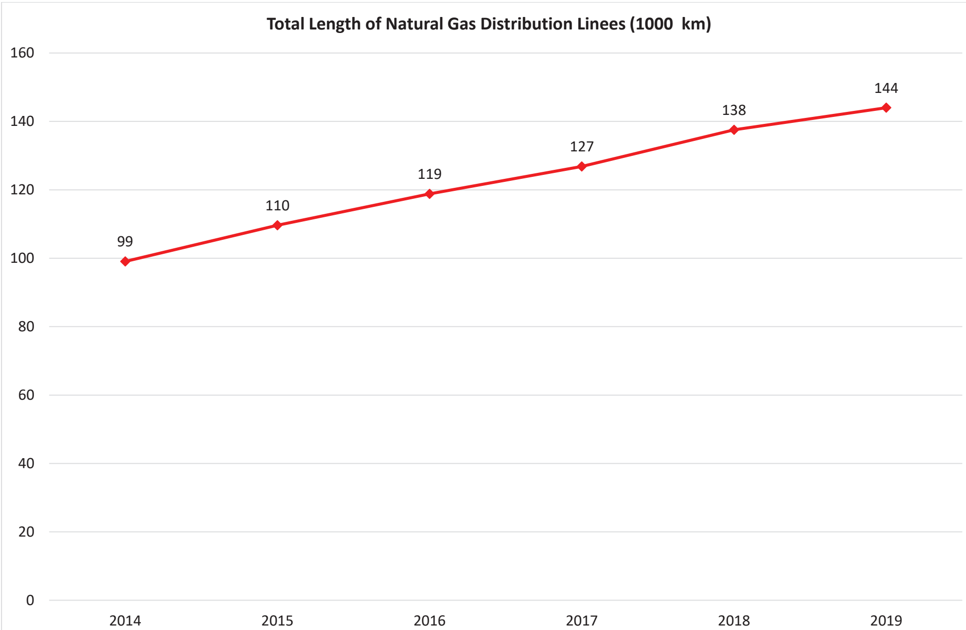
Turkey's gas distribution networks are among the largest in Europe and are largely privatized, except for Istanbul city network that is currently owned and operated by the city's municipality. When the NGML was first published in 2001, the number of provinces having access to residential gas was only 6 (İstanbul, Ankara, Bursa, Eskişehir, Adapazarı and İzmit). Natural gas is now available in all of the 81 provinces, with gas available in 550 municipalities and towns. This is a result of a long pursued policy aimed at ensuring wider utilization of natural gas in households as a more sustainable and comfortable fuel choice compared to coal and oil products. The result is a major success, delinking demand for energy use in building from energy sources with a higher carbon footprint.

The distribution companies provide access to infrastructure in their licensed regions as part of requirements by EMRA during distribution licensing auctions and based on a regulatory framework defining investment schemes, operational aspects, and investor return. As a regulated business, the revenues of the distribution companies are dependent on service charges and tariffs approved by EMRA. The distribution network increased from about 100,000 km in 2014 to 144,000 km in 2019 (Figure 4.33). In 2019, natural gas distribution network grew by 6% and the total number of subscribers reached 15.9 million. In addition, there are about 0.6 million eligible consumers who are free to choose their suppliers. Until the end of 2019, there had been a cumulative investment of 52 billion TL in real terms by natural gas distribution companies.

At present, 65% of those having access to gas are active users. Natural gas is in cost competition with coal for domestic heating in some regions, and affordability is often a consideration. Furthermore, the cost of the domestic installations required to enable burning gas may act as a barrier for consumers who desire to switch to gas. Therefore, the distribution sector focuses on new business and financing models to enable more gas use in the already gasified regions.

Efforts are being made to use data analytics to advance gas use and increase its efficiency. New research is being undertaken to monitor and assess grid losses to improve efficiency. Another project aims at monitoring and assessment of gas use on an hourly and daily basis for different consumer segments as well as understanding different geographical and meteorological conditions and income levels.

Figure 4.33 The Total Length of Natural Gas Distribution Lines (2014-2019, km)



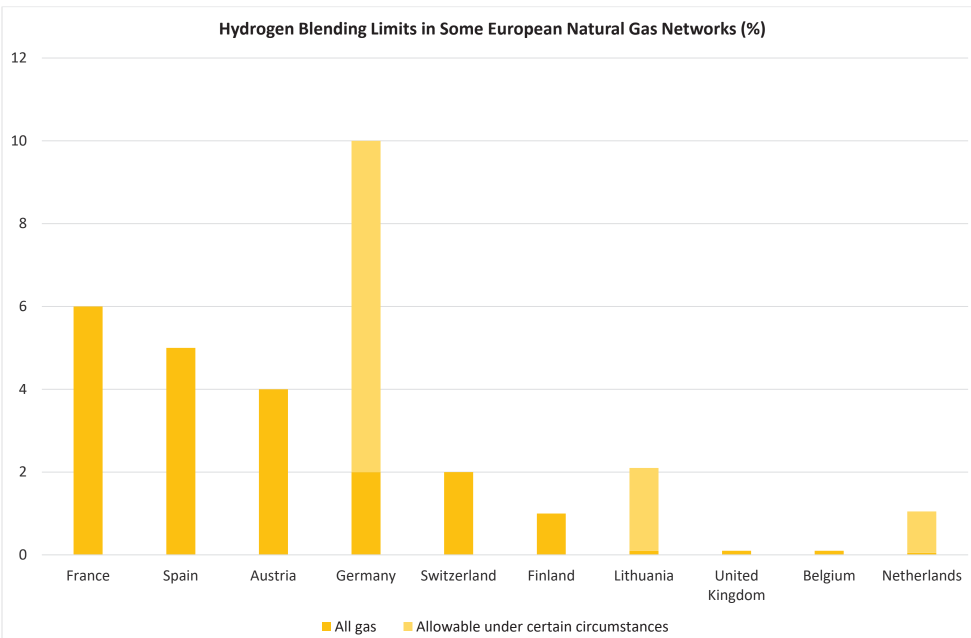
Source: BOTAŞ 2019; GAZBİR 2020

Most recently, a pilot project was launched on blending hydrogen into Turkey's natural gas network. This project, which has the support of EMRA, would employ "green hydrogen", produced from renewable electricity. An R&D center was established for this purpose in Konya within the Test and Calibration Center of GAZMER[49]. The first assessment of blending a percentage of hydrogen with natural gas has been finalized. It concludes that blending up to 20% might be feasible even though lower blending limits are being used in most other countries at present (IEA, 2018; Atfield and Pinchbeck, 2013). A number of factors need to be considered including the effect of higher hydrogen blends on end use equipment and the compressors used to transmit gas through the pipelines. A 6% hydrogen blend is targeted for the first commercial phase and is in line with limits being established in some countries although others have established 2% limits based on end-use equipment considerations (Figure 4.34). This project is expected to serve in preparation for a wider hydrogen roadmap for the Turkish energy economy as well as to provide some reduction of Turkey's carbon footprint. However, as the energy content of the pressurized volume of hydrogen gas is about one-third that of methane, a blend of zero carbon hydrogen at the 6% level only reduces the gas needs and the CO_2 emissions of pipeline gas by 2%.

[49] GAZMER was established in 2018 to consolidate training, audit and R&D activities in the natural gas sector.

The latest Government announcements include aspirations to produce hydrogen from Turkey's domestic coal resources. Although hydrogen use does not have an immediate potential to alter the energy balances for this or the next decade, these hydrogen initiatives are timely and should help Turkey benefit from global technology developments. IICEC believes that prospects for using hydrogen as an energy carrier would become much stronger for Turkey with sustained technology efforts, especially as a sustainable solution for industrial processes and other heating purposes, as discussed in Chapter 6 (The Energy Transition). IICEC also notes that carbon capture from coal is considerably less expensive when coal is being used to produce hydrogen than when coal is being burned to produce electricity. This is also discussed in Chapter 6 and could be a cost-effective way to use Turkey's coal resources in an environmentally sustainable way.

Figure 4.34 Hydrogen Blending Limits in Some European Natural Gas Networks



Source: IEA, 2020

Overview of Regional Projects

- **The Trans-Anatolian Natural Gas Pipeline Project (TANAP)**

The TANAP project was developed to open up a new gas supply line from Azerbaijan to Europe through Turkey and serve for improved supply security and diversity in the Turkish and European gas markets. The opportunity to accomplish this began with the discovery of a large gas reserve in the Caspian Shah Deniz field.

The Azerbaijan Shah Deniz Phase-II sale contract was signed in 2010. Later, a MoU was signed between Turkey and Azerbaijan for the construction of TANAP in December 2011 incorporating a Framework Agreement that 6 bcm/yr. from the project would be purchased by Turkey and 10 bcm/yr. would be sent to Europe via BOTAŞ' transmission network. Azerbaijan then decided that it wished a stand-alone transit line to Europe and both the Intergovernmental Agreement (IGA) and Host Government Agreement (HGA) for this were signed in 2012 and ratified by the Turkish Parliament in 2013.

Initially, TANAP was projected to cost $11.7 billion. By realizing various efficiencies in all aspect of project development, the actual cost was reduced to below $8 billion. TANAP partners received $3.75 billion in loans from a number of different international finance institutions, including the European Bank of Reconstruction and Development (EBRD), the Asian Infrastructure Investment Bank (AIIB), the World Bank. Also, the European Union allocated a grant of $10.2 million.

The activities related to the project are carried out by TANAP Natural Gas Transmission Company where BOTAŞ has a 30% share, Southern Gas Corridor Corporation[50] 58% and BP 12%. The TANAP pipeline has a 56-inch diameter in the 1,330 km long section between the Turkish - Georgian border (the Türkgözü Entry Point) and Eskişehir Exit Point. Gas deliveries into BOTAŞ's national transmission grid started at Eskişehir in June 2018. The system is scalable up to 30 bcm/yr., by adding additional pumping capacity, if warranted by supply and demand considerations.

The emergence of TANAP marked the end of the Nabucco Project to carry gas from Azerbaijan to south-east Europe. The Nabucco Project was reshaped, starting from Turkish-Bulgarian Border, and renamed Nabucco-West. This project then found itself in competition to act as connection with Europe with the Trans Adriatic Pipeline (TAP) using the Greece-Albania-Italy route. In June 2013, the TANAP consortium selected TAP to complete what is now often called the "Southern Gas Corridor". TANAP together with the South Caucasus Pipeline (SCP) and the Trans-Adriatic Pipeline (TAP) now form the elements of this corridor into Europe (Figure 4.35). The Trans Adriatic Pipeline (TAP) is an 870 km-long gas pipeline which starts from Kipoi, at the vicinity of the border between Turkey and Greece (the interconnection point with TANAP) and ends at Brindisi in Italy, having passed through Greece, Albania and the Adriatic Sea. The lengths of the Greek and Albanian section are 547 km and 211 km, respectively. The offshore pipeline section length is105 km, at a maximum depth of 820 m. The initial capacity of the pipeline is about 10 bcm/yr. TANAP is expected to commence its deliveries to Europe in late 2020.

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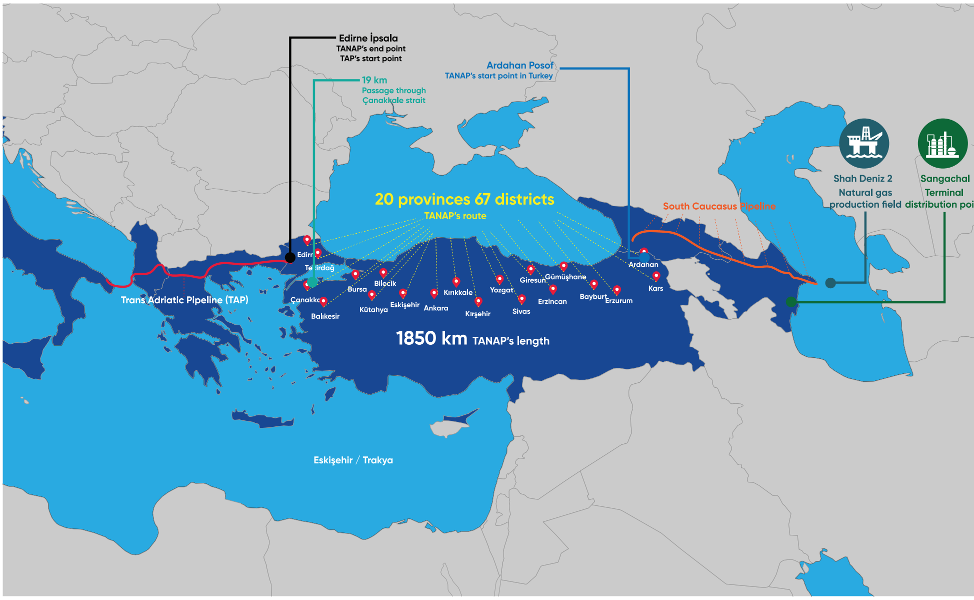
50 The joint venture of SOCAR and Azerbaijan Economy Ministry.

Figure 4.35 Shah Deniz Phase II Value Chain, the TANAP and TAP Project Routes



Source: TANAP, 2020

- **TurkStream Project**

The TurkStream project dates back to the efforts of Gazprom in 2010 to add a new gas export route to the Europe under the project "South Stream". Problems in gas transit arrangements with Ukraine side were the main driving factor for this project. South Stream was planned to pass from Russia under the Black Sea to Bulgaria, Serbia, Hungary, and Austria. The capacity of this trunk line was planned to reach 63 bcm/yr. and the cost estimated at $50 billion. However, differences between Russia and the European Commission, along with appreciation of Turkey's increasing role as a gas transit player and its domestic gas demand, led Moscow to propose an alternative route, Turk-Stream, that would provide a direct link to the Turkish gas transmission system and also transit Turkey to access Europe.

With the project reduced from four lines of 15.75 bcm/yr. capacity to two, the IGA between Russia and Turkey was signed in 2016. Laying of the pipe for the first offshore string started in 2017 and construction and commissioning works for the receiving terminal (Kıyıköy) and interconnection pipeline (with BOTAŞ Grid at Lüleburgaz) were completed during the last quarter of 2019.

The TurkStream pipeline system is made up of two parallel lines: TurkStream 1 and TurkStream-2, each with 15.75 bcm/yr. capacity. The pipelines run from the Anapa compression station in Russia to Kıyıköy on the European side of Turkey. The offshore part of the pipeline from Russia to Turkey crosses the Black Sea bed, reaching a maximum depth of 2,200 m. The individual lines have a 32-inch diameter and the pipeline walls are made from carbon manganese steel, 39 mm thick, to enable it to withstand the high pressure at the 2,200 m depth. The length of the offshore part is 910 km.

The first gas deliveries to Turkey and Europe were in January 2020. It was reported that 54% of this volume was delivered to the Turkish domestic market, while the remaining 46% was transported into the Turkish-Bulgarian border. TurkStream-1 feeds exclusively the Turkish gas market and its delivery point is at Luleburgaz where it connects with the main west-east line of BOTAŞ. Turk Stream runs from Kıyıköy to the Bulgarian border and link up with Bulgarian grid at Malkoçlar. In 2020, TurkStream 2 was supplying gas to Bulgaria and Greece. From late 2021, it is due to be connected to the Serbian and Hungarian gas grids (Figure 4.36).

Figure 4.36 TurkStream Pipeline

Source: TurkStream, 2020

- **Other Potential Gas Import Sources for Turkey**

Turkmenistan has the richest gas sources among Central Asian countries. Gas import from Turkmenistan to Turkey and further to European gas market has been on the regional energy policy agenda for a long time. The most plausible option for a pipeline is via the Caspian Sea using Turkmen and Azeri territorial waters. The continuing unsettled legal status of the Caspian Sea creates an obstacle for developing such projects. The latest development for the status of the Caspian Sea has been the signature of the "Convention on Caspian Sea's Legal Status" in August 2018 by surrounding countries. While this Convention was an important step forward, especially with respect to drilling rights, the general view is that there is still lack of clarity in opening the way for pipeline projects across the Caspian Sea. In order to avoid the Caspian Sea, a pipeline would have to be built through Iran to reach Turkey but, for a variety of reasons, that is also not a commercially attractive approach.

The gas production potential in Iraq, specifically in the North, has drawn attention in global scale with its very low extraction costs and favorable economic feasibility prospects. Although much of produced gas in Northern Iraq would be projected for local consumption (specifically to fuel gas fired power plants), a considerable volume could be exported to Turkey. The construction of the branch line with Turkey is nearly completed. It starts from the Turkey-Iraqi border and interconnects with the Turkish grid at Bismil with a length of a 300 km and 40-inch size. Future developments would yield introduction of Iraqi gas as a new source into Turkey's developing gas market.

4.3.6 Market Developments

When the first gas import contracts came to the agenda, BOTAŞ (Petroleum Pipeline Corporation) originally established to transport crude oil through pipelines, was empowered to handle the transportation and trade of natural gas. Decree 397 of 1990 on Natural Gas Utilization gave it the monopoly of natural gas import, transportation and wholesale. Where distribution was concerned, decisions on this were left to the Council of Ministers.

The formal monopoly of BOTAŞ (except in the distribution sector) continued until 2001 and was then limited by the Natural Gas Market Law (NGML) in 2001. The enactment of the NGML was an important step for the Turkish natural gas sector. The law aimed at liberalization of the natural gas market and the formation of stable, transparent and financially sound market conditions to ensure that natural gas would be supplied at competitive conditions. The law defined six market activities - import, transmission, wholesale, distribution, (re) export and storage (LNG terminals and underground storage facilities). Participants in all these activities required licensing from the regulatory authority, the EMRA. Normally a separate license is required for each activity, though an entity holding an import license is not required to obtain a separate wholesale license. Production is excluded from the purview of the law, and this also allowed gas producers (mainly in the Thrace area) to operate pipelines to supply gas to their customers.

Transit is not classed as a market activity (see Table 4.5) but the NGML requires EMRA to take transit activities into account when considering investments in the national grid and authorizes it to establish preferential tariffs for gas transit (Articles 4.4.c.8 & 11.2).

Table 4.5 The Number of License Holders in the Natural Gas Market (December 2019)

License Type	Number of Licensees	Number of Active Licensees
Import (Long Term)	18	16
Import (SPOT LNG)	52	12
Transmission (Pipeline)	1	1
Transmission (LNG carriage)	14	9
Storage (LNG Terminals)	4	4
Storage(UGS's)	4	1
Wholesale	41	20
Wholesale(Producers)	10	8
CNG (Transport-Distribution)	41	23
CNG (Sale)	38	32
CNG (Auto CNG)	16	15
Export License	17	2
Distribution	72	72
Total	**328**	**215**

Source: EMRA, 2019

BOTAŞ was the sole shipper using Turkey's gas distribution system until 2007 when a private wholesale company began shipping gas produced offshore in the Akçakoca area of the Black Sea. At the end of that year, Shell also started using the system, the first of four companies which had taken over imports of a total of 4 bcm/yr. formerly supplied by Gazprom to BOTAŞ via Malkoçlar. Table 4.6. shows the development in the number and type of license of shippers that have access to the transmission network. The number of wholesale companies qualified as shippers increased from 2010 onwards. This was caused by the amendments made to the network code (ŞİD) in 2008 to facilitate the title transfers among shippers by means of virtual point designations such as "National Balancing Point" and "Transfer Entry/Exit Points". It should be emphasized, however, that BOTAŞ remains the operator of Turkey's only national gas transmission network (TSO) and regulator of Turkey's gas infrastructure system.

Since 2001, Turkey has taken a number of steps aiming at the formation of a competitive natural gas market (Figure 4.37). At the time the NGML was drawn up, Turkey gave priority to becoming a full member of the EU, and the NGML was influenced by the First Gas Directive (98/EC/30). However, few of the 2001 targets have been pursued.

Table 4.6 Shippers with Access to the Natural Gas Transmission Network (2007-2019)

	Import Licensee	Wholesale Licensee	Export Licensee
2007	2	1	1
2008	2	1	1
2009	6	3	1
2010	6	9	1
2011	6	12	1
2012	6	13	1
2013	9	18	1
2014	9	20	1
2015	9	22	1
2016	9	23	1
2017	9	32	1
2018	9	33	1
2019	9	33	1

Source: BOTAŞ, 2020

The NGML required the unbundling of BOTAŞ's trading, transmission and other activities into separate companies. The name BOTAŞ would be carried by the company carrying out trading activities and holding the import contracts. The transmission company would remain a state entity. Others would be privatized "within two years". All this was to start after 2009. However, BOTAŞ was unbundled only where its accounting was concerned - and such accounts have not been published.

The NGML also required BOTAŞ to reduce its share of imports to 20% by 2009. However, of the 47 bcm of gas imported to Turkey in 2019, BOTAŞ was the counterparty for 96%, up from 83% in 2017. BOTAŞ thus remains the major supplier in the market, the single owner and operator of the gas transmission system and both storage facilities, the operator of two out of four LNG terminals and booker of major shares of the capacity of the other two, and with de facto priority access to transmission capacity. Continuing this situation indefinitely would preclude the competitive evolution of Turkey's gas market, not only because of BOTAŞ's favorable position as both gas trader and gas system operator but because any competitive market cannot be dominated by any entity, whether private or public. As long as one party is the counterparty to essentially all of Turkey's natural gas imports, it means that one party controls the supply, and therefore the price, of Turkey's natural gas in the domestic market. Should it choose for public policy reasons to sell gas below its cost of imports – which it did in 2017 and 2018, when it recorded operating losses – this makes it hard for private sector importers to supply gas without incurring losses. Evidence of this is the fall in imports by private importers from Gazprom since January 2019. Equally, the lack of any private imports of spot LNG (apart from the occasional cargo by Ege Gaz through its own terminal) evidences the difficulties for importers of exercising their statutory rights for third party access.

Figure 4.37 Key Steps in Development of the Natural Gas Sector in Turkey

1987	The start of first natural gas imports over the Western Line from Russia (Malkoçlar)
1988	Urban natural gas distribution activities began in Ankara
1992	The start of natural gas distribution activities in Bursa and Istanbul
1994	BOTAŞ Marmara Ereğlisi LNG Terminal goes into operation
2001	Enactmant of the Natural Gas Market Law
2004	Opening of the BOTAŞ Transmission Network to third parties Network Code (ŞİD) coming into force
2006	Commissioning of EGEGAZ LNG Terminal
2007	Commissioning of TPAO Silivri Underground Storage Facility
2009	The start of Spot LNG imports, 4 bcm/yr. contract transfer from BOTAŞ to private sector Amendments to the ŞİD
2013	6 bcm/yr contract takeover by the private sector
2015	The Establishment of Energy Exchange Istanbul (EPİAŞ)
2017	Publication of Market Operating Rules and Procedures (PUE) Commissioning of the first phase of BOTAŞ Tuz Gölü Storage Facility Commissioning of the first FSRU (Etki Liman)
2018	Launch of the Organized Wholesale Natural Gas Market (OTSP) Commissioning of the second FSRU (Dörtyol)
2021	The establishment of Futures Market (planned)

Implementation of the Network Code (described above) has played an important role in terms of liberalization and preparing the ground for an organized wholesale market. New products such as short term (daily) capacity booking and interruptible capacity booking are complementary to what has been achieved so far. Further developments would also be related to the alignment with the ENTSO-G Network Codes that are applicable for the cross border transmission systems and trading with Europe. Harmonization of the nomination processes and offering bidirectional flows at the western interconnections (both with Greece and Bulgaria) are opportunities for more international gas trade and the ability to balance Turkey's gas demand, supply and storage system and realize opportunities for cost reduction, arbitrage and profits.

The establishment of the Energy Stock Exchange (EPİAŞ) is a key development for both the power and natural gas markets. Since 2015, EPİAŞ has been carrying out its operations to improve efficiency and transparency in the natural gas market. In 2017, EPİAŞ initiated the Organized Wholesale Natural Gas Market (OTSP), the first such market in Turkey and its region. Trading started on September 1, 2018, with EPİAŞ offering gas market participants the opportunity to trade in daily, intraday, and day-ahead markets.

The platform enables spot market transactions in natural gas, balancing transactions and reconciling of imbalances which is of great importance in line with Turkey's ambition of becoming a gas trading center in the region and will enable the country to have a strong and effective role in the pricing of natural gas. Turkey would more strongly contribute to the region by enabling natural gas trading activities to be performed in an equal and transparent manner. The goal for the OTSP is to become a more liquid platform for day-ahead and intraday gas trading with reference market prices. The market is not yet designed to have long-dated futures contracts. All market players need a Standard Transportation Contract signed with BOTAŞ. BOTAŞ participates as the Residual Balancer[51] .

With the commissioning of the OTSP, Turkey has become the first country in its region to open a trading platform for natural gas on a daily basis. The daily reference price (GRF)[52] is the weighted average aggregate of the day-ahead and intra-day contracts. EPİAŞ operates a central data and analysis platform, its so-called Transparency Platform which has been meticulous in its publishing and reporting of market data.

In June 2020, EPİAŞ added weekly products to trading opportunities (Figure 4.38). In addition to the 54-hour market structure for day-ahead and intra-day markets (Figure 4.39), this newly-established market provides trading with two, five and seven-days delivery and supports balancing actions of market participants on a weekly basis.

[51] A Residual Balancer can carry out transactions under the OTSP to assure physical balancing of the network when needed.

[52] The Daily Reference Price (GRF) is the natural gas price determined in accordance with the finalized bilateral settlements and delivery dates.

Figure 4.38 Key Innovations in the Continuous Trading Platform

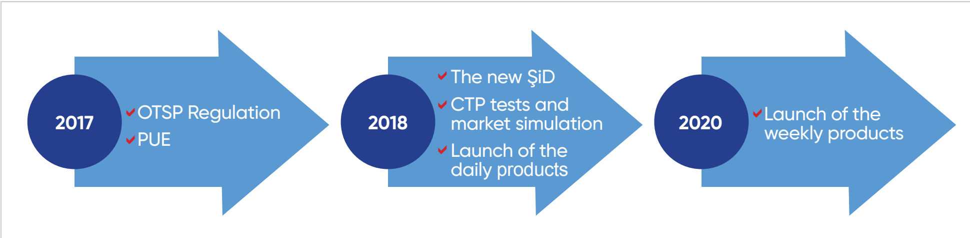
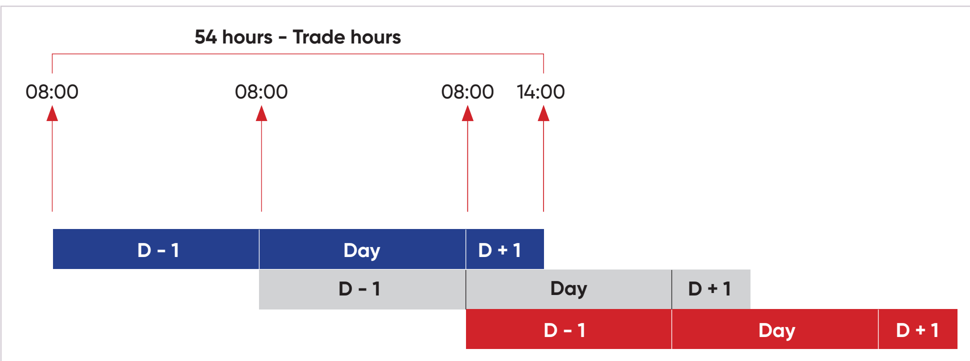


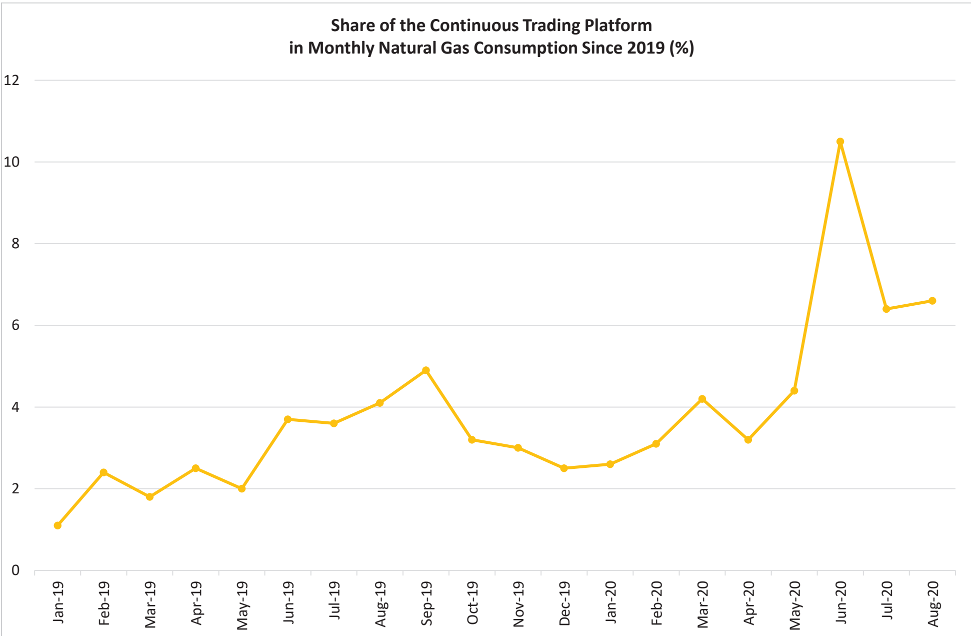
Figure 4.39 Daily Trade in the Organized Natural Gas Market



The OTSP has been encouraging more participants to trade volumes. However, due to its dominant market position, BOTAŞ has dominated the exchange. For example, during the initial four months of operation in 2018, more than 70% of the traded volumes were the outcome of BOTAŞ's balancing actions. Less than 30% of the trades were between private sector participants. Since the beginning of 2019, OTSP -traded volumes only corresponded to 3.8% of Turkey's natural gas consumption (Figure 4.40). The OTSP achieved its record monthly matching volumes in June 2020 with 238 mcm, almost double the monthly average for September 2018 to May 2020. This might indicate that the OTSP is moving in a direction to expand its role and functionality. However, BOTAŞ's dominant position and its long-term contracted volumes with take-or-pay provisions inherently limit the role that the OTSP can provide in terms of price discovery and competitive trading.

As of autumn 2020, about 40 participants were operating in the OTSP. Attracting more participants from the value chain, including power plants and distribution companies, is needed to achieve higher volumes. However, regardless of how many market participants there are, the existence of a dominant player with the capability to add or withhold substantial volumes of gas into the market is incompatible with the market competition required to enhance the efficacy and status of the OTSP.

Figure 4.40 Share of the Continuous Trading Platform in Monthly Natural Gas Consumption Since 2019 (%)



Source: EPİAŞ, 2020

EPİAŞ also plans to establish a Futures Natural Gas Market with forward price signals and physical deliveries by December 2021. A more predictable and competitive commodity market could provide hedging opportunities for both suppliers and consumers. If accompanied by a reduction in the market predominance of BOTAŞ with increased role for the private sector, this would be a critical step in advancing natural gas market liberalization in Turkey to a next stage, and would take place in parallel with, and be boosted by the expiry of about one-third of existing annual contract ToP volumes in this period. This market is expected to offer a wide range of products including monthly and annual contracts for a range of different load profile characteristics such as base-load, weekdays, weekends, and off-peak. Developing such a market, creating price discovery and acting as a key hedging tool for market participants, would be instrumental for decisions around new investments in the natural gas value chain and future supply volumes.

The benefits from a well-functioning organized natural gas market would be multi-fold. Commodity prices, when established in a liquid market, would give producers and consumers the information they need to make rational investment and other decisions. Increasing liquidity with a wide range of products could also provide hedging and additional risk management and flexibility opportunities.

With developing regional gas trading opportunities, price discovery based on supply and demand fundamentals could act as a reference for cross-border trading. A liquid market with sufficient depth and a wide range of differing products would attract more competitive import volumes offering more flexibility and lower costs.

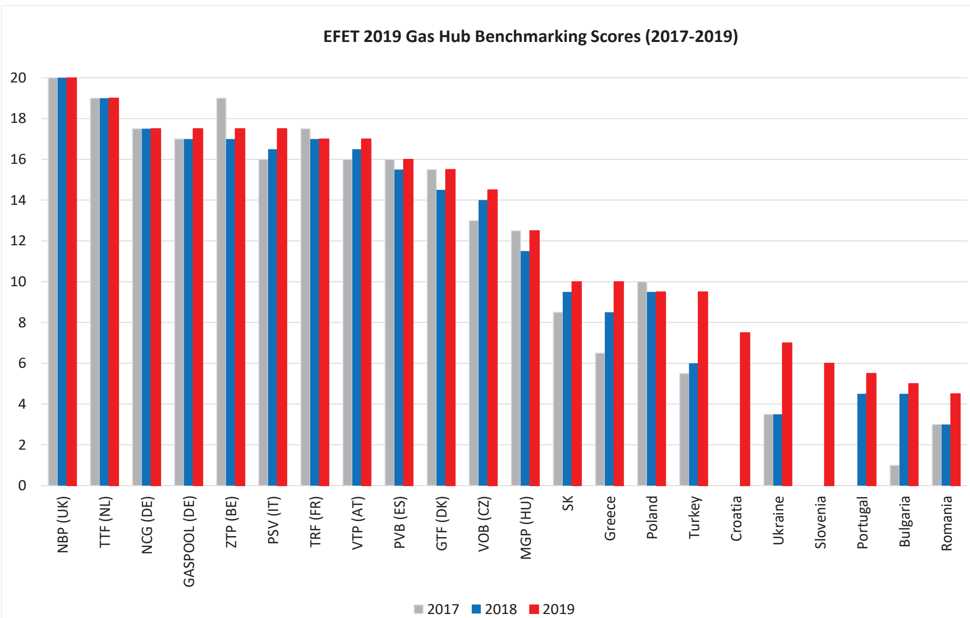
Developments in this direction are also important to sustain secure and reliable operation of the gas system in Turkey. A balancing regime correlated with organized trading platforms would enhance system integrity by reflecting current and anticipated supply and demand structures. Given the strong interrelation between power and natural gas markets in Turkey, advancing the organized trading schemes in the gas market would increase synergies and harmonization with the power market that already achieved a far more advanced structure.

Another development in the natural gas market of potential importance is the introduction of auctions of unutilized capacity on import pipelines. According to regulations issued in 2019, importers having long term contracts preserve their rights to the capacities they require while any remaining capacities are allocated to a new "spot pipeline" market. The first auctions of such unutilized capacity were held during 2020. The main motivation is to encourage new supplies and increased source and price diversity for the Turkish natural gas market. They are also important to effectively utilize the idle pipeline capacities and can be extended into different pipelines linked to differing gas sources. The prospect of such auctions may assist BOTAŞ in its negotiations about expiring contracts and IICEC would recommend that private sector involvement in such negotiations would also be effective.

Unbundling BOTAŞ' trading position is a necessary requirement for the natural gas market to further develop in Turkey. As discussed above, continuing BOTAŞ' role as the counterparty to the majority of Turkey's natural gas import contracts would be the primary impediment to a truly competitive Turkish natural gas market. Extending BOTAŞ' long-term contracts simply puts off for possibly decades the opportunity to establish these competitive markets. In addition to reducing BOTAŞ role as a counterparty to the bulk of Turkey's gas import contracts, establishing a market based cost-reflective pricing system is also necessary. The efficiencies and transparencies of a competitive market require that there are many suppliers and customers none of whom are able to dominate pricing because of their dominate market position. The wholesale prices and supplies established on such markets then need to be provided to retail customers by private parties with either competition or government regulation preventing excessive markups. While retail prices end up reflecting the current costs in the market, the government would still retain measures to address social responsibilities to prevent fuel poverty in certain residential segments. This can be achieved without distorting wholesale and retail prices. These changes would be in parallel with the best practices in natural gas markets in other industrialized countries and take full advantage of global and regional dynamics.

A competitive natural gas market in Turkey could also serve as a regional gas trading hub. Turkey is one of the most prominent candidates to act as a trading hub in its region for increased gas trading according to the benchmarking studies[53] by the European Federation of Energy Traders (EFET). Turkey's progress in this direction stepped up in 2019 and 2020 (EFET, 2020). One of the major achievements over the past few years has been expansion of the transmission system as a whole with increased inflow capacities and higher diversity in import supplies both in terms of sources and routes (Figure 4.41).

Figure 4.41 EFET Gas Hub Benchmarking Scores (2017-2019)



However, establishing a physical trading hub requires a wider perspective including interconnections, especially with the potential trading outlets in the South-East Europe (SEE). This requires elimination of current technical limitations for bidirectional flows and amendment of the network codes in harmony with the ENTSO-G. This regional focus is also necessary for system level integrity and flexibility as Turkey's gas demand is also concentrated on the north-west of the country where a large fleet of natural gas fired plants, gas-consuming industrial facilities and large residential consumption regions such as Istanbul are located. While these interconnection and storage capacities are important they would not be a major barrier as much more significant improvements in Turkey's gas distribution system have been achieved in recent years and the required investments would not be the major impediment to establishing a Turkish gas trading hub.

53 EFET's gas hub benchmarking study is based on assessment on sixteen criteria including system balancing, entry-exit, standardized contracts, licensing and reporting obligations, and spot and forward hub-based pricing,

The recent gas discovery, and any further discoveries in offshore or unconventional gas, would also add to the strengths of developing a trading hub in Turkey. Domestic gas supplies would add significant diversity of supplies especially if government sales contracts were auctioned off to private entities ensuring that these gas supplies would come into the trading hub through private parties controlling smaller volumes of supply. Therefore, it will be of great importance how recent gas finding in the Black Sea in addition to further discoveries will be marketed in the country. Although Turkey's recent progress toward a more liberalized market, as discussed above, helps meet the requirements for a gas trading hub, significant improvements are still needed in a number of commercial and regulatory areas (IICEC, 2019). These particularly include renegotiating existing contracts to eliminate destination clauses (as is current practice), reducing ToP obligations that are not linked to hub pricing, increasing further flexibility in supplies, ending BOTAŞ's market predominance, and moving towards a cost-reflective pricing system, ultimately derived from a competitive gas trading market. This competitive market would require that no entity, including BOTAŞ, would be able to influence prices out of proportion to other market participants.

The prospects for establishing a regional gas trading hub in Turkey would not likely motivate the difficult reforms, discussed above, if they were not also necessary for Turkey fully to enjoy the economic benefits of a competitive natural gas market and lower energy import expenses. However, a physical gas hub and trading exchange could provide Turkey additional benefits. The exchange would stimulate considerable private trading and banking activity adding to Turkey's finance sector, as well as generating additional demand for Turkish consulting, IT and law firms in addition to many high-paying professional jobs in the exchange itself, since trading firms especially require technical and legal support. Once a well-functioning hub is created, new market participants would grow creating demand for new office space as commodity traders and data science professionals are hired by commodity traders and their clients. Lastly, the expertise gained in these areas would benefit other trading focused businesses in Turkey and could expand Turkey's financial activities in many unexpected directions.

4.4 IICEC Policy Recommendations

- **Improving Turkey's Terms of Trade for Foreign Natural Gas Supplies**

Turkey has entered a new phase in the development of its natural gas market, with supply constraints eliminated for the foreseeable future, a strongly diversified range of suppliers, and having high excess LNG import capacities to deal with any disruptions in supply. Turkey's security of supply is strong and, with only modest growth in the consumption of natural gas projected for the next two decades, is set to remain so. The recent gas finding in the Black Sea will improve the security of supply and result in lower import requirements starting in this decade.

These structural changes go hand in hand with the current dynamics in the global gas market with its increased emphasis on short-term and spot supplies and on contract pricing based on gas-to-gas competition. Use of long-term fixed contracts with destination clauses and other flexibility impediments has declined. Rising supplies of LNG have been an important catalyst in these changes, and Turkey is already a key player in the new global LNG market. LNG now meets one-third of Turkey's demand, and spot LNG a substantial share of this.

These accomplishments are cited here again because they enable Turkey to reduce its natural gas import bill. Achieving improved terms of trade is a particularly important policy goal in the natural gas sector. Unlike the oil sector, where the emphasis is on using less oil, the use of gas is encouraged since gas is a healthier fuel than coal or oil, apart from in the power sector, where IICEC's Alternative Policy Scenario projects a significant decrease in use. For the next two decades. Therefore, except in the power sector, fuel shifts away from natural gas are neither practical nor desirable. Government policies have little effect on the terms of trade of petroleum and petroleum products as they are internationally traded and transparently-priced commodities with transport costs that are modest. Turkey's efforts to increase natural gas supplies through increased domestic production have achieved important results with new discoveries that will further reduce Turkey's energy import bill and increase its energy security. In addition, new domestic production that reduces the need for future natural gas imports strongly improves Turkey's negotiating position to achieve better terms of trade, something that will remain important as Turkey will continue to rely on natural gas imports. The most important ways to reduce Turkeys' energy import bill is to both increase domestic production and achieve improved terms of trade for imported natural gas.

IICEC's Alternative Scenario anticipates that Turkey will take advantage of current market conditions, its extensive gas infrastructure, import flexibility, global trends and accelerate its pathway to a competitive natural gas market. It also projects higher domestic production with increased investments into exploration activities including offshore and the largely unexplored unconventional basins. IICEC estimates that, in addition to other benefits, these would be the most important way to accelerate progress towards a privatized natural gas sector. As discussed below, this would more quickly lead to Turkish energy companies freely competing in a transparent market underpinned by cost-reflective wholesale and retail gas prices. However, whether such reforms can be accomplished in the near to mid-term or must be put off to the more distant future critically depends on how expiring BOTAŞ contracts are renegotiated and how quickly the private sector can play a stronger role as contract counterparties and move to a more competitive gas market structure. However quickly this can be accomplished, lower import costs should be achieved by linking contract pricing to European hubs such as the TTF or, eventually to Turkey's own developing domestic natural gas market, the OTSP. There may also be good opportunities under current Gazprom contracts to defer new purchases in favor of low cost obligations to fulfill current ToP obligations that have been deferred ("make-up-gas").

Turkey has made the significant infrastructure investments that are required for this strategy to work: it now has access to a variety of pipeline gas and LNG suppliers and can flexibly procure its natural gas needs as market conditions change. Turkey has also made significant E&P investments that are now paying off. In all this, BOTAŞ actions to reduce its long-term import contracts would provide an opening for Turkey's private sector to undertake its own contracts with foreign suppliers or participate in the spot gas market. However, as recent experience has shown, this would be unlikely unless private firms know that they can market gas in wholesale and retail markets that have competitive cost-reflective pricing. To date, BOTAŞ has accepted responsibility to ensure adequate natural gas supplies for Turkey, and has admirably accomplished this, currently and in the past. Liberalization of gas markets means the transfer of this responsibility to the market as a whole, a major change.

These recommendations are fully in line with Turkey's stated natural gas policies as articulated in Section 4.2. Only the Government and BOTAŞ can design and implement the particular near-term and mid-term strategies that are needed to realize Turkey's long-stated competition and privatization goals, taking account of the global and Turkish market realities and opportunities discussed earlier. They could also anticipate more private-sector involvement in import contracts and in the spot gas market. Domestic gas supplies could also add significant diversity of supplies and contribute to a more competitive market, if government sales contracts were auctioned off to private entities ensuring that domestic gas supplies would come into trading hubs through private parties controlling smaller volumes of supply. Overall, for Turkey, a portfolio approach to managing price risk makes sense but would be more responsive to market fundamentals with increased private sector participation. In this environment, gas contracts should reflect gas-on gas-competition, avoiding unnecessary long-term obligations and flexibility restrictions.

- **Developing a More Competitive and Cost-based Natural Gas Market**

Although the Natural Gas Market Law was enacted in 2001, the long-required liberalization of Turkey's natural gas market has remained limited. In 2017, Turkey took the legal steps to establish an organized natural gas trading platform including day-ahead and intra-day components. This platform started offering daily products in September 2018 and in June 2020, the market added weekly products, a further regulatory and technical step towards creating market places for gas trading. A futures market with physical deliveries is in preparation and planned to become operational in 2021. These markets, with a diverse set of daily, weekly, seasonal and yearly products, can transform the Turkish natural gas market into the more competitive structures that are essential for a more efficient and broader energy economy. However, some uncertainties remain.

BOTAŞ currently holds the great majority of import contracts and 95% of the supply market. Markets cannot generate competitive prices if the commodity is controlled by a single player however well-intentioned that market player may be or the social benefits it may be providing. A competitive gas market needs multiple suppliers, none of which dispose of sufficient supplies to dominate the market or set prices. Achieving this requires that the private sector play a much stronger role in purchasing foreign gas and marketing it to domestic customers in addition to engaging in a competitive gas trading bub for flexibility purposes.

Similar to the experience in the European market, Turkish gas prices would become more closely linked to European hub pricing and, as the Turkish trading hub evolved, would gravitate to the Turkish hub price. More liquid spot and futures markets, under the OTSP, would serve as a platform to divert supply volumes directly to a well-functioning and competitive market. Suppliers and customers that value price certainty would find several financial instruments available to them with which to lock in future prices.

Achieving these outcomes requires cost-based pricing to be built in. Vulnerable residential consumers could be protected from price increases by other government programs that do not intrude on the gas market itself. Fuel poverty for these vulnerable customers can be avoided via a variety of mechanisms including a social tariff that does not distort gas prices in the market, similar to the direction taken in the power market. This would also support a more efficient industrial sector and incentivize demand-side management. A more competitive natural gas market backed by increasing domestic production and diversity of supplies would also enhance the efficiency of the market and provide a surer guide to private sector energy investments. While natural gas prices themselves do not necessarily become "predictable", the market rules are predictable and business decisions can be gauged on fair assessments of future demand and supply fundamentals, as is the case in almost any industry.

- **Optimizing Natural Gas Supply and Demand with Enhanced Flexibility, Efficiency and Technology-oriented Business Models**

Natural gas is a leading fuel in residential, commercial and public buildings and in industry. Therefore, improving the energy efficiency of combustion and other efficiencies in gas-using appliances, compressors and other elements of the value chain is also an important policy objective for Turkey. Research and regulatory efforts to achieve this should be supported. Increased investment and policy incentives for industrial demand-side management would also provide important economic benefits during times when gas demand rises, for example, during cold winters. Nonetheless, unlike the key role that energy efficiency and fuel substitution play in the oil sector, there are far different priorities for Turkey's natural gas policies. To take an example, strong policy efforts are recommended to divert travel from low-occupancy petroleum-fueled vehicles to non-petroleum and high-occupancy alternatives. In contrast, for natural gas, the expected reduction of natural gas use in the power sector is a consequence of the uptake of low-cost renewable generators. More significantly, there is no policy incentive to even reduce natural gas services outside of the power sector as natural gas is a healthier and lower GHG-emitting fuel than the fuels it is replacing (coal and oil). This is why the IICEC Alternative Scenario shows more residential and commercial energy needs being served by natural gas than in its Reference Scenario.

In the past, winter peaks in demand resulted in gas cuts. Now, supply volumes well outpace consumption, both in annual volumes and in terms of seasonal and daily balances. Turkey's infrastructure investments have produced a more secure and reliable natural gas system with increasing flexibility.

The efficiency of Turkey's natural gas economy depends on the ability to allocate value chain investments in an optimal way. Although the investments on the supply side are important to sustain a reliable gas system, a focus shift to the demand side would also provide benefits. Turkey has already achieved a flexible gas entry structure and IICEC projects modest demand growth in the next two decades. Seasonality will become an increasingly important feature of the Turkish natural gas system with residential users, with their markedly seasonal offtake profile, accounting for an increasing share of total gas demand. A natural gas system that is secure, efficient and cost-effective would result from achieving efficiencies and flexibility for both the supply and the demand for natural gas under different seasonality and other conditions. Enhancing domestic production will also require sustained technology oriented investments in the offshore and extending into unconventional plays and CBM.

The Turkish gas industry is active on implementing new technologies to reduce inefficiencies in the value chain and these efforts would well complement the wider energy efficiency objectives of Turkey. Introduction of demand side management starting from large consumers is already a policy target and IICEC believes that it would contribute to a more competitive and efficient gas market. The R&D programs backed by policy and regulatory frameworks should also continue to improve the technical performance of the gas system in multiple areas including reducing gas losses, assessing gas consumption patterns as a function of meteorological conditions, efficiency of the gas burning stock and building envelopes and developing new technologies. Turkey's initial steps for hydrogen blending are timely to keep abreast of global technology developments and to gain experience of the role that hydrogen can play in the longer run (see Chapter 6, The Energy Transition).

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CHAPTER 5:
OTHER SECTORS AND FUELS

Summary

- Building on existing progress, TEO scenarios show strong opportunities to improve end-use energy efficiency and shift to a more sustainable fuel mix.
- Important efficiency opportunities exist in all energy end use sectors.
- IICEC projects that more energy services will be provided by electricity. Coal and oil consumption in buildings, industry and agriculture will decline while natural gas, other thermal sources and renewables replace them.
- Solar heating and geothermal will also have a strong role to reduce energy expenditures.
- These developments also provide more localization opportunities and will increase Turkey's high-tech industrial sectors and exports.

Industry

- The industry sector represents 35% of Turkey's final energy consumption reflecting its focus on heavy and energy-intensive industries (iron and steel, cement) especially compared to some more developed economies. Shifting the mix towards more value-added and technology-oriented industrial sectors is likely to support economic growth, reduce Turkish commodity imports and increase technology exports. These changes also reduce the average energy intensity of the Turkish industry.
- Despite the trend to increase average efficiencies, within each industrial activity, there are many cost-effective opportunities to further improve efficiency, especially electric motors and motor systems. The absolute benefits are large since motors are responsible for two-thirds of industrial electricity use and almost one-third of Turkey's net electricity consumption.
- An energy certificate program is recommended for electric motor replacements using technical assessments. The detailed assessment and accounts of Turkey's electric motor systems will enable the most cost-effective program for replacement.
- By 2040, the Alternative Scenario projects that renewable energy (especially biomass and solar heating), electricity and natural gas will provide 86% of industrial energy use. Even in the Reference Scenario, 75% is provided by these fuels, compared to 63% in 2018.
- The share of renewables almost doubles from 10% in 2018 to 17% in 2040 in the Alternative Scenario.
- In the Alternative Scenario, energy demand in 2040 is 14% lower than in the Reference Scenario as a result of wider efficiency gains backed by investments and business models.

Buildings

- The building sector has the largest efficiency potential among all final demand sectors. Turkey has already established a certificates program for new buildings beginning in 2020. However, a great majority of the existing building stock remains out of the certification programs. In addition, IICEC analyses, based on a comparative assessment with country peers with similar climatic conditions show that the energy efficiency performance of the building stock is poor.
- The recent positive steps to advance building energy performance should be followed up with defined targets and supporting programs for commercial and residential buildings.
- More programs for older buildings are also needed.
- Efforts should include designs for near-zero or net-zero energy buildings. These should be the long-term goal for the building energy efficiency roadmap.
- The Alternative Scenario reflects a progressive program for improvement including mandatory measures and, especially, effective financial models to enable the transformation of the old and inefficient building stock.
- The Alternative Scenario also realizes the best available technologies, including the deployment of near-zero/net-zero buildings that employ more rooftop PV, solar thermal heating and geothermal heating.
- The Alternative Scenario also includes measures to increase the uptake of cost-effective implementation of district heating and cooling (DHC) systems. These work best when high heating and cooling demands exist along with circumstances that make them practical alternatives.
- Efforts are needed to step up the replacement of inefficient appliances and, especially, to ensure purchase of the most-efficient HVAC systems. While most new appliances (such as "white goods" are already marketed in the best performance classes, HVAC equipment is an exception. There are a variety of product origins that are observed in the market, many with poor energy efficiency performance. New AC units should only have the highest efficiency.
- Another opportunity for good savings is to replace the relatively old household refrigerator stock with the best available models. This will require a dynamic regulatory framework reflecting energy labeling to ensure success.
- Natural gas will remain the leading fuel in the buildings, supported by Turkey's expanding gas transmission and distribution network and increased flexibility in natural gas supplies (Chapter 4). In the Reference Scenario, coal use in buildings drops from 12% in 2018 to 7% by 2040. The Alternative Scenario realizes a faster substitution driving the coal share in buildings to only 2% by 2040.

- Oil use by 2040 decreases to 2% in the Reference Scenario and only 1% in the Alternative Scenario although oil use was already low (3% in 2018). Electricity contributes to over 40% of the buildings energy demand in both scenarios and when combined with renewables represents 54% of the building energy demand in 2040 compared to 44% in 2018.
- Turkey has several energy efficiency incentive programs that could be elevated by establishing standardized Energy Performance Contracts (EPCs), a successful model widely used in different regions and countries. While EPCs were recently initiated to improve public buildings' efficiencies, EPCs could have a much wider impact in commercial and residential buildings. EPC programs can de-risk energy efficiency investments and lower their interest rates resulting in reduced Turkish energy consumption and wider national benefits. EPCs can also be used in industry especially when combined with thematic targets such as electric motor systems and LED lighting.

Agriculture

- The agriculture sector, including farming and fisheries, corresponds to less than 5% of final energy demand but it deserves special attention as it is vulnerable to adverse consequences of global climate change and remains critical for food security.
- Agriculture relies on electric power and diesel fuel. Reducing diesel fuel use is a priority. Although a replacement program for old and inefficient tractors and other agricultural machinery can provide large efficiency gains, this may not be a socially practicable objective especially because the utilization rate of the existing tractor fleet is so low. This suggests a more innovative solution using shared services programs to increase utilization of the most efficient tractors.
- Programs to upgrade irrigation pumping with new mini and micro-grids would save power and improve the power sector's management of seasonal and daily loads.
- Geothermal energy for greenhouse farming is another important opportunity. Building upon existing applications, geothermal heating can be extended into more regions and agricultural products. This provides another opportunity for Turkey to become a regional and world leader.
- The TEO Scenarios also demonstrate larger use of solar PV and heating as well as a phase-out of traditional biomass with wider use of modern biomass applications such as biogas initially by investing in demonstration cases at scale. Renewables contribute to over one-third of total agricultural energy demand in both TEO scenarios, up from 14% at present.

Final Points

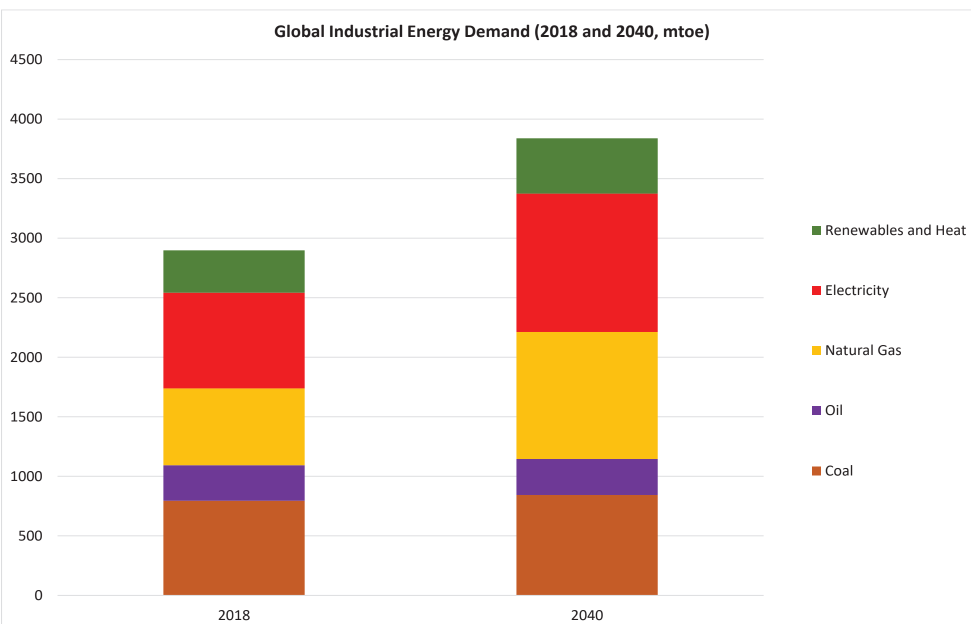
- Awareness and behavioral change is a core aspect of energy efficiency, especially in final demand services. Energy user choices on the purchase of new equipment as well as consumption habits play a major role in energy consumption patterns, especially in controlling building energy use. Raising energy efficiency awareness is an element of Turkey's Energy Efficiency Action Plan. But there are opportunities to improve information and awareness. Overcoming up-front costs and access to finance are the biggest challenges so consumers can act on information that they are already aware of. The widespread use of information technologies will be an increasingly important asset as government programs can be more effectively communicated to consumers. Energy consumers will become more aware of the money they can save by being more efficient and the programs that they can use to overcome past barriers that prevented them from enjoying energy efficiency savings.
- Digitalization is an underlying aspect of improving energy efficiency performance and opening up opportunities to use more renewable energy. Driven by increasing connectivity, vastly extended data services illuminate and integrate energy management opportunities within the wider economic activities of the industry, building and agricultural sectors. We expect that increased use of ESCOs will advance "energy-as-a-service" instead of purchasing energy supplies.

5.1 Global Developments

In addition to the power, transport, oil and natural gas sectors, each discussed in Chapters 1-4, other end-use sectors must be considered to have a complete analysis of Turkey's energy economy. This chapter considers Turkey's industry, buildings and agriculture sectors. With some other miscellaneous uses, these complete the energy balances in the TEO Reference and Alternative Scenarios. There are also important stories in each of these sectors as their fuel mixes will be undergoing change and, most significantly, they each have important opportunities for improved energy efficiency, especially in the buildings sector. Exploiting these opportunities for improved energy efficiency will enhance Turkey's energy security and environmental sustainability.

Industry: Globally, industry represents 29% of total final energy consumption. A country's stage of industrialization and the structure of its industries have a large impact on industry's role in each country's energy economy. Driven by a strong electrification trend, electricity now accounts for 26% of global industrial energy use followed by coal (25%) and natural gas (21%). In spite of an increasing trend, renewables account for less than one-eighth of total industrial energy demand. Global industrial energy demand is expected to increase from 3 btoe to 3.8 btoe by 2040 (or a cumulative 31% increase (IEA, 2019a). The majority of the growth is anticipated from the developing countries.

Figure 5.1 Global Industry Energy Demand (2018 and 2040, mtoe)



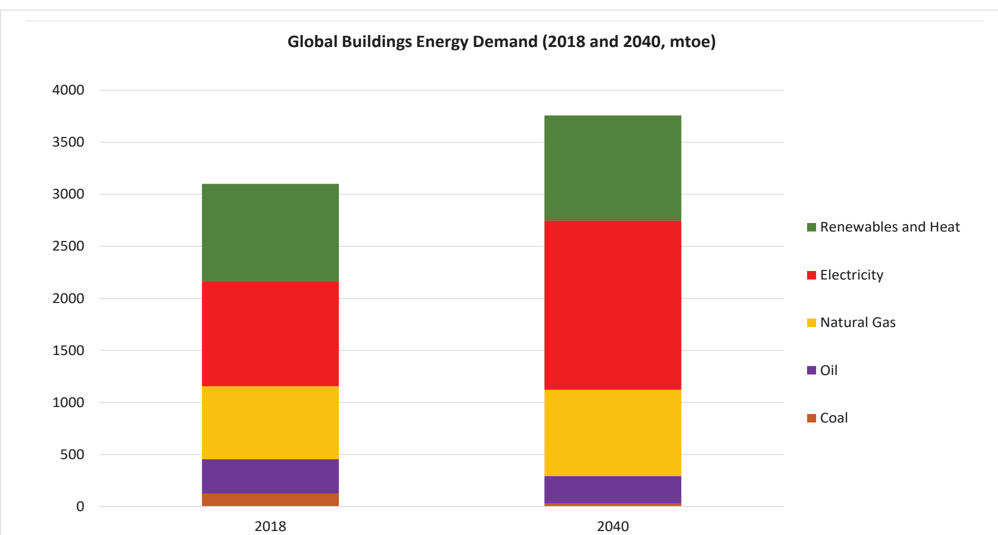
Source: IEA, 2019

The trend towards electrification is expected to continue and grow from 26% to 30% of industrial energy demand by 2040. Natural gas will increase its share to 27% and displace coal as the second largest source after electricity. The contribution of coal will gradually decline, displaced by electricity, natural gas and renewables (IEA, 2019a). Despite about a 30% increase in supply, the renewables share will remain unchanged at 12% absent any further policies to speed up a wider and larger contribution (Figure 5.1).

Buildings: Buildings energy demand is driven by rising income and increasing welfare, emergence of new urban centers, urban transformation programs, and the rising global population with increasing needs for household energy services as well as other buildings that serve the public and commerce. Currently the sector is the largest energy end-use consumer and represents 31% of total final energy consumption worldwide. Buildings energy demand is estimated to grow to 3.8 btoe until 2040 from 3.1 btoe in 2018 (or 23% cumulative increase). Energy efficiency strategies and investments are expected to play a key role in reducing the growth rate of demand, especially in the area of building insulation and electric appliances.

Electrification is again the key trend in the evolution of the buildings fuel mix with an increasing population gaining access to modern electricity services. Electricity currently meets one-third of building energy demand and its share is anticipated to reach over 40% by 2040, a 60% increase of electricity consumption. Renewables is expected to remain the second-largest source with close to 30% share in building final energy demand[54]. The only decrease is expected in coal with a reduced share from 5% currently to only 1% by 2040 as it is replaced by more modern and healthier fuels (Figure 5.2).

Figure 5.2 Global Buildings Energy Demand (2018 and 2040, mtoe)



Source: IEA, 2019

[54] Biomass, solar and geothermal heating

Agriculture: The agriculture sector consumes less than 5% of global energy demand. Major energy uses include petroleum fuels in tractors and other farming machinery, biomass, mostly in traditional forms, and electricity to serve irrigation needs. There are good opportunities to increase the renewables share with solar, geothermal and modern biomass.

Efficiency: Policy and technology efforts mainly focus on development and deployment of more efficient and sustainable energy services. These include building envelopes, motor-driven industrial systems, increased data and digitalization capabilities, increasing penetration of solar collectors, heat pumps, geothermal heating, district heating and cooling networks and micro-grids. A common aspect of these technologies is their increased energy efficiency and their ability to replace oil and coal with electricity (Figure 5.3).

Figure 5.3 Key Global Energy Efficiency, Fuel and Technology Trends

Energy Efficiency in the Buildings	Energy Efficiency in the Industry	Key Fuel and Technology Trends
■ Building envelopes and improved heating and cooling performance ■ A more efficient appliances stock	■ Efficiency improvements in the industrial processes ■ A more efficient electric motor stock	■ Electrification and gasification ■ Solar Collectors ■ Modern biomass ■ Heat pump systems ■ District Heating and Cooling networks

IICEC assessment based on international reports and data

All of these technologies, together with the power sector and transport technologies discussed in Chapters 1 (Power Sector) and 2 (Transport) will reduce the world's carbon footprint to at least partially offset the worldwide growth in energy service demand or, if applied to the fullest possible extent with other measures, limit the growth of energy sector GHG emissions to achieve a global temperature increase below 2 ^{0}C (see Chapter 6, The Energy Transition).

5.2 Turkey's Energy Policies in Buildings, Industry and Agriculture

Turkey's energy policies are to increase energy efficiency in each of these end-use sectors and to develop a more sustainable fuel supply mix. These policies contribute both to energy supply security and localization. Turkey's regulatory framework has been in development since the enactment of the Energy Efficiency Law in 2007. In March 2018, The National Energy Efficiency Action Plan supplemented the law with 55 actions in six areas (energy industry, buildings and services, transport, industry and technology, agriculture, and cross-cutting or horizontal topics).

The horizontal actions include establishing and increasing the efficiency of energy management systems, developing financial mechanisms, developing standardized contracts for technical, legal and financial aspects, implementing data and reporting systems, energy audits, and awareness-raising and training. The Plan foresees the achievement of 23.9 mtoe cumulative savings until 2023[55]. The Plan identifies priority areas for energy efficiency in the buildings and industry. For example, it aims to increase energy efficiency certificates for existing buildings, promote efficiency certification for new buildings, promote central and district heating and cooling systems, improve energy efficiency in public buildings and municipal services and further develop efficiency labels and standards. The plan sets the target of 10% reduction in energy intensity for all industrial sectors by 2023. Policies in the agricultural sector include replacement of the old tractors and harvesters with efficient ones and enabling energy-efficient irrigation methods. The plan includes increasing the use of renewable energy in the end-use sectors, for example integrating renewable energy into buildings.

Although some of these targets have been supported by secondary legislation, progress could be accelerated in key areas including building certification, expanding appliance efficiency coverage and maximizing industrial efficiency performance. In some areas, secondary legislation preparation and implementation is still underway. The Regulation on Energy Performance of Buildings (2008 and amended in 2013) introduced a common methodology for energy performance calculations. It also set minimum requirements for new buildings and those in need of major renovation. Turkey has also adopted the EU Eco-design and Labelling Directives of 2009 and 2010. Public building managers can now engage energy service companies (ESCOs) to help meet a 15% savings target by 2023. Since the beginning of 2020, all new buildings are obliged to have an energy efficiency certificate but no legal measures are yet in place for older buildings.

The key policy documents considered in the TEO include the 11th Development Plan issued by the Presidency of Turkey in July 2019 and the Strategic Plans of the Ministry of Energy and Natural Resources and other relevant ministries. Each of these documents focuses on plans and goals towards 2023. The TEO Scenarios also take into consideration the National Energy Efficiency Action Plan along with the key legislation in place or under consideration.

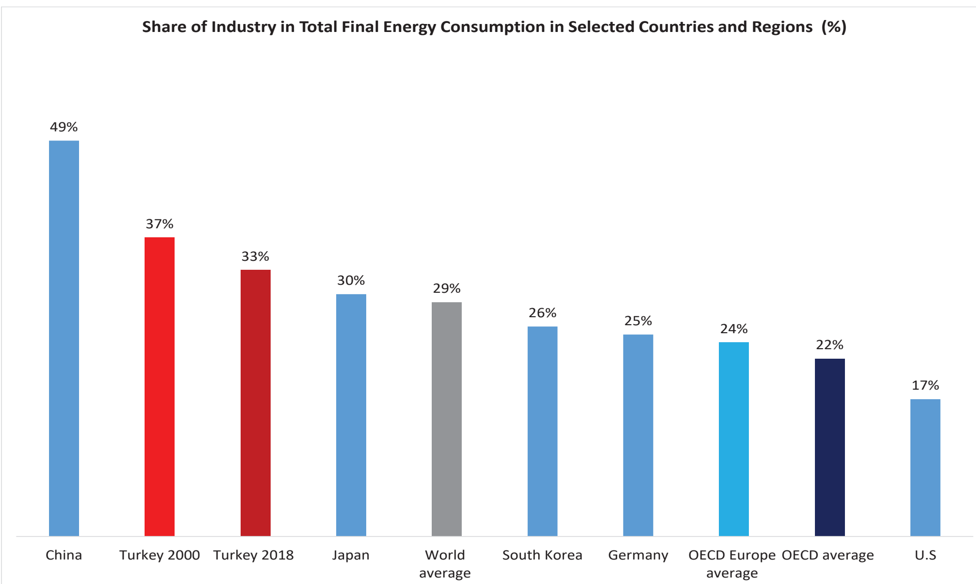
55 In 2017-2019 period, cumulative investment in energy efficiency actions defined in the Plan is estimated at $4.1 billion with an estimated corresponding savings of about $1 billion.

5.3 IICEC Overview, Scenarios and Analyses

5.3.1 Industry

Industrial energy use increased from 22.9 mtoe in 2000 to 36.2 mtoe in 2018 (58% more) as a result of ongoing industrialization and expanded economic activity. The industry sector represents 35% of Turkey's final energy consumption excluding the non-energy uses. This reflects the energy-intensive structure of the Turkish industry compared to many European peers, other advanced economies, and the OECD average (Figure 5.4).

Figure 5.4 Share of Industry in Total Final Energy Consumption by Selected Regions and Countries (%)

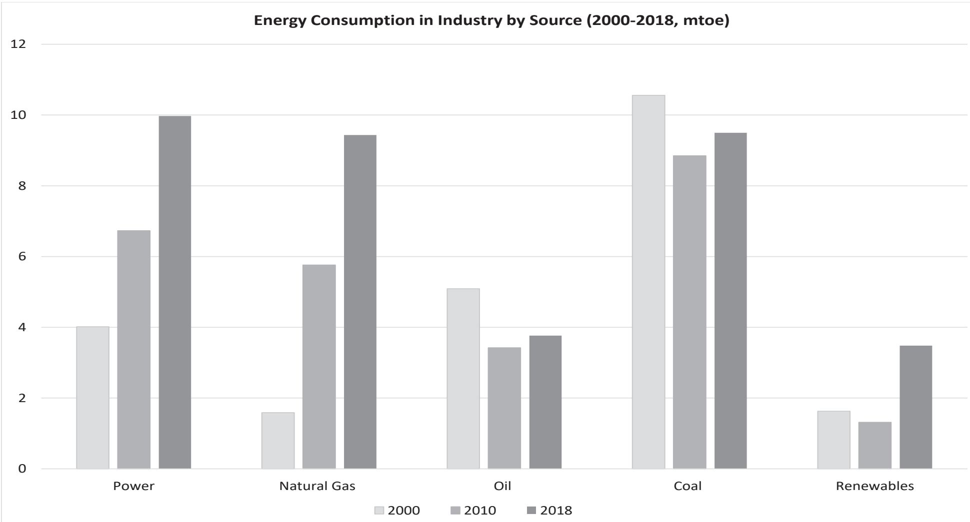


Source: MENR; IEA, 2020

Note: 2018 data for regions and countries unless otherwise specified.

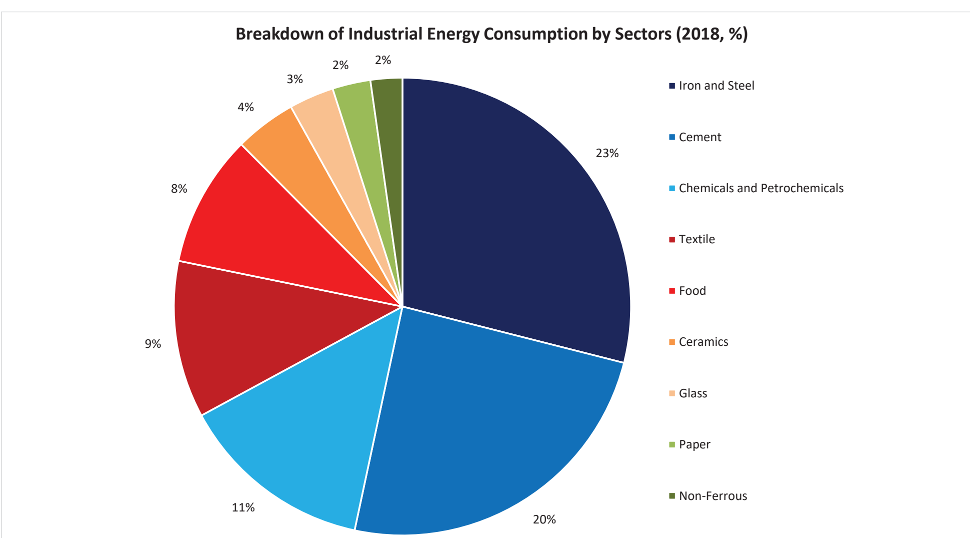
Significant shifts have occurred in the fuel mix patterns of the Turkish energy industry over the past two decades mainly driven by technology progress and investments enabling wider access to electricity and gas services as well as sectoral shifts especially expanding automotive, machinery, and electric-electronics manufacturing that needs more electricity than other industrial sectors. Power demand increased by 2.5 times, gas demand raised by almost six times while renewables also showed an increasing uptake mainly from biomass use in a wide array of sectors led by cement and woodworks as well as solar heating applications for low-temperature process heating. These developments resulted in reducing demand for both coal and oil (by 10% and 26% since 2000, respectively). Electricity, natural gas and renewables now provide 63% of total industrial energy demand, up from 32% in 2000 (Figure 5.5).

Figure 5.5 Energy Consumption in Industry by Energy Source (2000-2018, mtoe)



Turkish industrial energy consumption is dominated by iron-steel and cement. These two industries account for 43% of total industrial energy demand. Other major energy users include chemicals and petrochemicals (11%), textile (9%), food (8%), ceramics (4%), glass (3%), and paper and non-ferrous manufacturing (each 2%). These nine sectors correspond to 82% of total industrial energy demand. Tracking the fuel mix and energy efficiency developments in these sectors will show how all of the Turkish industry is likely to develop (Figure 5.6).

Figure 5.6 Breakdown of Industrial Energy Consumption by Sectors (2018, %)



Turkey's energy intensive iron and steel and cement industries have shown an improved efficiency performance over the past two decades but they both fall short to achieve best practices. Energy intensity of the Turkish iron and steel industry is estimated at 9.5 GJ/t compared to the worldwide average of 18.6 GJ/t (IEA, 2020a). However, the lower energy use per production is due to the difference in the technology portfolio. Blast furnaces produce less than one-third of total crude steel in Turkey whereas 80% of the global iron and steel production is orientated to blast furnaces. IICEC estimates that the energy intensity of Turkey's integrated blast furnaces is around 10% higher than the current global performance. Energy intensity of the cement industry is estimated at 4.1 GJ/t with thermal energy use per clinker production standing at 3.8 GJ/t compared to the global average of 3.4 GJ/t (IEA, 2020b), again showing about a 10% gap.

These two industries also have the highest share of energy costs to total production costs. Energy costs represent 70% of total production costs in the cement industry and around one-third in the integrated blast furnace steel industry. They also consume the bulk of the coal supply into the overall industrial sector. Their combined share in industrial coal demand is 76%. In 2018, half of the total energy consumption in the iron and steel industry was from coal (mainly coking coal and hard coal). Coal supplied one-thirds of total energy input to the cement industry. These two industries are also responsible for 29% of industrial electricity use with iron and steel by itself consuming over 20%. As discussed in Chapter 3 (Oil), petcoke is a predominant fuel in the cement industry with only marginal use otherwise and represents 46% of cement sector's total final energy consumption.

Fortunately, options remain to achieve a more diversified and sustainable energy mix, particularly by increasing renewable energy. For example, 1 million tons of municipal waste burned in the cement industry in 2018 that replaced about 0.6 million tons of hard coal consumption. Despite an increasing trend of biomass, it still represents only 6% of cement production energy use. This is higher than the global average of 3% but far lower than EU practice that approaches 50%[56]. Over 30 million tons/yr. of municipal waste is produced in Turkey. This would yield a fuel stock of 7 million tons and replace around 3 million tons of hard coal consumed in the industrial sector[57]. Wastes from other industries can also be assessed and coordinated across sectors to reduce coal imports by the cement industry. Another important pathway is using waste heat for electricity production. Waste heat recovery power generation that now produces about 0.5 TWh can be doubled to 1 TWh (or 12% of the sector's current aggregated electricity demand) based on a 2007 plan to increase capacity to 270 MW, according to the estimates of the Turkish cement industry. Increasing electricity efficiency to melt scrap is also a good opportunity to save energy as this accounts for half of the energy consumed in electric arc furnace production.

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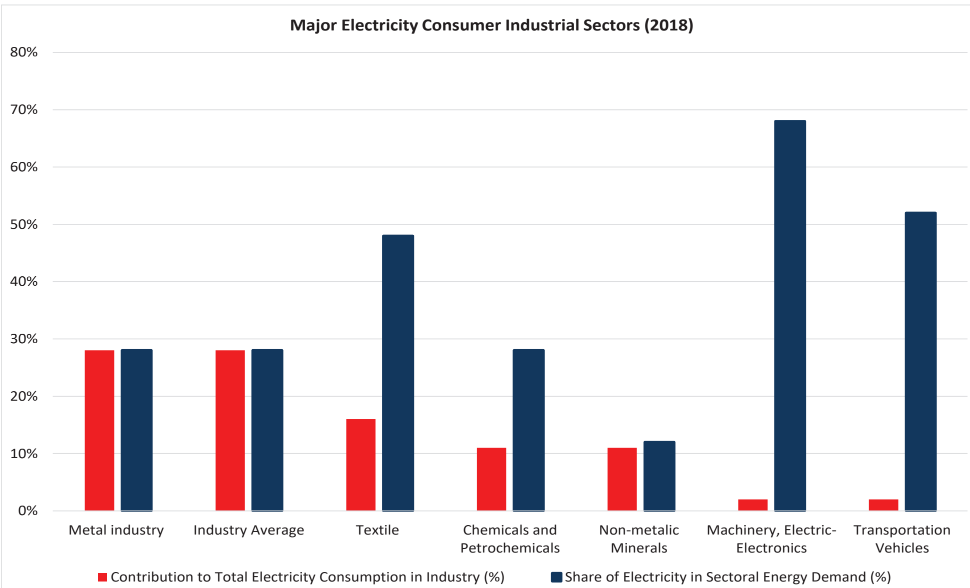
[56] From waste and biomass.

[57] Average calorific value of municipal wastes is estimated at 40-45% of hard coal. Turkish cement industry consumed 2.9 million tons of hard coal in 2018.

Turkey is one of the global leaders in the textile industry. As such, textiles are the third-largest energy consumer in Turkish industry and the second-largest electricity consumer after steel production. This is due to the electricity-intensive finishing processes (Figure 5.7). Other major industries that are substantively driven by electricity, due to their manufacturing process chain characteristics, are machinery, electric and electronics (68%), manufacturing of transportation vehicles (52%), mainly automotive (50%), and the chemicals and petrochemicals industry (28%).

Figure 5.7 Major Electricity Consumer Industrial Sectors (2018)



The industrial structure of Turkey is anticipated to undergo a significant change over the next two decades. The Eleventh "Five Year Development Plan" of the Presidency targets a sectoral prioritization approach to increase productivity growth with a technology orientation. This will cause a faster structural change towards higher value-added industries than would occur naturally. Six priority industries (chemicals, pharma and medical devices, electronics, machinery and electric equipment, automotive, and railway vehicles) are identified by this high-level Plan to meet these overall objectives[58]. All of these priority industries are in the medium-high and high technology sectors[59] and they

[58] Identification is based on assessment on contribution to trade, industrial production, value-added, employment, technology levels per manufacturing industry, and linkages among sectors.

[59] According to the NACE Rev.2 definitions, the high-technology manufacturing sectors are pharmaceutical products and pharmaceutical preparations, computer, electronic and optical products, air and spacecraft and related machinery. The medium-high-technology sectors are chemicals and chemical products, electrical equipment, machinery yard, motor vehicles, trailers, semitrailers and other transportation equipment excluding ships and boats, medical and dental instruments and supplies, and weapons and ammunition.

also have high export potential. As they develop, Turkey's industrial energy use patterns will change. The changes include a higher GDP/energy ratio and a movement away from fossil fuels to electricity. Development can be rapid as targets include increasing the share of exports from these medium-to-high technology industries from 36% in 2018 to 44% by 2023. This also brings Turkey more in line with world trade norms as the trade in medium-high and high-technology sectors is 60% globally. While 2023 is mentioned as a target year, progress in the technology orientated industrial development of Turkey is a long-term project requiring sustained efforts and an effective marriage of integrated planning and private sector participation.

IICEC analyses show that Turkey's manufacturing industries that have the highest value-added also have low energy consumption. Comparing the value-added contribution and energy use per sector indicates that this holds true except for textiles, chemicals and petrochemicals (Figure 5.8). For example, machinery and electronics represent 14% of manufacturing value-added while only consuming 1% of total industrial energy. The automotive industry has a similar value-added as iron and steel (8%) but consumes 20 times less energy. Chemicals and petrochemicals contribute to 14% of manufacturing value-added and consume 11% of industrial energy. As a comparison, cement, glass, and ceramics, each with a value-added contribution below 2% consumes much more energy (cement at 20%, ceramics at 4% and glass at 3%).

The industrial orientations discussed above will lead to a less energy-intensive industrial sector. IICEC analysis also shows that this pathway would lead to an increased export share from the highest value-added sectors[60].

Electric motor systems are a high priority for improved energy efficiency. Globally, these systems are responsible for over half of the world electricity consumption and about 70% of the electricity demand in industry. About two-thirds of industrial electricity use and almost one-third of Turkey's net electricity consumption is from electric motor systems employed in the manufacturing industry. It is estimated that at least 3.5 million AC motor systems are inefficient according to a study by the Ministry of Industry and Technology. Most of this inefficient stock is employed in small and medium enterprises (SMEs). Transforming this stock to the current best available technologies[61] would reduce power demand by significant TWh. In order to realize this efficiency potential, the "Transition to Energy-Efficient Electric Motors in Industry" program (TEVMOT[62]) was launched in 2018 targeting a 1.5 TWh savings until 2022. Pilot applications including SME funding started in 2020. The energy savings that can be realistically achieved are estimated to be much higher than the initial target of 1.5 TWh. However, achieving these potential savings requires persistent and flexible policy actions along with technical advancements.

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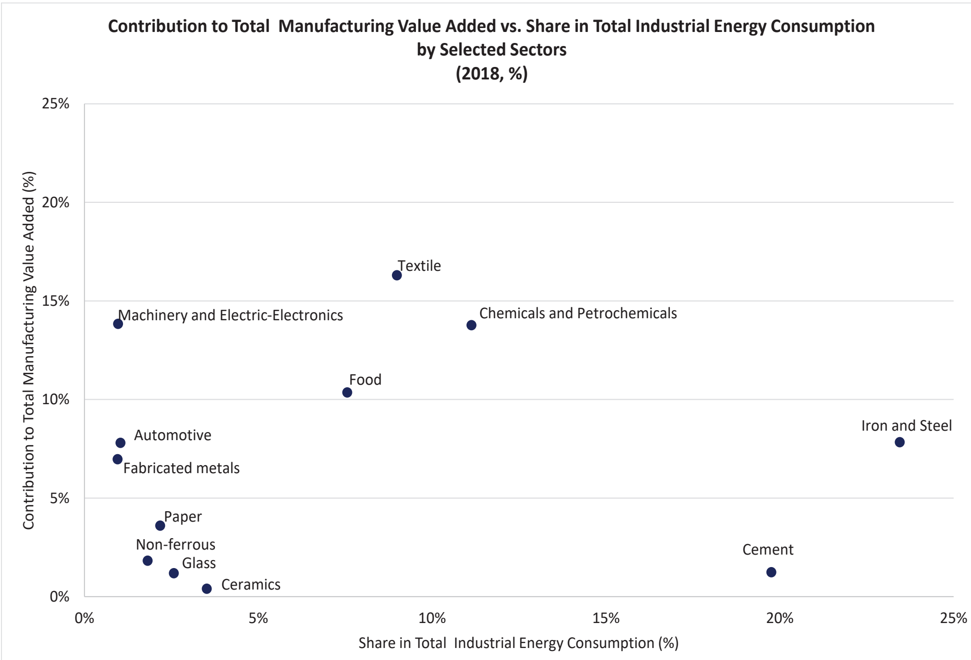
60 Turkey's exports were realized at $180.5 billion in 2019. Automotive industry contributed to about one-sixth of total exports followed by sectors producing machinery, mechanical and electric equipment.

61 The energy efficiency of an electric motor is calculated as the ratio of the mechanical output power to the electrical input power. The energy efficiency level is expressed in International Energy efficiency classes (IE), IE1 being the lower class and IE4 the highest: IE1 Standard Efficiency, IE2 High Efficiency, IE3 Premium Efficiency, IE4 Super Premium Efficiency.

62 TEVMOT Project is conducted by the Ministry of Industry and Technology under financial support by the Global Environment Fund (GEF) and in cooperation with the UNDP.

Figure 5.8 Contribution to Total Manufacturing Value Added vs. Share in Total Industrial Energy Consumption by Selected Sectors (2018, %)



IICEC analysis based on MENR and Turkstat data

Note: Value-added analyses at factor costs[63]

Turkey has two main support mechanisms applicable to industrial energy efficiency projects. The Energy Efficiency Improvement Projects (VAP) program provides grants up to 30% of efficiency project costs and are capped at 5 million TL. VAP efficiency projects are also limited to two years' duration. Industrial facilities having energy consumption of above 500 toe/yr. are eligible to apply for this incentive. Its scope includes recovery of waste energy, elimination of energy losses including insulation, and process specific actions. The industrial enterprises should have certified energy managers and ISO 50001 energy management certificates[64] . Until now 270 projects have been finalized with total support of 30 million TL. More than a hundred projects are currently under implementation with granted support of around 23 million TL.

[63] Value added at factor cost is the gross income from operating activities after adjusting for operating subsidies and indirect taxes.

[64] ISO 50001 is an international standard created by the International Organization for Standardization (ISO). The standard specifies the requirements for establishing, implementing, maintaining and improving an energy management system to enable an organization to follow a systematic approach in achieving continual improvement of energy efficiency performance.

Another support mechanism is voluntary agreements where, as with the VAP program, industrial enterprises with an annual energy consumption of over 500 toe/yr. can apply as long as they have assigned energy managers and ISO 50001 certifications. These agreements use a reference point based on the average energy intensity over the past five years and aim to achieve more than a 10% reduction at the end of a three-year monitoring period. If this is achieved, the facility can receive 30% of total energy costs (up to 1 million TL). Total investment under these two models now reached to over 210 million TL.

Despite a detailed legislative framework and growing interest from the industry, both models remained short of what can be increasingly achieved. For example, since 2009 only a small percentage of industrial facilities engaged in voluntary agreements. One of the reasons has been the major program focus on electricity consumption. This does not reflect the thermal energy-intensive structure of overall industry use, especially large consumers such as the iron, steel and cement sectors. Changes in these programs are expected to give increased attention to thermal energy use.

In general, the financial support mechanisms can be improved. For example, a fast-acting and cost-effective solution would be to focus financial grants on specific areas that have obvious efficiency potential such as electric motor systems and LED lighting. IICEC analysis shows that a more rapid transformation towards efficient electric motor systems will provide significant cost-effective energy savings. Mandatory energy audits are a proven tool to assess the inefficiencies and improvement areas and currently, all industrial facilities with consumption of 1.000 TEP or higher are within the scope of auditing. Most recently, it was announced that industrial projects can benefit from "Fifth Region"[65] incentives regardless of their location, provided that they achieve 15% savings in their base consumption.

The current government efficiency programs could play a stronger role in enhancing industrial energy efficiency but IICEC believes that more substantial gains can be realized by creating an effective ecosystem for energy performance contracts (EPC), a model that has been widely used in most advanced and emerging energy economies as an established business partnership between the energy consumers and the energy service companies (ESCOs). The global EPC market including buildings and other services reached $27 billion in 2017. An EPC commits the ESCO to assume any technical risks and installing the necessary equipment to advance energy efficiency, provides a performance guarantee and establishes the terms of any upfront or later payments. These payments are intended to be more than offset by reduced energy costs. The two most common models of EPCs are shared savings and guaranteed savings [66].

65 According to the regional basis investment incentives, fifth region investments are eligible to receive 40% contribution to their total investment and a tax deduction rate of 80%.

66 In North American, European and Australian markets, guaranteed savings EPCs are more heavily utilized. Japan use the shared savings model where the ESCO can provide financing with the energy savings shared between the ESCO and the customer over the contract period. for over two-third of their EPC contracts. Several factors determine the choice between these two models and in general guaranteed savings models are used in more developed markets with an established banking structure. However, where an ESCO might not have lending ability, they may need to use a guaranteed savings model, where the customer is responsible for financing the project.

Turkey's initial approach is towards a combined use of government incentives and ESCOs. However, Turkey's EPC/ESCO market is still at the very early stages of development and has not been progressing at the necessary pace. One of the main bottlenecks is financing due to equity limitations and the nature of such contracts relying on long term agreements, sometimes over 10 years, in spite of the favorable economics offering much shorter pay-back periods, even 2-3 years in some cases. As an EPC is built upon an extensive project time-line including audits, projection of base and targeted trajectories regarding energy demand reductions, necessary installations, and ultimately performance verifications, financial commitment from the customer (energy user) is a prerequisite. Most needed actions are within the SMEs rather than large, institutionalized facilities which have been able to show improvements in their energy performance as part of their commercial business strategies over the years without ESCOs. Engaging the industry into power and gas markets by the developments discussed in Chapter 1 (Power Sector) and Chapter 4 (Natural Gas) is expected to contribute a wider use of the EPC/ESCO model in Turkey provided that various barriers are overcome, for example, by using innovative insurance models to reduce counter-party credit risks.

A large portion of the industrial energy demand is consumed in the Organized Industrial Zones (OIZs) in Turkey. Currently, over 40% of total industrial natural gas use and almost 30% of total industrial power demand takes place in OIZs. The OIZs are natural targets to achieve wider efficiency gains and larger penetration of on-site renewable energy. Industrial engineering assessments can also optimize resource use and supply chain efficiencies creating, not only energy savings, but other cost reductions. A similar approach can provide gains in university campuses and techno-parks.

IICEC's industrial energy demand scenarios are presented in Table 5.1. Both scenarios reflect a pathway for a more energy-efficient industrial growth with a more balanced supply mix to contribute to the localization and sustainability goals of the Turkish energy economy. The Reference Scenario reflects the current progress and targets defined in the policy documents until 2023 and considers higher efficiency improvements in the medium to long term towards 2040. Industry energy demand increases by 1.8%/yr. on average (or a cumulative 48% increase). The fastest-growing fuel is electricity from 10 mtoe in 2018 to 17.4 mtoe in 2040. Electricity becomes the leading fuel before 2030 and corresponds to 32% of total energy demand by 2040 up from 28% in 2018. Natural gas is the second fastest-growing fuel source representing 30% of industrial energy demand in 2040 compared to 26% at present. The renewables supply doubles, mainly from increasing biomass utilization replacing coal consumption in various industries, especially in the cement sector. Solar heating also becomes widely deployed in industries with low-temperature heating applications such as drying, washing, sterilizing in the textiles, food and beverages, and chemicals. 13% of the demand is met by renewables heating compared to around 10% currently. Coal consumption remains largely driven by major energy users such as iron, steel and cement but its share in total industrial energy demand decreases from 26% in 2018 to 21% in 2030 and further to about one-sixth by 2040. Oil's contribution slightly decreases from 10% to 8% until 2040 and is limited to petcoke use in the cement industry. Continuous improvements are achieved in realizing the energy efficiency potential across industries but the performance remains short of the overall potential of 25-35% due to a lack of more stringent policy actions to drive efficiency investments by means of new business models and additional incentives and requirements.

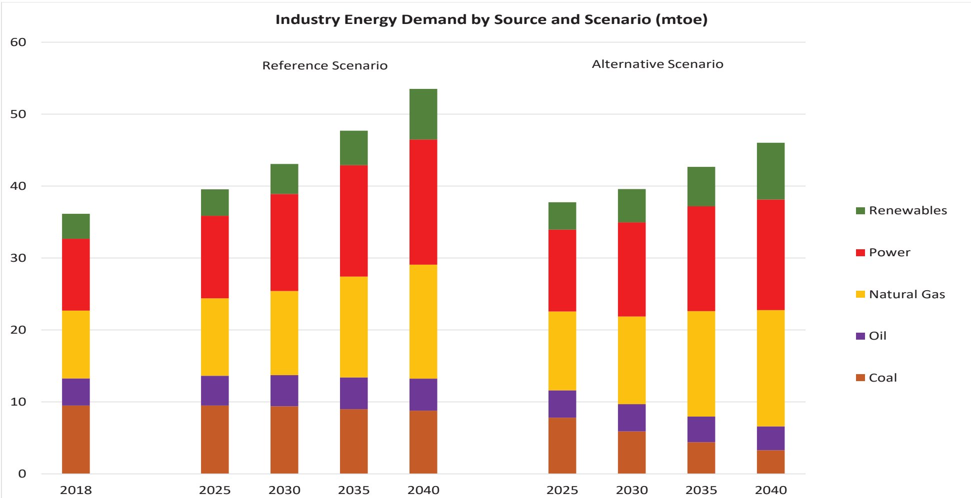
Table 5.1 Summary of Industry Energy Demand in Scenarios

Scenarios		**Reference Scenario**		**Alternative Scenario**	
mtoe	**2018**	**2030**	**2040**	**2030**	**2040**
Industry Energy Demand	36.2	43.1	53.5	39.6	46.0
of which					
Coal	9.5	9.4	8.8	5.9	3.3
Oil	3.8	4.3	4.5	3.8	3.3
Natural Gas	9.4	11.7	15.8	12.2	16.2
Electricity	10	13.5	17.4	12.2	15.4
Renewables	3.5	4.2	7	5.6	7.9
Share of Electricity (%)	28%	31%	32%	31%	33%
Share of Electricity and Renewables Combined (%)	37%	41%	46%	45%	51%

Alternative Scenario policies cause a more efficient industrial sector. Energy demand through 2040 increases by 1.1%/yr. (a 27% cumulative increase). This is achieved by more effective implementation of various mechanisms such as EPCs that are backed by a stronger ECSO ecosystem, financial guarantees, and incentive mechanisms. Government incentives are designed more thematically into areas such as electric motor systems and LED lighting where large savings can be realized. These investments reduce industrial electricity demand by 12% until 2040 over the Reference Scenario. With increasing electrification reflecting the structural transformation of the Turkish industry, electricity share increases to one-third, just behind natural gas at 35%. These two fuels combined supply almost 70% of total demand compared to 62% in the Reference Scenario by 2040 (up from 54% in 2018).

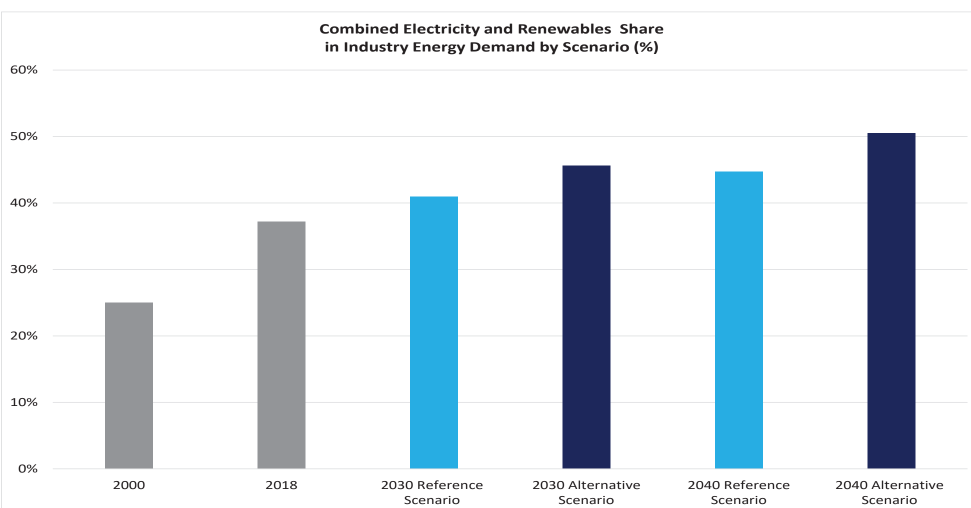
Coal declines with higher energy efficiency performance in the coal-using sectors and larger use of alternative thermal energy sources such as biomass and waste heat. Industrial coal use decreases by two-thirds to only 7% of industrial energy demand by 2040. Oil supplies another 7% in 2040. The renewables share increases to 17%. In sum, the Alternative Scenario has 14% less energy consumption than the Reference Scenario by 2040 and with a more sustainable fuel mix (Figure 5.9).

Figure 5.9 Industry Energy Demand by Source and Scenario (mtoe)



As discussed above, the industrial energy supply mix will transform into a more electrified supply structure including an increasing role for natural gas and with substantial increases in renewable supply. In the Alternative Scenario, electricity and renewable heat combined provide slightly over half of the total industrial energy demand by 2040 compared to 46% in the Reference Scenario and 37% at present (Figure 5.10). This shift in the supply mix results in significant reductions in both the emission growth and emissions per unit energy used in the Turkish industry as discussed in Section 5.3.5 below.

Figure 5.10 Combined Electricity and Renewables Share in Industry Energy Demand by Scenario (%)

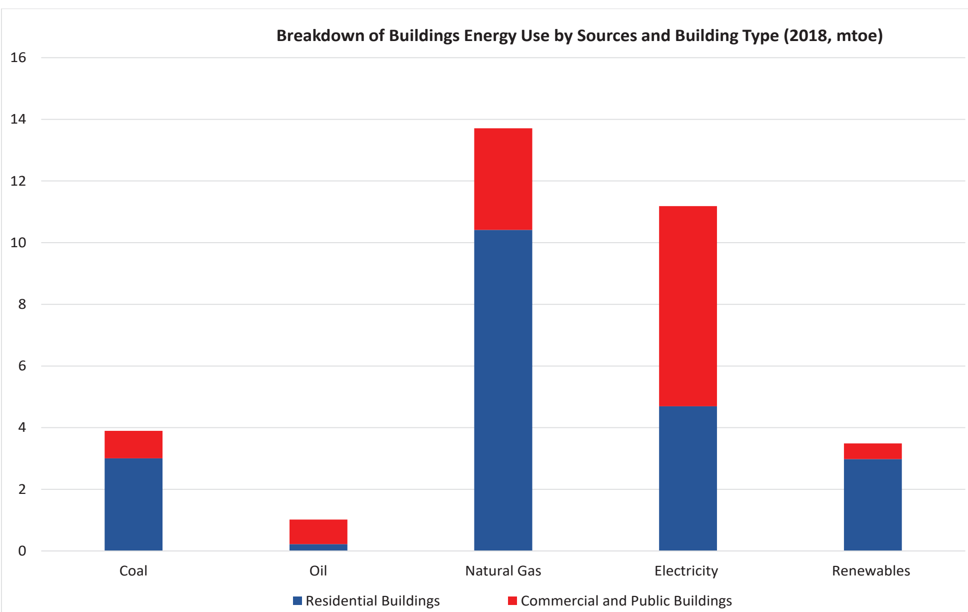


5.3.2 Buildings

Buildings represent one-third of final energy consumption in Turkey. Energy use in buildings will grow due to increasing population and increased access to modern energy services. Since 2000, buildings energy demand has grown from 19.6 mtoe to 33.4 mtoe (a cumulative 71% increase) with the fastest increases occurring in gas use, by over four times, and electricity use, doubled. This is in line with global trends.

In residential buildings, which correspond to 64% of total buildings energy demand, natural gas has become the leading fuel in Turkey (49%) followed by electricity (22%). Energy demand from coal is on the decline but still has the same share with renewables (biomass, solar and geothermal) at 14%. Electricity represents 54% of energy demand in commercial and public buildings especially because lighting and HVAC equipment are more widely used than in residential dwellings. Natural gas contributes to 28% of energy demand in commercial and public buildings, followed by coal and oil (each with 7% share) (Figure 5.11). Coal and oil are mostly used in old, less efficient buildings, especially residential buildings.

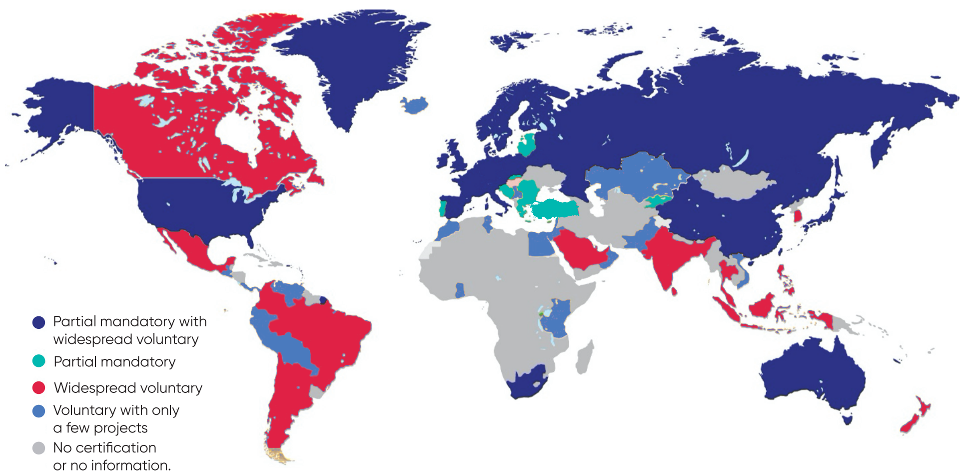
Figure 5.11 Breakdown of Buildings Energy Use by Sources and Building Type (2018, mtoe)



Turkey's total building stock is composed of 8.1 million residential buildings and 1.3 million commercial and public buildings. It is estimated that about three-quarters of the total floor area is in residential dwellings. In the last five years, the residential building stock has increased by about 100 thousand/yr., in line with the growing population, rising urbanization and emergence of new urban centers.

Around 90% of the current building stock was built before 2011 when the Energy Performance Certificate system began. Also, 85% of Turkish buildings were built before 2000, when Turkish insulation regulations were established. However, there are no certification requirements for buildings built before the end of 2019. While Turkey is among the countries with mandatory building codes (Figure 5.12) there is a wide variation as to what these requirements are and how completely they are specified and enforced.

Figure 5.12 Building Insulation Regulation by Regions Globally[67] (IEA, 2020c)



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of ant territory, city or area.

Source: IEA, 2020. Turkey reflecting the current status.

Since 2011, buildings with EU certified energy performance have accounted for only around 10% of the total building stock. 20% of certified buildings were constructed before 2011. Less than 1% of the certifications represent the most efficient A class buildings. B class buildings account for about a quarter of the certified stock. Beginning in 2020 all new buildings are required to have at least a (EU) C label certificate. The C label means that energy consumption is 80% to 99% of a reference building within the same climatic zone (Figure 5.13), in other words, a bit better than average. These figures show a need for expanding certification across the complete buildings stock, especially to transform Turkey's older buildings. As shown in Figure 5.13, the differences in building energy performance are very wide. Taking 100 as a reference figure, an A-class building consumes at least 61% less energy and a G class building consumes at least 75% more energy.

[67] According to the IEA data, about 85 countries had building energy certifications in 2019. Only 40 had mandatory building energy certification policies. 20 had widespread voluntary certification policies or programmes. The remainder had only a handful of voluntary projects.

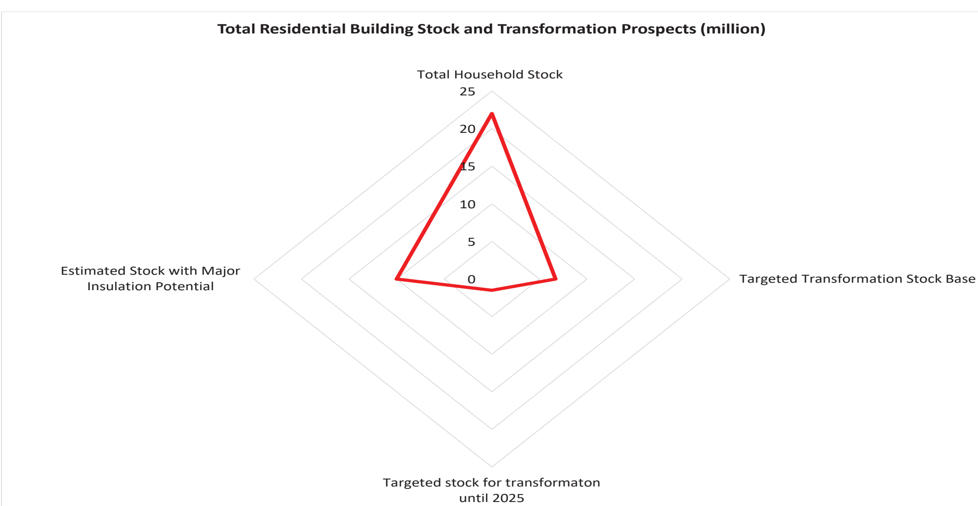
Figure 5.13 Energy Performance per Buildings Classification and Corresponding Energy Use

A	0 - 39
B	40 - 79
C	80 - 99
D	100 - 119
E	120 - 139
F	140 - 174
G	175 - ...

Note: Energy use normalized in terms of energy consumption of a reference building in the same climatic zone.

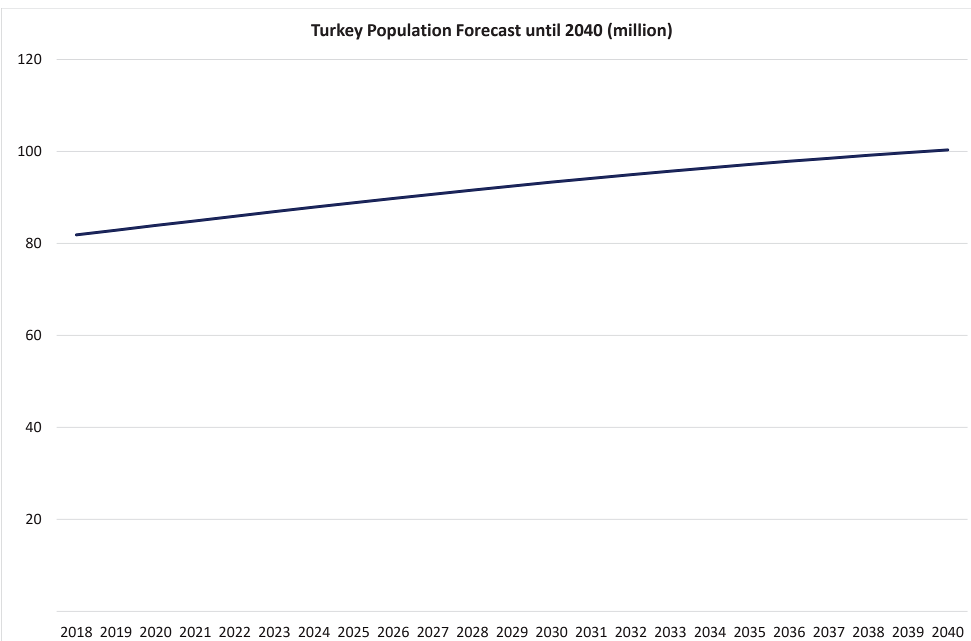
Turkey's inefficient building stock may represent the largest opportunity for efficiency gains compared to all other end use sectors. This is particularly true for residential buildings that are typically less efficient than commercial buildings. The number of housing units is now over 22 million. Since 2012, 1.4 million residential units have been transformed for earthquake preparedness purposes. As part of Turkey's earthquake resistance programs, 1.5 million units are in urgent transformation plan by 2025. The total stock for transformation was targeted at 6.7 million, or one-third of total residential housing units. In comparison, housing units that need improved insulation are estimated at 15 million and, of these, 10 million have inadequate insulation (Figure 5.14).

Figure 5.14 Total Residential Building Stock and Transformation Prospects (million)



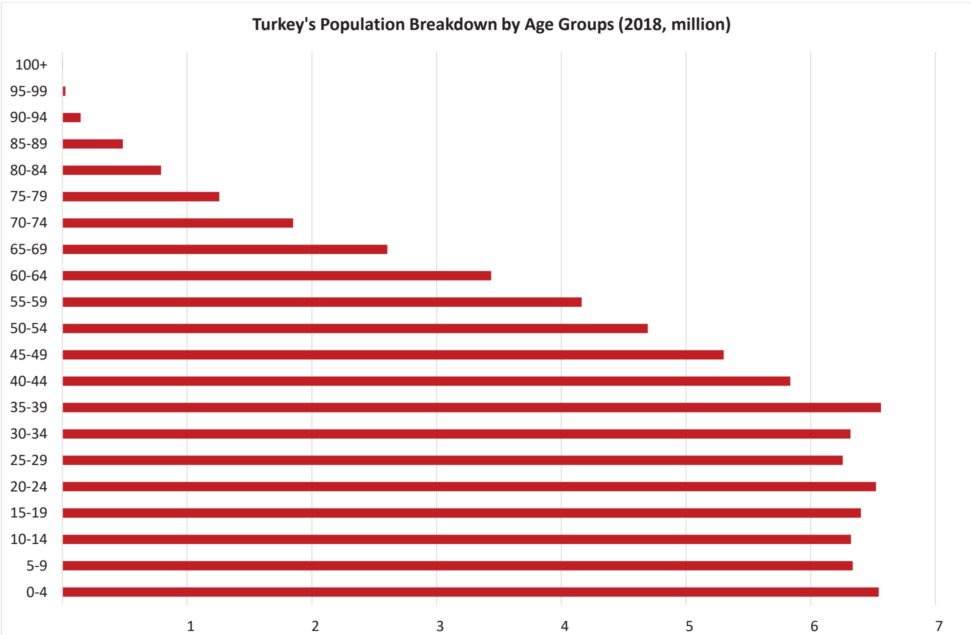
With a population of over 83 million now, Turkey is more populated than any EU country as of 2020. The population is projected to reach over 100 million by 2040 (0.3% annual growth). (Figure 5.15). Another key demographic is its relatively young population (32 years median age). (Figure 5.16). Turkey is also rapidly urbanizing as major economic centers are growing in a number of regions. This is accompanied by a movement of employees from agriculture to services and industries. As discussed in Chapter 2, 23 cities now have a population of over 1 million. All of these factors will affect how Turkey's cities, urban centers, and building stock develops. How this building stock develops in terms of the energy efficiency performance has far-reaching implications compared to any other energy end use as the building stock is so long-lasting. The average building stock development will not reach its maturity until many decades after the TEO horizon. Consequently, reducing energy use during the TEO horizon requires a focus on the existing stock, but efforts to ensure top efficiency performance in new buildings are a long-term investment in Turkey's economic and energy security future.

Figure 5.15 Turkey Population Forecast until 2040 (million)



Source: Turkstat, 2020

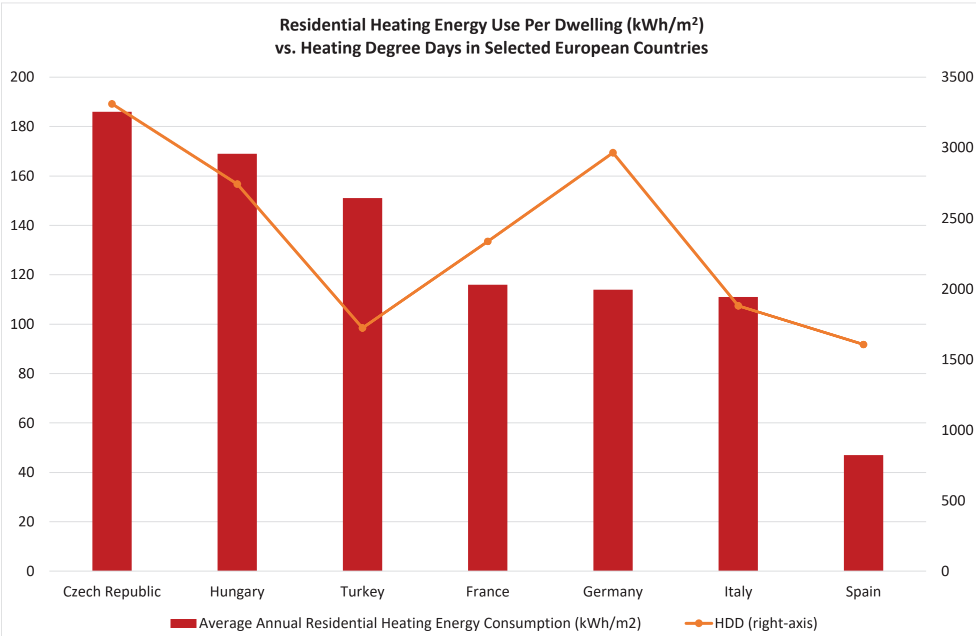
Figure 5.16 Turkey's Population Breakdown by Age Groups (2018, million)



Source: Turkstat, 2020

Two-thirds of the energy demand in buildings stem from heating and cooling services and the remaining one-third is by lighting and appliances. In residential buildings, depending on the climate zone, heating and cooling demand represent up to 70% of total building energy consumption in Turkey. Based on residential energy use and total floor area of dwellings, residential building energy use is at 100 kWh/m^2. However, part of the dwelling units is not completely active either representing an unsold stock or due to seasonal or temporary use such as summer houses. When these factors are taken into account, residential building energy use is estimated at 200 kWh/m^2 per dwelling. This figure is much higher than many European countries, especially central and southern Europe with similar climate characteristics as Turkey. IICEC analysis evaluating the energy performance as a function of heating degree days (HDD) demonstrates that Turkish residential units consume 30-40% more energy for heating compared to their peers in Italy, France and Germany (Figure 5.17). Although the C class buildings provide a performance of around 100 kWh/m^2, the majority of the stock is older, as discussed above, and needs to be transformed for achieving energy performance levels comparable to global best practice. For example, current plans of the EU include achieving below 15 kWh/m^2 by implementing "near-zero energy buildings" technologies. While these technologies include many others besides insulation, insulation performance remains important. Market data indicates that the average building envelope thickness is less than half of the insulation in European countries in similar climatic zones.

Figure 5.17 Residential Heating Energy Use per Dwelling (kWh/m²) vs. Heating Degree Days in Selected European Countries



IICEC Analysis based on State Meteorological Institute, IEA, Eurostat data, 2020.

Note: 2018 data for Turkey and 2017 data for other countries. Calculations are based on an estimation of the active residential units

ICEC concludes that the most important barrier to achieving improved building energy efficiency is access to finance. Improving the ease and terms of securing energy efficiency finance would greatly increase Turkey's energy efficiency progress and allocate capital to high productivity areas as the returns in energy savings are much more reliable than the economic returns of other investments. Ease of access is also important because the ecosystem involves a large number of small property owners who have limited awareness of the benefits they will achieve by improving insulation and making other efficiency investments. A recurring issue is the uncertainty that a building owner will be the one to benefit from the investment since these actors often don't know how long they will be the property owner. Therefore, building labeling is important to capitalize the value of efficiency investments.

IICEC recommends that mandatory programs and attractive financing opportunities are the two most important strategies to speed energy efficiency investment in residential buildings. These programs should be guided with cost-benefit analyses to ensure the high payoffs to building owners, Turkish energy consumers and the objectives of energy security, that these investments can provide.

Non-residential buildings, on the other hand, promise a more energy-efficient outlook due to several reasons. Public buildings with an annual energy demand over 250 toe or are larger than 10 thousand m^2 and commercial buildings having more than 500 toe annual consumption or are larger than 20 thousand m^2 must have certified energy managers. The energy managers must report their annual energy consumption to the Ministry of Energy and Natural Resources. Other public and commercial buildings are also obliged to report their energy consumption in last three years in a five-year reporting period.

Public buildings are one of the key target areas in the Government's energy efficiency agenda. Energy Efficiency Law has been amended in 2018 to allow public institutions to make long term EPC/ESCO agreements for up to 15 years. For all public buildings, reducing energy consumption by at least 15% by 2023 has been mandatory since 2019[68] including the municipalities. Several demonstration projects were launched in 2020. It is targeted that all public buildings will achieve class C after the implementation until 2023.

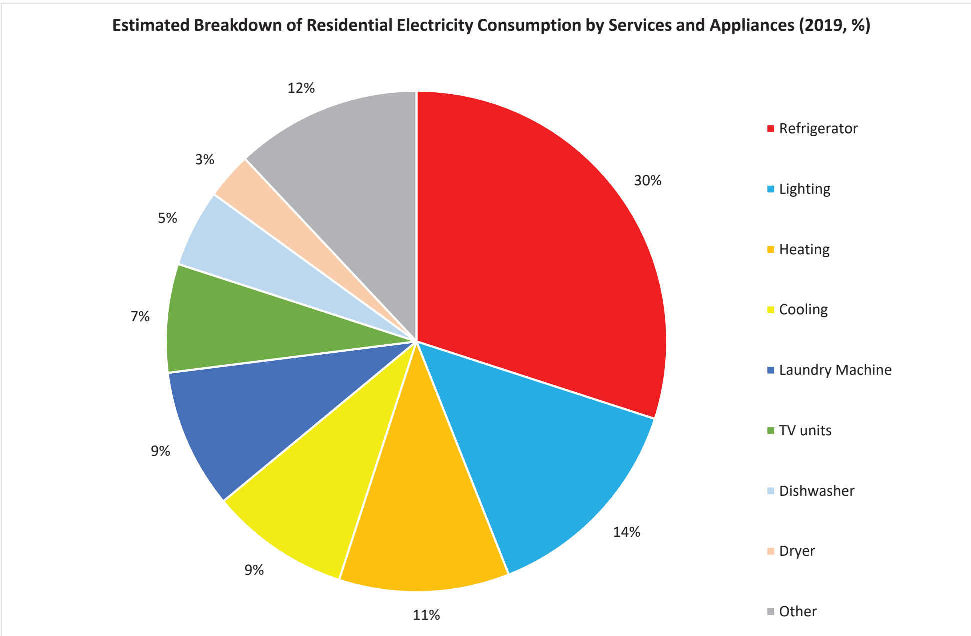
The expected impact will be two-fold. It will reduce the energy intensity of Turkey's large public buildings base in all 81 provinces. Compilation of data via multiple case studies would demonstrate actionable results for other buildings such as private schools, hospitals, shopping malls, commercial office buildings, and others. IICEC recommends that the EPC/ESCO model, discussed in Section 5.3.1, play an important role across non-residential buildings, especially the publicly owned ones. For public buildings, there is practically no counter-party risk and the efficiency projects for commercial buildings are relatively less complicated compared to industrial facilities involving several different components and processes.

Another area where Turkey presents high energy efficiency potential is appliances. Turkey's building stock is increasingly electrifying and electricity now represents 22% of residential energy demand. More than half of the electricity demand in households is from increasing penetration of whitegoods. It is estimated that refrigerators are responsible for about 30% of total residential electricity use, followed by lighting (14%) and heating and cooling equipment (20%). Recently TV units and other whitegoods such as dryers and dishwashers are increasing their penetration as a function of urbanization and increasing income (Figure 5.18).

Turkey is one of the leading manufacturers and exporters of whitegoods and complies with energy efficiency regulation in the EU. Therefore, new Turkish whitegoods have the best available energy performance. New products will comply with the recent EU eco-design and the new energy label which will take place in March 2021 improving efficiency performance even further.

[68] The project is based on a funding of $200 billion provided by the IFC, the Clean Energy Fund of the Worldbank, and the EBRD.

Figure 5.18 Estimated Breakdown of Residential Electricity Consumption by Services and Appliances (2019, %)



Source: TURKBESD, 2020

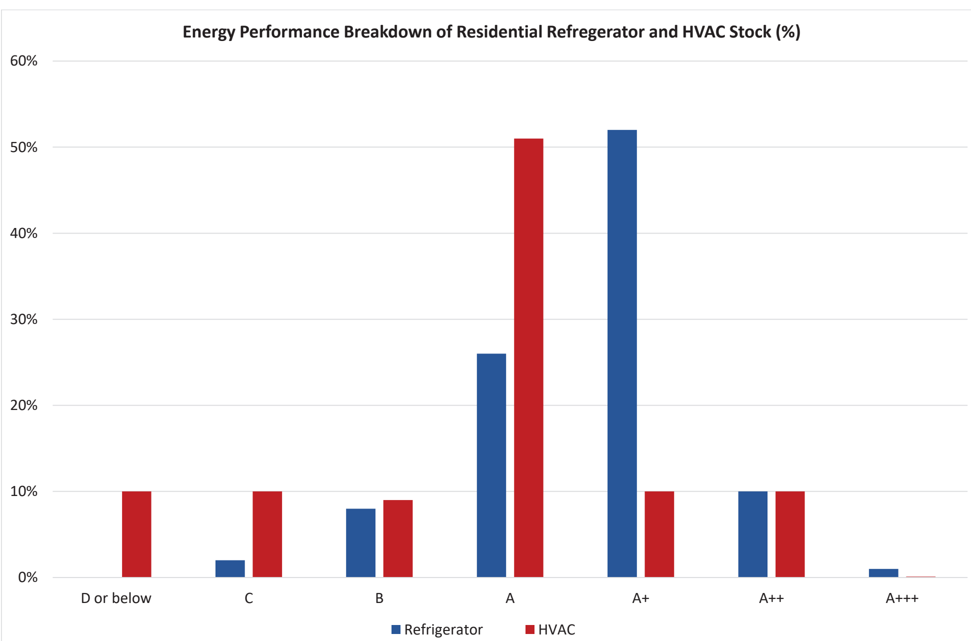
Despite these develoments, energy efficiency potential through an effective replacement of the appliance stock is significant. For example, energy performance of an AAA+ refrigerator over an A rated model of the same brand is 60% higher. Over 7.5 million refrigerator units are class A or below (Table 5.2). A complete transformation of this large stock to A+++ is calculated to yield about 5 TWh/yr. savings (or about 10% of current household electricity consumption).

Table 5.2 Relative Energy Efficiency Performance of Refrigerators

	B	A	A+	A++
A+++	71%	60%	50%	34%
A++	56%	40%	24%	
A+	41%	20%		
A	27%			

HVAC equipment also deserves special focus as only 10% of the existing stock is with A++ or higher performance while almost one third is still below A (Figure 5.19). These are also imported from different country of origins resulting in lower energy performance, for example, compared to Turkish and European energy standards. The demand for cooling is on the increase in Turkey, along with global drivers and trends. Air conditioners and electric fans represent about one-fifth of the total electricity use in buildings globally, or 10% of world electricity consumption. They correspond to 12% of buildings electricity demand in Turkey, including non-residential buildings. HVAC penetration rate in Turkey is around 15%. Similar to all emerging energy economies, the low current use of air conditioning, particularly in households, implies high future growth as incomes rise. Therefore, regulations should be established before this growth occurs to ensure that the most efficient HVAC units are used, even if they have higher upfront costs, because the investment in the most efficient units saves money for all subsequent users and is required to support energy security. Improving the efficiency of AC units also benefits the power sector because more efficient air conditioning would reduce the load variations that need to be managed across the power system through measures as discussed in Chapter 1. These load variations could have significant system-wide costs on the Turkish electricity system, especially with increasing shares of intermittent power and a growing need for more seasonal storage.

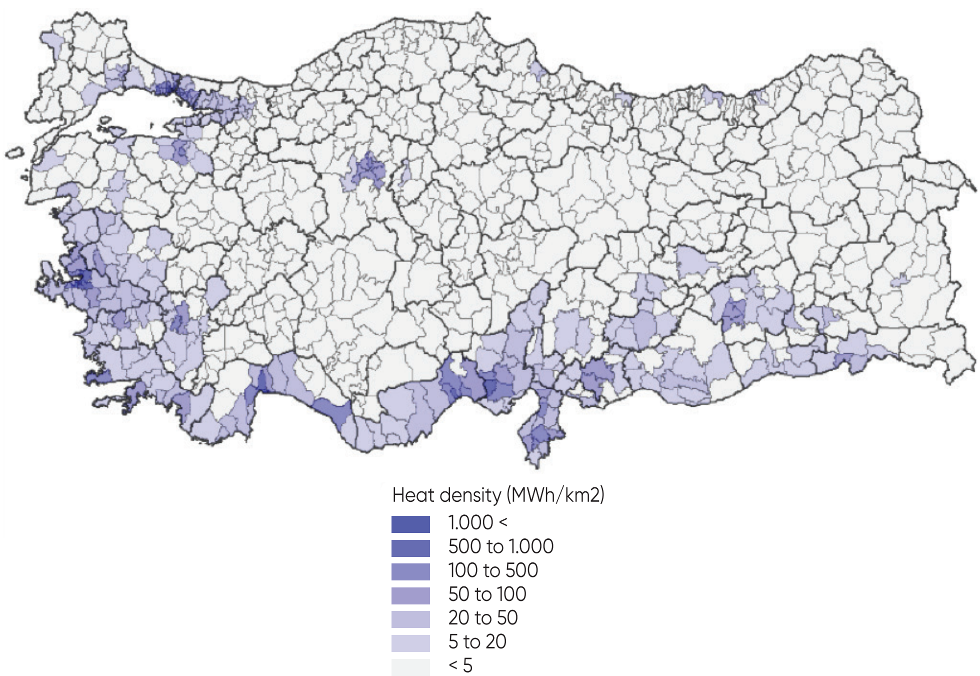
Figure 5.19 Energy Performance Breakdown of the Residential Refrigerator and HVAC Stock (%)



Source: TÜRKBESD, 2020

Complementary to conventional air conditioning equipment, heat pump systems[69], stand-alone or integrated into district heating and cooling (DHC) systems, can provide a sustainable solution to meet growing cooling demand in Turkey within the TEO horizon. Cooling density is over 1000 MWh/km^2 along the Aegean and Mediterranean coasts and above 500 MWh/km^2 in many large cities and urban centers such as Istanbul and Ankara (Figure 5.20). Heating density in certain areas in Istanbul, Ankara and some other industrialized spots stay above 80 GWh/km^2 (Rud, 2019). These figures indicate a large potential for implementing heating and cooling supply solutions on-site and benefitting from an integrated perspective by cost-effective DHC systems.

Figure 5.20 Estimated Cooling Density in Turkey



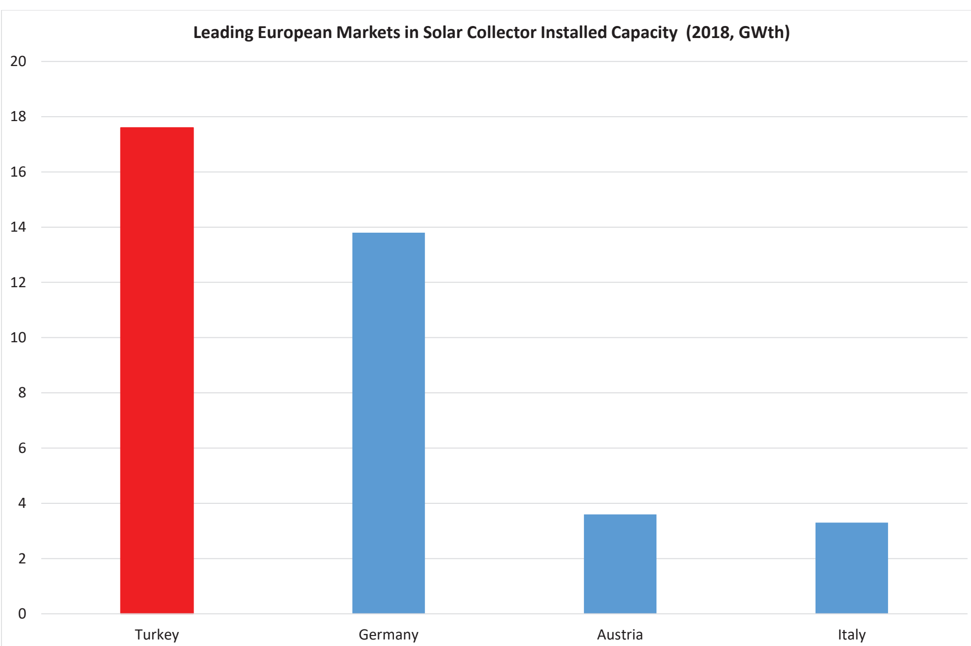
Source: Danish Energy Agency, 2019

[69] Around 20 million households purchased heat pumps in 2019 worldwide. Although heat pumps have become a common energy technology in newly built houses in many regions, they meet only 5% of global building heating demand. The IEA estimates that in many markets, the installed costs for heat pumps relative to potential savings on energy spending often indicate that heat pumps may be only marginally less expensive over 10 to 12 years, even with their higher energy performance.

DHC systems consist of pipe networks that also integrate energy resources, power plants, and efficient energy technologies such as combined heat and power to realize waste heat recovery. A DHC connects multiple thermal energy users (heating and cooling demand) to optimize energy supply. Energy efficiency results not only in a saving of fuels but also in a consequent reduction of environmental pollution due to a combined impact of renewables and energy efficiency. There are a few DHC examples such as geothermal heating networks in some cities in the Aegean part of Turkey. Since 2019, Turkey has been working on preparations for designing a road map for implementing DCH systems in selected regions. Heat maps defining heating and cooling requirements on a regional basis have been developed. All heat sources such as renewable heat from biomass, solar and geothermal, excess heat from existing thermal power plants, and industrial facilities are under consideration.

Turkey is one of the early adopters of solar heating by collectors. With a total installed capacity of about 18 GWth, it leads the European market (Figure 5.21) and ranks third only after the United States and China globally. Turkey is also among the top ten countries globally in terms of penetration of solar collectors for heating at 217 kWth/1000 inhabitants (IEA, 2020d). Solar collectors provide 0.9 mtoe of final energy demand about two-thirds of which is utilized in buildings, mostly in residential housing units.

Figure 5.21 Leading European Markets in Solar Collector Installed Capacity (2018, GWth)



Source: TÜRKBESD, 2020

The TEO Scenarios for buildings energy demand and fuel use are summarized in Table 5.3. The buildings will be the fastest growing end-use energy demand sector including transport. In the Reference Scenario, the demand increases by 2.3%/yr. (a cumulative 61% increase to 2040). Energy demand growth in the Alternative Scenario is lowered to 1.7%/yr. (a 45% increase instead of 61%). Although both scenarios reflect a growing stock driven by increasing population, urbanization and urban transformation needs, total energy use and consumption by fuels and technologies are estimated to be significantly different.

Table 5.3 Summary of Buildings Energy Demand by Scenario

Scenarios		**Reference Scenario**		**Alternative Scenario**	
mtoe	**2018**	**2030**	**2040**	**2030**	**2040**
Buildings Energy Demand*	33.4	43.4	53.7	41.8	48.4
of which					
Coal	3.9	3.7	3.5	2.6	0.6
Oil	1.0	1.1	0.9	1.0	0.7
Natural Gas	13.7	17.6	19.8	18.1	20.7
Electricity	11.3	16.6	23.3	15.6	19.7
Renewables	3.5	4.4	6.3	4.5	6.7
Share of Electricity (%)	34%	38%	43%	37%	41%
Share of Renewables (%)	10%	10%	12%	11%	14%

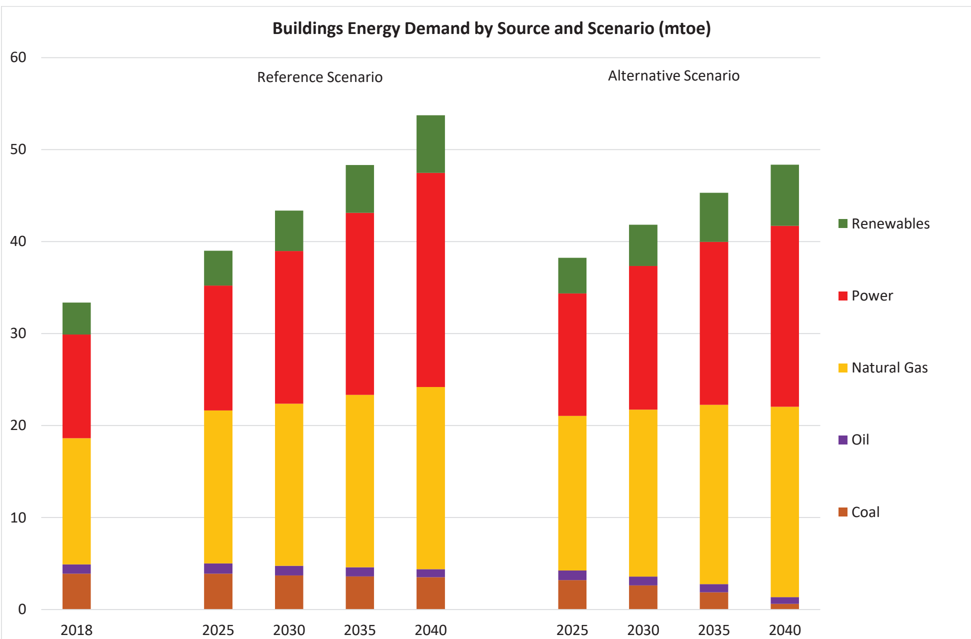
Note: *Including other public and commercial services

In both TEO Scenarios, more stringent energy performance measures are applied to new buildings. The Alternative Scenario reflects a more progressive pathway including mandatory measures and effective financial models for transformation of the old and inefficient stock in residential and commercial buildings. It also realizes best available solutions for building energy use including deployment of near-zero and net-zero energy buildings that integrate a wider use of rooftop PV and renewable heating technologies, again mainly from solar and supported by geothermal. The Alternative Scenario assumes cost-effective implementation of DHC systems when there are high heating and cooling demands and other local opportunities to make these solutions practical. The TEO Alternative Scenario includes programs to replace inefficient appliances and ensure purchase of efficient HVAC systems. The measures bring the energy performance of the building stock to best practices observed in European peers with similar climatic conditions.

In both scenarios, natural gas will remain the leading fuel supported by Turkey's expanding gas transmission and distribution network and increased flexibility in natural gas supplies. Advancements towards a more competitive natural gas market will be instrumental in serving increasing natural gas needs of public, commercial and residential buildings in an efficient and sustainableway.

IICEC observes that the recent gas discovery in the Black Sea will reinforce Turkey's policies to replace oil and coal use with clean natural gas by significantly reducing Turkey's natural gas import bill. Natural gas, electricity and renewables can replace a large portion of coal heating in buildings with significant environmental benefits. In the Reference Scenario, coal use in buildings drops from 12% in 2018 to 7% by 2040. The Alternative Scenario realizes a faster substitution driving the coal share to only 2% by 2040. Similarly, 2040 oil energy use drops to 2% in the Reference Scenario and only 1% in the Alternative Scenario although oil use was already low (3% in 2018). Electricity contributes to over 40% of the buildings energy demand in both scenarios and when combined with renewables represents 54% of the final energy demand in the buildings in 2040 compared to 44% in 2018 (Figure 5.22).

Figure 5.22 Buildings Energy Demand by Source and Scenario (mtoe)



Additional gains by the Alternative Scenario over the Reference Scenario requires close cooperation among the relevant Government entities and other key public institutions such as the Ministry of Energy and Natural Resources, the Ministry of Environment and Urbanization, and the municipalities. Collaborative efforts are needed for realizing cost-effective and urgent energy efficiency measures and advancing a sustainable shift towards fewer imported fuels. Improvements in the building envelopes should be facilitated by suitable financial packages to realize the significant efficiency potential in the urbanization progress, particularly within the ongoing urban transformation program that may be well extended to cover a larger number of residential housing units throughout this decade.

5.3.3 Agriculture

Turkey has a large agriculture industry providing employment to almost 20% of the total population and accounting for 6% of GDP, down from over 10% in 2000. Turkey has 23.2 million ha agricultural land and 5.1 million ha arable land. The country is an important producer and exporter of many agricultural commodities. It has the largest agricultural economy in Europe, it is the second-largest among OECD countries and among the top ten globally.

Agricultural activities, including forestry, farming and fishery, account for 4.4% of total final energy demand in Turkey, down from 5.3% in 2000. Oil remains the predominant fuel (65% of agricultural energy use) because of Turkey's large tractor fleet (1.9 million tractors). Half of the tractors are over 25 years old and, as such, are considered to be past their expected working life. Replacing these tractors would achieve significant efficiency benefits but the social dimensions and funding requirements would be challenging. Other approaches include sharing programs[70] that would typically optimize the working hours of tractors since the current practice indicates 500-600 hours of annual operation per tractor on average. Sharing programs can also be expanded to other agricultural machinery to lower energy use. Electric tractors are also on the agenda of the Government with early demonstration projects ongoing.

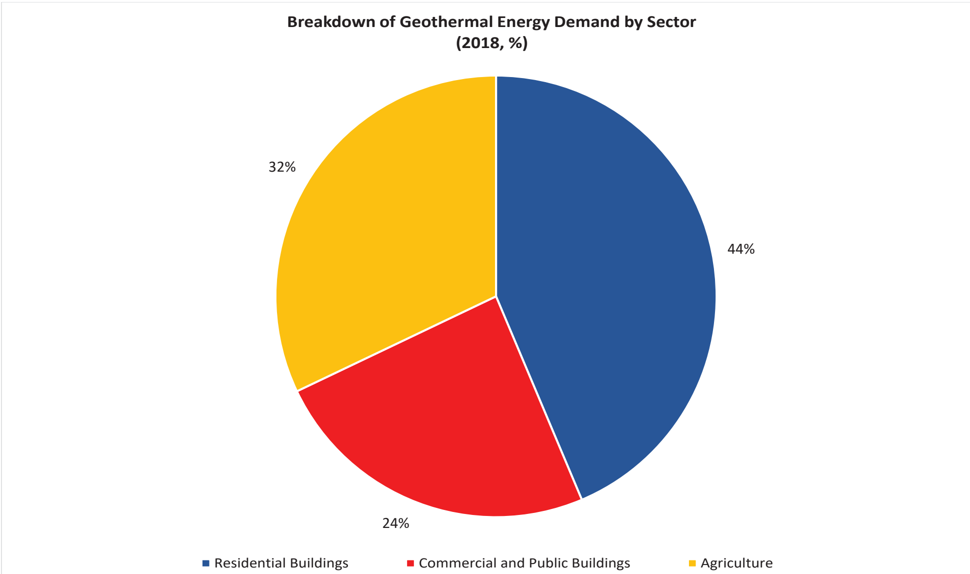
Electricity is the second largest agricultural fuel mainly due to irrigation needs. Agricultural power demand reached 9 TWh accounting for 17% of total energy use in agriculture up from less than 10% in 2000. Approximately 70% of power use stems from irrigation. There are significant opportunities to reduce irrigation power losses and improve efficiency. It is estimated that a 15% efficiency improvement is achievable and would yield 1 TWh of savings.

Geothermal energy is a central element in Turkey's agriculture system. Geothermal heating for greenhouse farming represents 14% of agricultural energy demand. Utilization of geothermal resources has been increasing especially over the past decade from 0.3 mtoe in 2010 to over 0.6 mtoe at present. Turkey is ranked first in Europe in terms of its geothermal energy resource base and one of the leaders in geothermal heating at present (IEA, 2019b)[71]. Currently over 4 thousand decares of the agricultural area is being heated by geothermal resources (or about 30% of total greenhouse farming) but the prospects are stronger with an estimated potential of 30 thousand decares. 99% of greenhouse farming is on vegetables and fruits.

[70] The sharing model can be based on allocating the tractor fleet in defined regions for common service for an increasing utilization factor per energy use. As Turkey poses differing climatic conditions across regions, which define the working seasons of the agriculture, this approach would yield limited impact on the overall agricultural productivity.

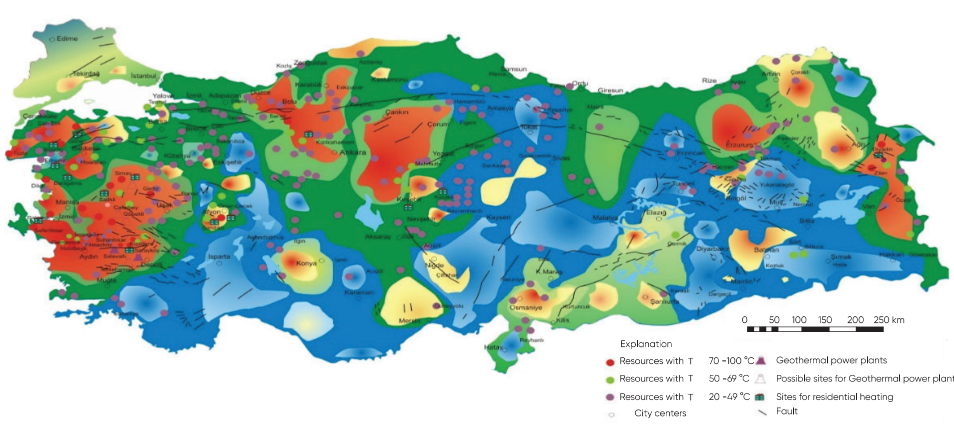
71 China and Turkey accounted for around 80% of global geothermal heat consumption in 2017.

Figure 5.23 Breakdown of Geothermal Energy Demand by Sector (2018, %)



As shown in Figure 5.23, agriculture accounts for 32% of Turkey's total geothermal final energy consumption, the remainder being residential and commercial buildings. Turkey's geographically diverse geothermal resources and agricultural opportunities will enable agriculture to become the leading final consumer of geothermal energy within the next two decades (Figure 5.24). There are several opportunities for a wider penetration of geothermal greenhouse farming in a variety of products expanding into vegetables and fruit drying as well as fisheries, especially in the western and central regions in Turkey.

Figure 5.24 Turkey's Geothermal Resources



Source: MTA

TEO Scenarios for the agriculture sector are presented in Table 5.4. In both Scenarios, the agricultural energy demand increases, however its share in total final energy consumption in Turkey continues to decline from 5% in 2018 to 4% in 2040. Demand in the Alternative Scenario is 13% less than in the Reference Scenario by 2040, mainly as a result of more efficient energy use of tractors and other agricultural machinery, measures implemented in irrigation pumps for improved energy efficiency and increasing employment of renewable energy resources.

Table 5.4 Summary of Agriculture Energy Demand in Scenarios (mtoe)

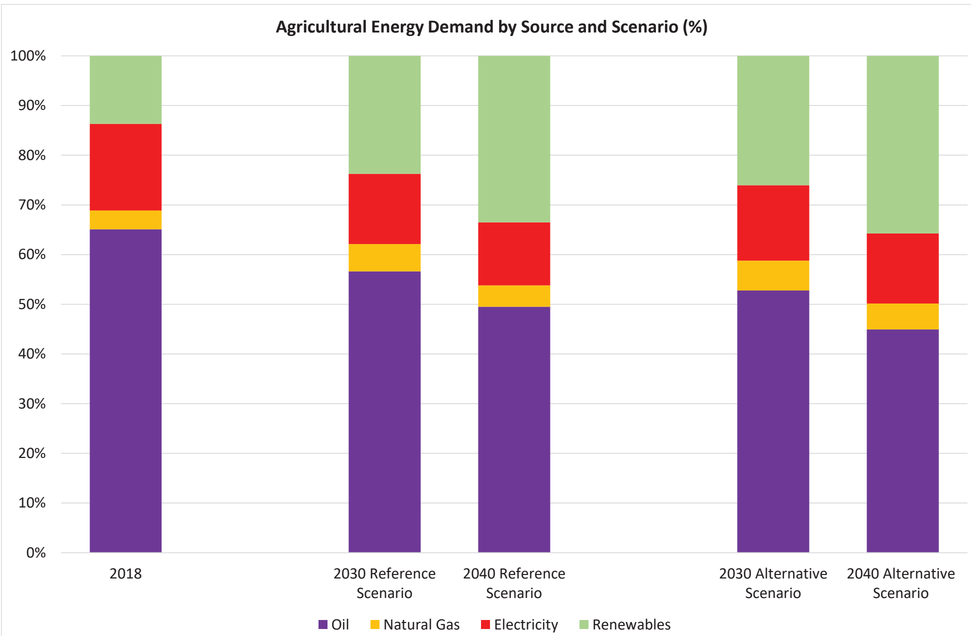
Scenarios		Reference Scenario		Alternative Scenario	
mtoe	**2018**	**2030**	**2040**	**2030**	**2040**
Agriculture Energy Demand*	4.6	5.5	6.3	5.0	5.5
of which					
Coal	0.0	0.0	0.0	0.0	0.0
Oil	3.0	3.1	3.1	2.6	2.5
Natural Gas	0.2	0.3	0.3	0.3	0.3
Electricity	0.8	0.8	0.8	0.8	0.8
Renewables	0.6	1.3	2.1	1.3	2.0

*Including farming and fishery

Figure 5.25 shows the development of the fuel mix in the agriculture sector. The Alternative Scenario realizes a comprehensive transformation in the agricultural energy demand towards a more efficient and sustainable structure. The largest change takes place in the renewables supply in both Scenarios increasing from 0.6 mtoe to 2.1 mtoe in the Reference Scenario and 2.0 mtoe in the Alternative Scenario that estimates the deployment of more efficient technologies and wider implementation of energy saving practices. Renewables contribute to 34% and 36% of total demand in the Reference and the Alternative Scenario respectively by 2040 compared to only 14% in 2018. Use of traditional biomass is largely replaced by solar heating and modern biomass options such as biogas facilities. Geothermal energy remains the leading renewable source with expanded use in greenhouse farming activities.

Oil demand reduces from 3.0 mtoe at present to 2.5 mtoe in the Alternative Scenario compared to 3.1 mtoe in the Reference Scenario. This reflects implementation of a sharing program among farmers including tractors and other diesel consuming machinery taking into account the different seasonal characteristics. The Alternative Scenario also realizes electrification in the new tractor fleet backed by supportive financial models, however their use, and impact on the overall energy balances, will be limited absent any specific support program to enable purchases. Increasing electrification in agricultural lands largely offset the gains by the implementation of more efficient irrigation pumps and deployment of solar-powered heat pumps. Adopting mini and micro-grids by regulatory and power industry efforts help reduce the energy consumption with benefits to the overall power system management. All these technologies will constitute important elements of a more technology-oriented and a more sustainable agricultural energy ecosystem of the 21st century.

Figure 5.25 Agricultural Energy Demand by Source and Scenario (%)



5.3.4 Cross-Cutting Energy Efficiency Areas

5.3.4.1 Energy Efficiency Awareness

Awareness and behavioral change is a core aspect for energy efficiency, especially in final demand services. Energy user choices on purchase of new equipment as well as consumption habits play a major role in energy consumption patterns, particularly in buildings energy use. Understanding of energy user behavior is a critical consideration that needs be reflected in policy design and implementation, relevant business models and technologies. Raising energy efficiency awareness is one of the elements of Turkey's Energy Efficiency Action Plan. The Ministry of Energy and Natural Resources published the first methodology to measure energy efficiency awareness in May 2020 using an indexing approach incorporating multiple dimensions. The Energy Efficiency Information Index in the public has been determined as 177.9, out of the maximum score of 200. This value indicates that the public has a desirable knowledge about energy efficiency. However, when it comes to what consumers do, as opposed to what they know, the Energy Efficiency

Behavior Index drops to 137.5. This is at the medium-to-low level of consumer behavior indicating a large gap between knowledge and behavior. As the next step for increasing awareness, a strategic communication plan was prepared in June 2020.

Among many energy using applications, one particular finding is that there is still a lack of information about energy efficiency in one key area: performance certification and its benefits for buildings. Also, up-front costs are cited as the major reason for not acting on the knowledge when the benefits are known. Financing and access to credit remain a key bottleneck from the customers' perspective.

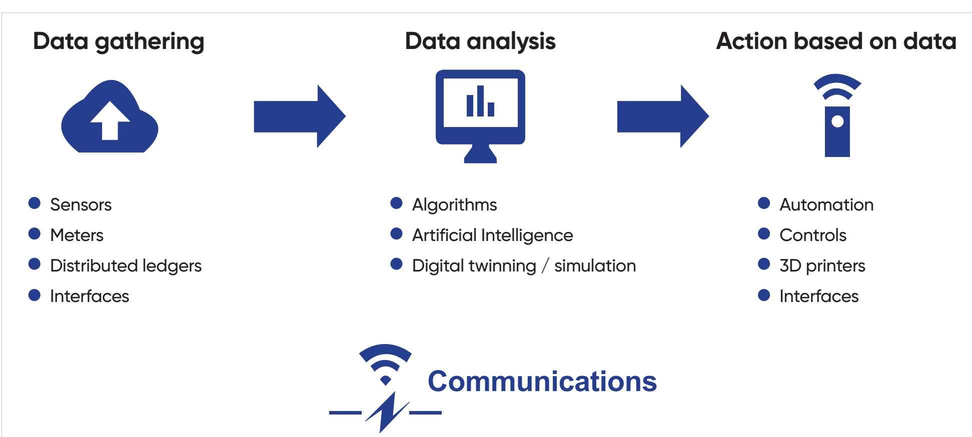
Another study focusing on industrial energy efficiency awareness was also finalized. Industrial energy efficiency could be enhanced by integrating energy management systems into the organizational culture and incorporation into corporate strategies.

The rapid digitalization is now facilitated by the increasing ownership and penetration of information technologies, smart phones and other data oriented devices. As discussed below, it also suggests a new dimension to scale up behavior change developments.

5.3.4.2 Digitalization Opportunities

Digitalization is one the key global trends as discussed in Chapter 1 and could bring several energy efficiency improvements in the energy sector. Buildings and industry are the most promising energy consuming sectors for taking advantage of digitalization. From a wide set of data gathering to data analytics, digitalization enables efficiency actions including automation and controls (Figure 5.26). These lead to greater reliability and energy savings and also enable streamlined measurement and verification practices. The deployment of smart meters, increased penetration of active energy management systems, and remote monitoring platforms would also support ESCO activities in both buildings and industry (IEA, 2019c).

Figure 5.26. Key Digitalization Elements for Energy Efficiency Performance



Source: IEA, 2019

One of the already common solutions in the buildings is use of smart thermostats in order to control the heating and cooling requirements remotely. Other smart applications such as lighting or windows can adjust in accordance with the occupancy or desired energy service levels. Household energy management systems provide information about energy consumption patterns, including recommended actions for energy users to rationalize their energy use. The developing digitalization solutions for the industry include energy management systems producing savings in electric motor systems, thermal and other processes. Enabling connectedness and IoT solutions is a pre-requisite for wider deployment.

A more comprehensive concept emerging in the industry is the "Digital twins" that are being developed. They represent, "twin," a real physical system by integrating Internet-of-Things (IoT), artificial intelligence, machine learning and many other software analytics. They use spatial network graphs as part of digital simulation models that update and change as their physical counterparts, the physical industrial assets, change. The ability of a digital twin is that it can continuously learn and update itself from multiple sources to represent its real-time status including working conditions and optimization pathways. This self-learning digital systems employ a wide set of sensor data, engage humans with relevant information and interacts with the larger systems and external environment of which it may be a part.

With its young and growing population, mobile phone subscriptions in Turkey is expected to reach 84 million by the end of 2020 (almost equal to the country's population). Wideband internet subscriptions also showed a rapidly increasing trend reaching about 70 million. Internet access penetration in households is 88% (2019). Existing digitized industries have already demonstrated increased operational performance and optimized resource allocation. Along its ongoing industrialization pathway towards more value-added and technology-driven sectors, Turkey could benefit more from data analytics supported by the state-of-the-art hardware solutions. All these opportunities driven by increasing connectivity and data services would be supported with increased collaboration with the wider ecosystem including the energy management companies and the utilities. As increasing prevalence of digital devices and required data servers cause undesired increases in power demand, if not managed carefully, close monitoring of power loads should become a more fundamental feature of Turkey's increasingly digitizing and electrifying energy economy.

5.3.4.3 Energy Efficiency Finance and New Business Models

Energy efficiency investments are based on the savings principle as opposed to generation of revenues from an underlying energy asset such as sales of power or gas. These investments encompass a diverse set of measures and technologies that need to be tailored to each business. Energy efficiency is now seen as the 'first fuel' to improve energy security, competitiveness, and environmental sustainability. The National Energy Efficiency Action Plan's target is achieving $10.9 billion investment from 2018 until 2023 for realizing a total savings equivalent to $30.2 billion by 2030. Similar to the global assessments and progress in many advancing and developed energy economies, the buildings sector should be the largest destination of energy efficiency expenditures in Turkey. The immediate need to improve the energy performance in the majority of the building stock should not be overlooked, as discussed in Section 5.3.2.

However, realizing the untapped energy efficiency potential and benefitting from the 'first fuel' necessitate certain policy and regulatory requirements to be fulfilled. These measures are applicable to all end-user efficiency programs and should define the general framework taking into consideration the different social, technical and economic characteristics of final energy user needs. For example, buildings investments can be in properties that are public, commercial or residential dwellings, each with distinctive characteristics in terms of technology and fuel mix patterns, time profile of energy demand, equity and financing capabilities. According to the best global practices, an effective and sustainable energy efficiency investment framework should be supported by:

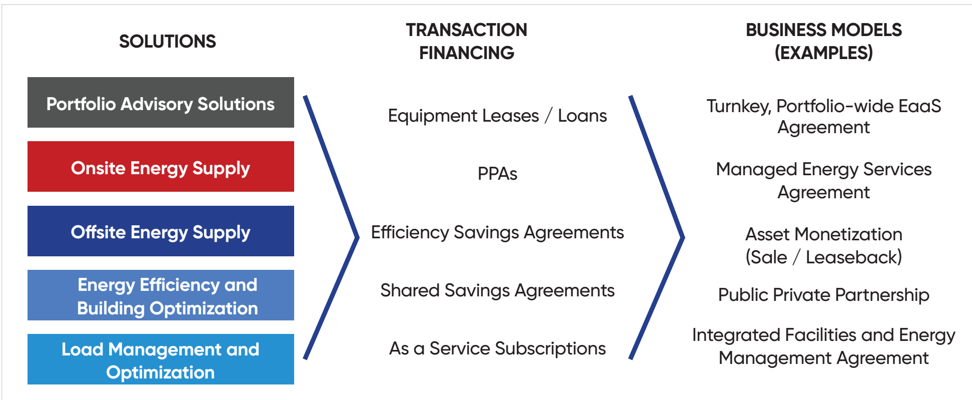
- Enforced regulatory frameworks for measures and incentives,
- Common and standardized certification processes,
- Open source databases on the building stocks and industrial energy efficiency benchmarking and best practices,
- Standardization of energy performance related contracts, energy efficiency metrics and measurement, reporting, verification, and insurance practices,
- Public funds and global cooperation to overcome any market failures with increasing private capital allocation.

The ESCOs will remain at the epicenter for a developing energy efficiency ecosystem. However, they remain at the early stages of development in Turkey compared to many established markets in different regions compared to their large energy savings potential. Public sector involvement would provide a solid role in creating demonstration cases, such as the ongoing project on public buildings, and industrial best practices can further be disseminated as part of industrial awareness and energy efficiency communications.

Another business model that may be increasingly instrumental in the Turkish 21st century energy economy is Energy-as-a-Service. This globally emerging business model integrates hardware, software and services on a technology-oriented basis, mostly over a data-driven platform. The essence of the energy-as-a-service model is that it locks the value generation by bundling various solutions including but not limited to energy efficiency into a single offering. For example, energy procurement or on-site generation alternatives can be developed matching with the energy users demand profiles (Figure 5.27). These models are scalable and can be implemented with flexible capital. Corporate and technology start-up collaboration avenues would also be explored for monetizing energy efficiency gains by increasing digitalization, dissemination of benefits and raising awareness.

Energy efficiency is a major investment focus area for the International Finance Institutions (IFIs). Currently, IFIs' support for efficiency measures are based on project finance in the forms of loans or lines of credit. These are sometimes accompanied also by capacity building services. IFIs are also exploring ways to increase investment in energy efficiency by de-risking investments and leveraging greater private sector financing. IFI financing for energy efficiency portfolios has been on the increase worldwide. As an example, the World Bank Group announced in 2018 to double its investments in this field to $200 billion between 2021 and 2025. Another example is the European Bank for Reconstruction and Development (EBRD) who increased its focus on energy efficiency spending in addition to a rapidly growing renewables finance portfolio.

Figure 5.27 Energy-as-a-Service Business Model Examples



Adopted from the Facility Executive Magazine, 2019

These two IFIs are also the leading parties in the emerging energy efficiency market in Turkey. The ambitious Turkish energy efficiency program for public buildings uses the EPC model where the savings realized will be used to repay the allocated loans. Another important facilitator is the Turkish Residential Energy Efficiency Financing Facility (TuREEFF) that targets improvement of energy efficiency in residential buildings. So far, about 3,000 residents have received TuREEFF mortgages and loans to either purchase efficient homes or household equipment with energy-saving technologies. Over 50 thousand other households have benefited directly or indirectly by installing efficient heating or cooling systems, windows or white goods that are acquired from specialized vendors. The program has financed more than 4000 projects since 2015 bringing its cumulative residential energy efficiency investments to $350 million. TurSEFF is a similar program for SMEs financing over 1,500 projects with €640 million funding ($250 million funding on resource efficiency in the areas including insulation, heating and cooling). Turkey Mid-Size Sustainable Energy Financing Facility (MidSEFF) is a larger credit line with up to €1.6 billion for on-lending to larger energy efficiency and renewable energy projects.

All these funding channels summarized above promote energy efficiency benefits with tailored technical and financial solutions while de-risking pay-backs or any other financial risks. Nevertheless, attracting more direct private capital into Turkey's energy efficiency efforts should be prioritized as there are still substantial opportunities to achieve further savings and a more efficient energy economy.

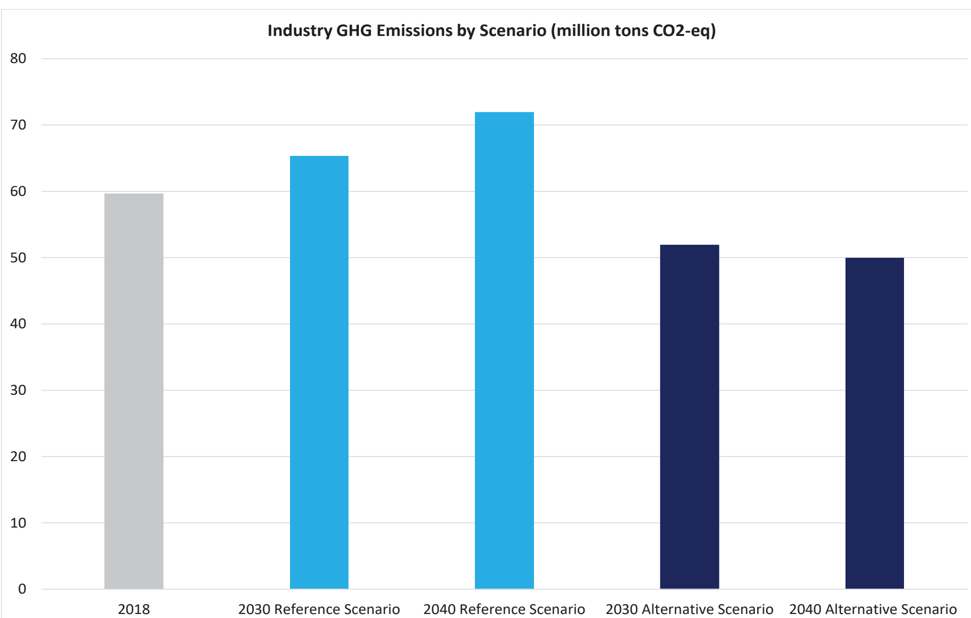
5.3.5 Emissions

5.3.5.1 Industry

Industry is the third largest emitter after power and transport. The sector represented 16% of energy related CO_2 emissions in 2018. The emissions of the sector are largely driven by coal use in many large energy consumers and oil product consumption despite a gasification trend in recent years.

In the Reference Scenario, the GHG emissions increase from 59.6 million tons (in CO_2-eq terms) in 2018 to 65 million tons in 2030 and 71.9 million tons in 2040. Despite significant shifts in the fuel mix towards wider use of electricity, natural gas and renewable energy, the emissions continue to grow due to energy demand growth absent a major shift lowering coal and oil use across the industrial sectors. In line with the fuel mix changes in the Alternative Scenario over the Reference Scenario, mainly through a substantial reduction in the coal share (from 26% in 2018 to 15% in 2030 and further down to 7% in 2040), the emissions see a major decline. The Alternative Scenario GHG emissions in 2040 are 12% lower than in 2018 and about 30% lower than the Reference Scenario's 2040 emissions (Figure 5.28).

Figure 5.28 Industry GHG Emissions by Scenario (million tons CO_2-eq)

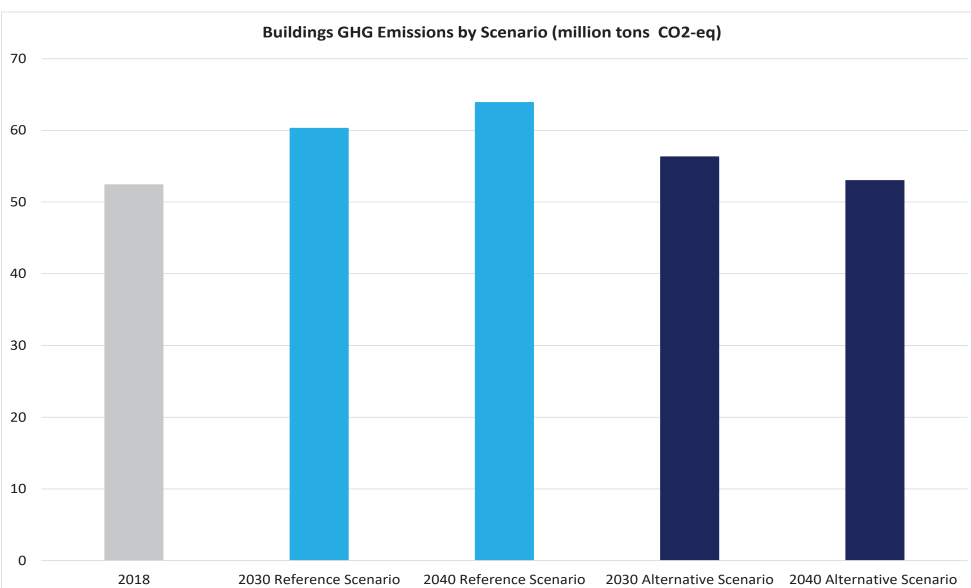


Achieving larger reductions in the industrial sector emissions require continuous efforts to delink the growth from high carbon-intensive fuels, primarily coal and oil, and deployment of cost-effective low-carbon fueling options. Hydrogen would provide a central role in enabling this transformation towards a more sustainable industrial energy supply beyond 2040. The role that hydrogen could play as an energy carrier in industry is discussed in Chapter 6 (The Energy Transition). Another particular technology that may be instrumental in some of the industries would be carbon capture, storage and utilization (CCUS). The challenges and opportunities of CCUS are discussed in Chapter 6. This discussion emphasizes the cost challenges of employing carbon capture in combustion processes, such as steam coal power but also highlights low-cost opportunities to apply CCUS in chemical processes such as using coal to produce hydrogen.

5.3.5.2 Buildings

The buildings sector with over 50 million tons of CO_2-eq emissions is responsible for 14% of total energy related emissions in 2018. The lower penetration of renewable supplies despite a large untapped potential and high reliance on coal particularly in some residential buildings, and oil consumption are the major drivers in building emissions. However, Turkey's ongoing electrification progress, expansion of natural gas use and policies, technologies that are supportive for wider renewables deployment, efforts to improve energy efficiency performance of the buildings are all set to alter the growing emissions from the residential, public and commercial buildings. Most notably, the differences between the Reference and the Alternative scenarios in terms of total energy demand and its breakdown into fuels and technologies result in substantial differences in the GHG trajectory out to 2040.

Figure 5.29 Buildings GHG Emissions by Scenario (million tons CO_2-eq)

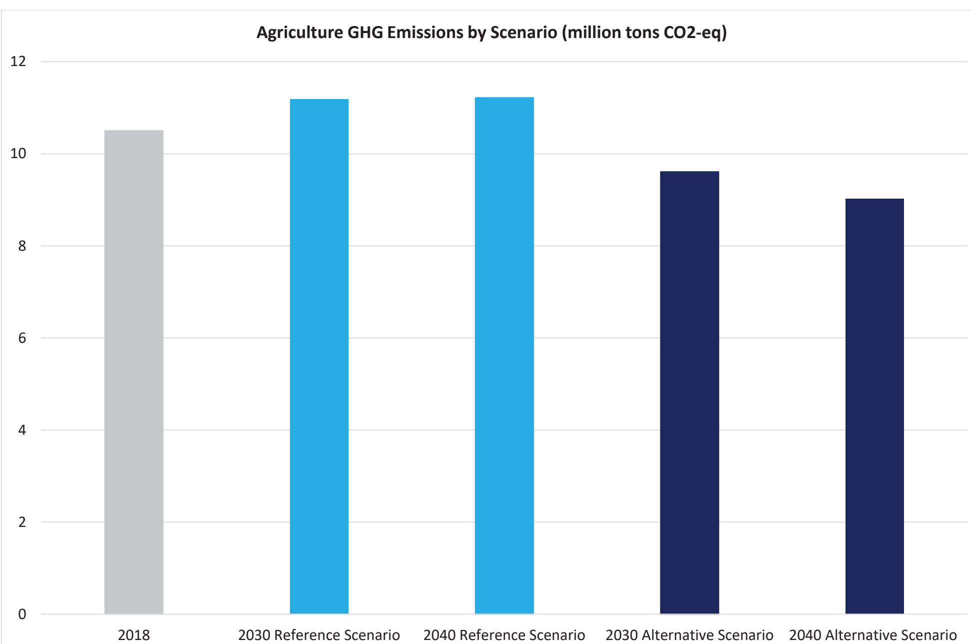


In the Reference Scenario, building emissions increase from 52.4 million tons CO_2-eq to 60.3 million tons CO_2-eq and despite a slowing growth further to 63.9 million tons CO_2-eq by 2040. The Alternative Scenario achieves a faster slow-down in emissions growth resulting in almost the same emission level with 2018 in 2040, despite a solid growth of the buildings stock, floor area and modern living environments. This is realized by almost a complete substitution of coal for heating services (from 12% in 2018 down to only 1% by 2040) by increased use of natural gas, electricity and renewable energy technologies, most notably solar collectors, heat pumps and geothermal sources. This also means that the Alternative Scenario achieves no increase in the building emissions while accommodating 45% more energy demand compared to 2018 (Figure 5.29).

5.3.5.3 Agriculture

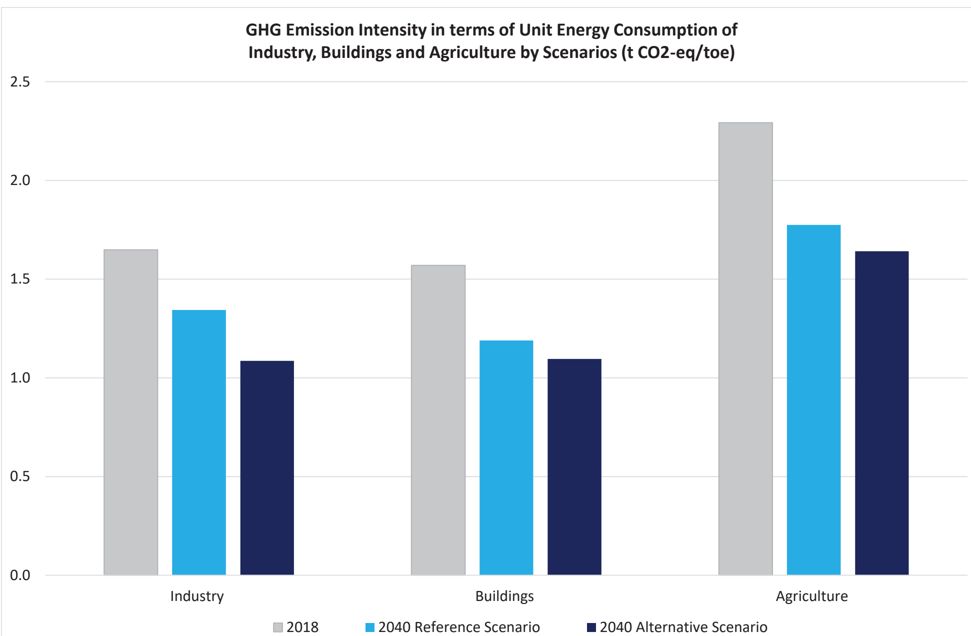
The agriculture sector is responsible for 3% of the energy related GHG emissions in 2018. As the fuel mix develops into a less carbon intensive structure in both scenarios, emissions growth slows down, and in the Alternative Scenario peaks before 2030. The Alternative Scenario achieves a 14% reduction of CO_2 emissions by 2040. This is a result of a more efficient agriculture sector that progressively develops into a renewables and electricity fuel mix share of over 50% in 2040 compared to 30% in 2018. The GHG emissions in the Alternative Scenario are 7% and 17% lower than the Reference Scenario in 2030 and 2040, respectively (Figure 5.30).

Figure 5.30 Agriculture GHG Emissions by Scenario (million tons CO_2-eq)



The TEO scenarios demonstrate significant reductions in the carbon footprint of all three sectors as measured by GHG emissions per energy services provided and energy consumed.[72] The industrial GHG intensity reduces from 1.6 tCO_2-eq/toe to 1.3 tCO_2-eq/toe in the Reference Scenario and further down to 1.1 tCO_2-eq/toe in the Alternative Scenario by 2040. Similarly, CO_2-eq emissions per unit consumption of energy in the buildings lowers from 1.6 tCO_2-eq/toe to 1.2 tCO_2-eq/toe in the Reference Scenario and further down to 1.1 tCO_2-eq/toe in the Alternative Scenario until 2040. In both sectors, the Alternative Scenario realizes over 30% reductions in GHG emissions per unit energy served. The agriculture emissions' energy intensity, measured by the same metric, decreases from 2.3 mtoe in 2018 to 1.6 mtoe by 2040 in the Alternative Scenario (30% reduction). All these Alternative Scenario reductions will launch increased improvements beyond 2040 supported by new technologies, in particular the renewables based supply solutions, larger electrification and development of hydrogen as a clean energy carrier (Figure 5.31).

Figure 5.31 GHG Emission Intensity in terms of Unit Energy Consumption by Sector and Scenario (tCO_2-eq/toe)



[72] While the following carbon footprint statistics are in terms of GHG emissions per unit of energy consumed, the reduction of GHG emissions per unit of energy services (e.g., CO_2 emitted per irrigated or plowed ha) is even larger since, in all scenarios, the efficiency of energy use is also improved.

5.4. IICEC Policy Recommendations

- **Overview**

Turkey's steps towards a more efficient energy system have gained momentum after the 2017 Energy Efficiency Action Plan. Subsequent arrangements in the regulatory framework provided a basis for advancing energy efficiency progress in various areas. However, the pace of energy efficiency improvements is not yet sufficient. Especially, there exists an important gap in building insulation actions vs. a vast potential, where mobilization of timely investments remains a main barrier. Continuous efficiency increases are being recorded in new appliance stock but still, the old and inefficient stock deserves policy action, notably in refrigerators and HVAC equipment. In the industry, while the portfolio of projects for the improvement of energy efficiency is growing by Government incentives and industry's initiatives, additional measures and incentives are still needed to further attract energy efficiency-focused investments in Turkey's large industrial base. A more secure and competitive energy sector necessitates stronger policies, new technology driven equipment and systems, energy management strategies, and higher investment into buildings and industry energy demand services.

In the next two decades, the Turkish energy efficiency ecosystem will be adapting to rising incomes and increased urbanization. This is both an opportunity and a risk as older energy intensive behaviors can be too easily replicated instead of best practices. Turkey can exploit huge opportunities to use digitalization, electrification, renewable energy and innovation to ensure best practices and a sustainable future. As shown in the Alternative Scenario, integrating the policies and adopting and developing best available technologies in the energy supply mix and demand services including more efficient use of energy would contribute to the reduction of energy imports as well as higher localization and Turkey's energy security goals. As elaborated in Chapters 1 and 4, investment allocation should be optimized towards a shift to the demand side and relying on developing competitive market mechanisms that would increasingly engage energy users.

- **Stepping up the Efforts for an Energy-Efficient Building Stock**

A great majority of the existing building stock remains out of the certification programs Turkey has already established such as the certificates program for new buildings beginning in 2020. More legislation is needed that focuses on older buildings. This is reflected in the account of certificates: only around 1 million out of the existing stock of over 9 million have been certified since 2009. Considering that a majority of the existing building stock was developed before 2010, the saving potential is large, especially in roof and surface insulations and windows. Low energy performance of the building stock, the residential dwellings, in particular is evident from a comparative assessment of heating and cooling energy demands compared to country peers with similar climatic conditions. Although the recent steps to advance building energy performance with a widespread program covering public buildings is a positive start, this effort needs to be followed up with defined targets and supporting programs for commercial and residential buildings. Despite increasing awareness on the benefits of improving building energy efficiency, affordability and equity limitations remain as bottlenecks. There is also the problem of the uncertainty to investors of whether they would reap the economic benefits due to the frequent turnover of building ownership over its effective life. To speed up progress in accordance with the Energy Efficiency Action Plan and the Government's desired policy objectives, overcoming these bottlenecks is a top priority.

Appliances are the second major area for better energy performance in buildings. The new products available in the market offer the best performance classes as Turkey is part of the EU Customs Union as a major producer of whitegoods and some other appliances. The HVAC equipment is an exception with different product origins that are observed in the market, and with relatively poor energy efficiency performance. Replacing old household refrigerators (20-year-old units are over half of the stock) and furnaces are a priority. In addition, making sure that the new AC units that are purchased have the highest efficiency is extremely important. This will require a dynamic regulatory framework to ensure success.

While policies and financing solutions are urgently necessary for rapidly transforming the inefficient current building stock and equipment, steps should be taken to require higher performance for new construction such as requiring performance beyond the current C class, stepping progressively into B and A. For example, moving from C to A in the same climate zone enhances the specific energy performance at least by half. Developing programs for near-zero and eventually net zero energy buildings should be the next element of a comprehensive building energy efficiency roadmap. Turkey's current urban transformation program, driven by earthquake preparedness measures, should be utilized as an avenue to speed up the energy performance progress in old and new buildings.

Another major buildings sector barrier is consumers' behavior, a generic issue with a growing research base (IEA, IPEEC and MEN, 2018). Turkey's first energy awareness assessment report indicates that while consumers may appreciate the benefits of energy efficiency, they don't necessarily act on them. For already informed energy users, financing remains a challenge that needs to be overcome by policy intervention. Evidence from different markets and regions showed that high-performance construction and renovation necessitate access to financing supported by business models in an ecosystem of building companies, insulation industry, municipalities and other technology providers. Government should improve access to financing to address financial barriers. Different mechanisms could be considered including tax exemptions, grants and obligations. Demonstration projects could also popularize energy efficient building investments. Energy efficient buildings is a global research agenda with several projects ongoing on ensuring larger thermal capacities and better adoption to changing climatic conditions. Another mechanism can be developed by including building energy efficiency investments into the existing VAP portfolios. Thematic incentive programs can also be developed targeting building insulation and replacing inefficient appliance stock with best available technologies in the market. Public buildings should also be visible as examples in the effort to rationalize energy consumption in buildings and can be centerpieces in public awareness programs.

Another significant benefit from building energy efficiency measures is the potential to create a large number of new jobs for more efficient construction of new buildings, design and implementation of near-zero and net-zero energy buildings, and retrofitting of existing buildings. The buildings industry is an important part of the Turkish economy and is a mainstay for employment and social welfare. Increasing and expanding job opportunities in the industry to achieve energy efficiency is another form of energy localization, just as important as building wind power turbines in Turkey. The investments are also supported by reliable economic returns for Turkey in terms of lower consumer expenditures on energy, a reduced foreign energy import bill and improved energy security.[73]

It is also important to connect the multiple programs in the industrial, agricultural and building sectors across government. This should include Ministries engaged in urbanization, city planning, urban transformation, and industrial and agricultural growth. This necessitates close cooperation and harmonization across the policy-making bodies. A National Energy Efficiency Action Plan Steering Board was established in late 2019 and provides a good example of what is needed.

- **Advancing the Industrial Energy Efficiency Supported by New Business Models and Digitalization**

Turkey's industry remains energy intensive compared to developed economies. The intensive industries, iron steel and cement, still represent a major share in industrial output. Some other energy intensive industries such as textiles play a key role in Turkey's industrial and trade balances. Current economic strategies and trends foresee a structural transformation towards a more value-added and technology driven industrial base with defined priority industries such as machinery, electric equipment, automotive, and electronics. These industries are also less energy intensive. This industry and technology pathway could result in reductions in the energy intensity of the Turkish manufacturing industry. However, Turkey should not be satisfied with improvements in energy use per GDP because of these structural shifts and instead aim for significant intensity reductions in all industrial activities.

Turkey started to develop benchmarking studies for large energy consuming sectors such as cement, textiles, iron and steel. These are instrumental to assess the energy efficiency performance among facilities within a sector and to compare and contrast with peer countries and global best practices. Turkey should expand these studies to cover, at least, the top ten major energy consuming industries, to further develop industry-specific targets. The Energy Efficiency Action Plan presents a general objective of a minimum 10% reduction in the energy intensity in each sector from 2018 to 2023. These goals can be significantly increased beyond 2023. Benchmarking and sector-based evaluations are also timely

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[73] As an example, the IEA estimates that of the 27 million job-years which can be created worldwide by the 'Sustainable Recovery Plan' announced in 2020, 35% are in energy efficiency projects in the buildings and industry sectors and 60% of this is estimated for buildings retrofits and new construction works. Turkey's domestic industry and supply chain can support more efficient construction material production.

steps to increase awareness of the benefits of industrial energy efficiency measures but, similar to buildings, attracting more investments into energy efficiency solutions require policy interventions. IICEC especially recommends a greater public effort to enable more investments by ESCOs, especially in SMEs.

Although Turkey has three different incentive programs to support energy efficiency investments in the industry, wider gains can only be achieved by implementing a performance contracts based model as the mainstream practice. IICEC observes that the long term nature of the energy performance contracts, a generic feature to achieve desired savings with bankable solutions, stands as a barrier on the customer side in many cases in Turkey. De-risking investments and addressing counterparty risks on the ESCO side also needs to be overcome by developing solutions to help predictability and security of the performance contracts, including insurance models.

Electric motor systems represent about two-thirds of the electricity consumption in the Turkish industry and an effective transformation into a more efficient stock will be decisive to lower power demand in Turkey. The recently launched incentive program to replace IE3 and IE4 motors is an effective step but IICEC assessments indicate that a complete inventory of the electric motor stock in Turkey is essential to measure the technical and economical saving potential in detail. A 10% reduction in the power demand of electric motors, on average, is equal to more than 3% of Turkey's annual net electricity consumption. At a minimum, an energy certificate program should be implemented for new electric motor installments by a thorough assessment of working hours, load profiles and other technical operational parameters.

In addition to process improvements by conventional methods, the Turkish industry should benefit from advanced data analytics and digitalization for energy efficiency. Enabling software and hardware solutions by increased connectivity and wider use of the IoT technologies are proven tools for tracking and improving energy performance. Recent industry trends such as implementing digital twins and utilizing energy-as-a-service business models could make Turkish industries more competitive by optimizing energy use. Turkey would also prioritize industrial symbiosis and related R&D programs to increase synergies among industrial sectors and facilities for enhancing resource utilization towards more sustainable energy consumption practices.

- **Enabling Further Fuel Shifts Supporting Sustainable Growth of Buildings Stock and Industrial Output**

Turkey's building and industrial sectors are both on the path of increasing electrification and further gasification, which will be strengthened by more efficient power and natural gas markets as outlined in the TEO Alternative Scenario. Coal and oil consumption in these two sectors will see a major decline as other thermal energy sources replace them such as natural gas, solar heating and geothermal. These renewable sources have a great potential to make Turkey's energy economy more localized and sustainable.

As discussed in Chapter 1, solar PV is expected to become the fastest growing power generation technology and the majority of new solar investments will be on rooftop PV supported by lowering technology costs, ongoing urbanization and urban transformation with a sizable new building stock, increasing customer knowledge and Turkey's enhancing technology localization capabilities. Utilization of solar energy is not limited to electricity production as Turkey can sustain its leadership in solar heating via collectors in more buildings. Turkey's extensive geothermal sources should also have an increasing role in regions where the resources are favorable.

A cost-effective heating and cooling strategy should be developed to benefit from these local alternatives with multiple benefits: lowered import dependency, lowered carbon footprint and improved environmental performance, and increased efficiency by delivering energy on-site or supplies that are closer to demand centers. Although there are a few examples, a nation-wide system has not been in place yet for enabling district heating based on local renewable energy alternatives and other heat sources such as waste heat from thermal power plants and industries. Turkey started preparations of mapping heating and cooling loads that would be followed up with a legislative framework to launch a heat market. Established district heating systems can offer sustainable solutions to Turkey's increasing cooling demand services, including integrated heat pumps. A cost-benefit assessment is needed to pick the most feasible regional alternatives that would also serve as role models for wider implementation as global cost progress is achieved. Nonetheless, IICEC continues to recommend solutions based on solid cost analysis to avoid expensive projects that could actually retard technology uptake.

Major opportunities in the industrial fuel mix include wider use of biomass as an alternative to coal in several industries (especially cement), and increasing use of waste heat and solar heating that is suitable for lower-temperature process applications. As will be discussed in Chapter 6 (the Energy Transition), longer term solutions will encompass hydrogen as an energy carrier that would serve high-temperature processes and, in general, join electricity to completely decarbonize the energy economy with minimum reliance on fossil fuels except, for example, coal that could be used with CCUS to produce hydrogen. Past 2040, electricity production would involve the minimum use of fossil fuels, mostly in gas peaker plants.

- **Benefitting from Efficiency, Renewable Energy and Electrification Opportunities for the Agriculture Sector**

Turkey's agriculture sector, including farming and fisheries, corresponds to less than 5% of final energy demand. However, it deserves special focus for three reasons: it is vulnerable to adverse consequences of global climate change and critical for food security, it is one of the major diesel fuel users largely in an old tractor fleet, and its power demand is increasingly driven by irrigation needs but often with inefficient pumping systems.

Although a replacement program for old and inefficient tractors and other agricultural machinery can provide large savings, this may not be a socially feasible approach given the role of the agriculture in Turkey's employment and GDP. However, the low utilization rates of the tractor fleet suggest a more innovative solution to reduce oil use. IICEC believes that a cost-effective model could be developed around shared services programs and the 'sharing economy. This can be achieved by planning based on different seasonal characteristics and regional agricultural activity periods across the country. A last-mile model connecting the farmer community could help utilize the established tractor fleet base in an effective manner.

Irrigation accounts for 70% of agricultural power demand. IICEC analyses shows that a 10% reduction could be easily achieved by an extensive program to monitor and replace pumping equipment which translates into over 3% of current annual power demand. A more comprehensive energy model should encompass mini and micro-grids that would support efficiency goals in the power sector with better management of seasonal and daily loads and minimized impacts on the grid.

Turkey's rich renewables will play a larger role in meeting agricultural energy demand. A particularly important application is using geothermal energy for greenhouse farming, building upon existing applications that can be well-extended into more regions and new agricultural products. Turkey can become a regional and world leader in this regard. The TEO Scenarios also demonstrate a phase-out of traditional biomass with wider use of modern biomass applications such as biogas. Turkey could utilize this technology with policy support, in the form of public funds, grants or low-cost credits, for investing into demonstration cases at scale. All these efforts would be supportive for a more sustainable agriculture sector, in line with the energy supply and technology developments in the other end-use sectors.

A complete and progressive Turkish energy economy is achieved by emphasizing efficiency and renewable energy in every energy sector. Even if, as may seem to be the case for agriculture, the numbers seem small, adding up all of the small numbers add up to a robust and secure Turkish economy. The TEO Alternative Scenario paints a pathway to this outcome by emphasizing cost-effectiveness, technology progress, taking advantage of global technology progress and cost reduction, relying on more competitive markets and strong leadership by the Turkish government. IICEC's Alternative Scenario shows the government continuing their past achievements and scaling up progress to support competitive markets, update regulatory requirements, eliminate bottlenecks, provide better access to financing and to develop Turkey's domestic energy resources. This virtuous combination of public and private progress, especially government policies that are attentive to how all Turkish industries, large and small, can be successful, should be an underlying storyline of Turkey's energy future.

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CHAPTER 6:

THE ENERGY TRANSITION

Summary

- The TEO Scenarios have quantified the progress Turkey can make towards reduced dependence on foreign fuel supplies, increased clean energy production and local production of advanced energy technologies. Enhancing the role of the private sector and establishing competitive energy markets are an underlying theme as well as exploiting energy efficiency opportunities. As a result, GHG emission intensities (GHG emissions per unit of energy service provided) decline significantly over the forecast horizon, especially in the Alternative Scenario.
- However, due to strong projected Turkish economic growth and the wider uptake of modern energy services, lowering total GHG emissions is challenging. The Reference Scenario shows a 30% increase in CO_2-eq emissions by 2040 over 2018 emissions while the Alternative Scenario achieves a 10% decrease. As noted in other chapters, the Alternative Scenario emissions trajectories show peaks about one decade out followed by an increasing decline to 2040. These declining emissions in the Alternative Scenario provide the setup for stronger post 2040 reductions that would enable Turkey to approach a net-zero energy economy.
- A word of caution must be sounded about any technological forecast that extends beyond 2 decades. In the nearer term, we are guided by the considerable installed energy capital and what we know about this capital. The renewable and efficiency technologies that are ready for near term commercial deployment are also relatively well understood. However, once we go beyond the near- to mid-term time horizons past 2040, we must rely on technology models based on a variety of critical assumptions concerning future technology performance and cost. For a variety of reasons discussed below, these models have a tendency to show an "all-of-the-above" outcome in order to produce a particular emission reduction target. These often include the widespread use of CCUS in the power sector and extensive replacement of gasoline and diesel-fueled vehicles with BEVs and HFCVs. There is relatively little in the way of determining whether high costs and policy challenges could be overcome to achieve the technology uptake that is "selected" by the model. Fortunately, the next twenty years are likely to produce technological solutions that would make the results of such models look very different if run two decades from now. They might well show a much more cost-effective suite of technologies that will have emerged to produce the net-zero energy economy.
- As many energy economies, including Turkey's, advance beyond 2040 to use less and less fossil fuels without carbon capture, the past policy priority for energy efficiency will diminish, at least with respect to lowering GHG emissions. Energy efficiency will remain an important economic priority but as the use of fossil fuels (without carbon capture) declines to very low levels, increasing efficiency produces negligible reductions in CO_2 emissions.
- The biggest challenge to increasing the role of variable renewable energy is to develop cost-effective and efficient technologies to balance load over multiple time periods from very short to seasonal. While arbitrage and demand-side management can reduce the

need for storage in the shorter time intervals, the need for storage and release capabilities over a wide range of time intervals will increase greatly as variable renewables grow to be a high share of power capacity and fossil-fuel plants are phased out. Pumped storage and batteries are likely to be the near-term investments but looking towards and past 2040, there may be some surprises for how we store excess renewable generation for use when needed. Hydrogen storage is often mentioned as a more comprehensive approach but there may be other technologies to consider including other chemical processes besides hydrogen, mechanical systems and biological methods, each with features suited for different storage needs and likely available over different timescales. A promising hybrid approach involves natural gas, batteries and pumped air storage. It is a good example of innovative concepts that are likely to be deployed prior to 2040.

- Global expectations for nuclear power are modest with an effort needed simply to maintain the current 8% share of global energy. A more significant growth of nuclear power probably requires a new generation of reactors that are less risky, more scalable with lower costs per kWh, and even greater levels of inherent safety than current large reactor designs. There are numerous projects worldwide to develop the small modular reactor (SMR). Instead of undertaking a time-consuming on-site reactor build, the SMR would be produced in a factory and delivered to a power customer, vastly reducing their financial risk. The smaller reactors may provide induction cooling, less frequent refueling, and better options for waste disposal. Even without any new government policies, we should see in a few years whether or not the SMR can overcome economic and public acceptance challenges, advance the demonstration cases into commercial scale, and grow the role of nuclear power in future decades.
- There is a growing interest in direct carbon capture from the atmosphere as the outlook for sufficient anthropogenic GHG emission reduction becomes less likely. These are discussed below but the physical and cost challenges appear to be at least as large as any technologies considered to reduce energy sector emissions.
- The challenges of developing clean energy supplies may be modest compared to developing a new clean energy carrier to supplement electricity. Electricity has inherent limitations that may require the more widespread use of at least one new clean energy carrier. For example, the poor specific energy of batteries makes electricity a poor clean energy carrier for most of the heavy duty trucks. High temperature process heat (above 400°C) in industry cannot be generated with electricity. Consequently, the focus has been to produce either "blue" hydrogen from fossil fuels with carbon capture or "green" hydrogen from renewable electricity as this second clean energy carrier along with a distribution network to make hydrogen available to retail service stations, industry and building uses.
- In the final section of this chapter, we suggest a new role for Turkey's domestic coal reserves. IICEC's cost analysis shows that adding carbon capture increase the LCOE of a lignite power plant by as much as 50%, but would increase the cost of blue hydrogen by 5% to 10%. In addition, the baseline LCOE of a lignite power plant is already high

compared to competing power technologies. In contrast, when carbon capture is added, coal, along with natural gas, is still, by far, the least expensive way to produce hydrogen, about one-third the cost of producing hydrogen with electrolyzers. Global technology progress is needed to make the transition to the "hydrogen economy" feasible. Nonetheless, the hydrogen energy carrier will likely be needed before 2050 to limit GHG concentrations to safer levels. Turkey will have good opportunities to take advantage of global technology developments and further reduce foreign fuel needs by producing blue hydrogen from domestic coal.

6.1 Introduction

Global warming is caused by high anthropogenic emissions of greenhouse gases (GHGs) that began very gradually with the birth of the industrial revolution with the invention of the first useful steam engine in the late 18^{th} Century. The industrial history of the 19^{th} Century was shaped by this invention that was first used to pump water out of coal mines. This was viewed as a virtuous cycle as the steam engine itself required ever larger supplies of coal. It shaped every sector of the industrial economy and transformed transportation. For the first time in human history, mechanical energy provided by fuels could be used to replace animal or wind-powered transport. Railroads and steamships quickly became the standards of advanced industrial economies. A century later, the advent of the internal combustion engine ushered in the age of oil having a similar transformative effect on transportation and industry. Its immediate application was to power motor vehicles and aircraft, two innovations that affected the trajectory of the 20^{th} Century just as much as railroads and steamships affected the 19^{th} Century.

Largely unnoticed, the CO_2 emissions produced by the use of coal and oil began to accumulate in the upper atmosphere. It wasn't until late into the 20^{th} Century that the danger posed by these emissions became apparent. Due to the obvious health and environmental consequences of the many pollutants produced by burning fossil fuels, many technologies had been developed to at least mitigate the worst effects. For example, the NOx, CO, and volatile organic compound emissions of light-duty motor vehicles were reduced by two orders of magnitude within 3 decades after the first auto emission controls appeared in the early 1970s. However, one emission was irreducible, carbon dioxide as it is a direct consequence of the oxidation of carbon molecules to release the energy of their hydrogen atoms. This is as basic as life itself as the linkage of CO_2 consuming plants producing free oxygen (O_2) for respiration by animals (metabolizing chemicals containing hydrogen through oxidation) has been the basis of life on Earth for over 3 billion years. Life itself was responsible for the significant volume of free oxygen in Earth's atmosphere as it did not initially exist except in trace amounts until sulfate-reducing bacteria and other sources began to produce vast volumes of free oxygen that were later required for complex animal life (Lane, 2002).

Given carbon dioxide's and oxygen's virtuous roles in this life-sustaining process, and the fact that the use of fossil fuels did not appear to be upsetting the natural balance between the use of O_2 by animals and CO_2 by plants, the danger that CO_2 emissions could affect the climate did not attract policy attention for many decades even after Svante Arrhenius predicted the problem in 1896 and many other scientists afterwards expressed concerns (Weart, 2008). For example, while the policy response to the 1970s "energy crisis" increased support for renewable energy and energy efficiency, concerns about climate change were not evident as these policies included programs to develop synthetic fuels from coal and limit the use of natural gas in the power sector in favor of coal (The Heritage Foundation, 1979). Coal-derived liquids would have significantly increased GHG emissions. Fortunately, the production of synthetic fuels from coal turned out to be uneconomic and, after the U.S. Synthetic Fuels Corporation received a $10 billion budget, of which only $1 billion was spent, the project was abandoned.

The scientific community finally elevated its concerns to the first World Climate Conference in 1979. A United Nations panel on climate change (IPCC) was established in 1988 and at the Rio Earth Summit in 1992 the United Nations Framework Convention on Climate Change (UNFCCC) was established. "Conference of the Parties" (COPs) meetings were inaugurated and by the third, the Kyoto Protocol emerged as the first legally binding agreement to limit GHG emissions requiring the rich (Annex I) countries to reduce their GHG emissions by 5% below 1990 levels between 2008 and 2012.

The United States never joined the Kyoto Protocol and for this and other reasons, it did not prove effective to change the world's trajectory of GHG emissions, especially in the developing world. At the 21st COP meeting in 2016, the Paris Agreement was established initially having U.S. participation but later the United States withdrew. This was a non-binding treaty relying on a combination of public pressure and financial incentives to achieve reduced worldwide GHG emissions. A more meaningful global agreement that equitably binds all countries has yet to be achieved as it would have to balance the different views of developing and developed countries, large emitters, and countries that themselves account for a small contribution to global emissions and a variety of other factors. Nonetheless, some countries and regions are proceeding with implementing the Paris Agreement. In particular, the European Union is taking strong measures to reduce its future emissions through the Green Deal (EC, 2020) in which Europe aims to become the "first climate-neutral continent."

The energy policies first developed in the 1970s have put the planet on a more sustainable pathway due to the progress these policies have achieved in energy efficiency and renewable energy. Standards requiring minimum energy performance for energy-using equipment, including motor vehicles, have become common. Early R&D and commercialization incentives have brought about substantial reductions in the cost of renewable power technologies, especially wind and solar PV. Based on cost-competitiveness alone, most new power sector investments in the recent decade have been wind or solar, and, in the future, investments in renewable power are expected to be 4 times higher than for fossil fuel plants (IEA, 2019a). Nonetheless, much more needs to be done to reach net-zero energy sector emissions as shown by several long-term modeling studies.

6.2 Uncertainties in Technology Modeling and Lessons for Energy Policy

A note of caution should be sounded regarding all projections of the longer-term technology outlook. In the nearer term, we are guided by the considerable installed energy capital and the information we have from their operating history, especially with regard to costs and other key variables. The near term alternatives are also well understood as they have also been under commercial development. Commercial experience thus far has demonstrated competitive current costs that well justify our expectations of a rapid expansion of solar PV in the power sector along with wind energy that has achieved low costs in onshore applications and, while expensive today, offshore costs are expected to come down. However, once we go beyond the near- to mid-term time horizons past 2040, we must rely on technology models based on a variety of critical assumptions concerning future technology performance and cost.

"Technology learning" is widely applied to estimate lower costs but this concept has a number of uncertainties. The technology learning curve has been well established for certain new technologies showing a constant percentage decrease in cost with each doubling of production capacity. Thus new technologies that have high costs and a very small market share, can expect to experience rapid declines in cost as they capture ever larger market shares until doubling of production takes longer and longer and no longer becomes feasible thereby providing an arithmetic brake on the cost reductions from technology learning. While this is a useful modeling concept, a number of assumptions need to be made about what aspect of a new technology actually experiences technology learning. If a new technology is a combination of well-established components with fewer innovative ones, the "learning rate" should only be applied to the cost component of the new and innovative element, not the cost of the entire process or product.

Another difficult area in longer-term modeling has to do with the benefits of research and development and the utilization of various "cost targets" that are published by many highly respected institutions engaged in energy research. In the real world of research funding and the need to justify project budgets, especially to governments, there is a natural temptation to make the "cost target" a "need-based" estimate rather than a solid assessment of what is possible over a given period of time from some particular line of research. The "need-based" estimate shows what is necessary for the technology to be commercially successful. Then this estimate is often widely interpreted to show that the technology will be commercially successful as a result of the research being undertaken.

The technology modeler is typically faced with bewildering literature on every candidate technology that could constitute a long-term clean energy future, frequently with significantly different estimates of costs or timetables to development, or no information at all with respect to future cost and performance parameters. A typical technology-rich linear programming model will have several hundred energy technologies to contend with and the challenge of translating the entire literature for all of these technologies into an integrated data system that treats all technologies in a consistent way. These models typically use cost-competitiveness (including various externality costs and other constraints) to select which technologies will produce the clean-energy future. Consequently, the outcomes are driven by the data systems that are developed for the model that are, themselves, reliant on a vast literature about each technology. In order to document the database in a particular model it would be necessary to identify, for each candidate technology:

- which sources of information have been used for each technology,
- how technology cost and performance differences in the literature were resolved,
- which technology learning rates were assumed, including whether they have been applied to the full cost or some sub-component,
- which assumptions have been made about the cost and performance benefits of new R&D,
- which assumptions have been made about the future investments in R&D, and
- information about many other factors that affect the model's data.

Considering the hundreds of technologies included in the model, communicating this background information is unrealistic. Despite these challenges, technology-rich modeling is necessary to analyze an energy economy as it moves away from a preponderance of existing capital equipment and currently available energy technologies to a future where many currently non-commercial approaches have become important. There is also a strong, needs-based focus on these modeling results as the system constraints are often specified to achieve an ambitious target of very low GHG emissions by 2050 or later. Consequently, there is a tendency to show an "all-of-the-above" outcome as the model finds that this is necessary to produce the ambitious target, including the widespread use of CCUS in the power sector and widespread replacement of gasoline and diesel-fueled vehicles with BEVs and HFCVs.

These comments are not being made to criticize the work of long-term technology modelers but to say that the level of uncertainty is bound to increase as the time horizon increases and as the number of untested uncommercial technologies are estimated to constitute significant parts of the energy system. In particular, we can be surprised by future unexpected developments. Such developments have had enormous impacts on our energy systems. The combustion gas turbine was itself an unknown technology until the jet engine was developed for military purposes and quickly transformed commercial aviation.

Much more recently, gas and oil deposits locked in tight rock formations, while known, were long considered to be commercially unimportant as they were not considered to be economically recoverable, even when oil and gas prices were much higher. At that time, there was considerably more interest in developing methane hydrates than trying to extract natural gas from tight geological formations. During the 21st Century, this outlook suddenly changed with the application of some known technologies in a new way causing a hydrocarbon revolution in North America. As individuals and research institutes explore new ways we can have a more sustainable energy economy, there is every likelihood that progress will be achieved in unexpected directions, perhaps with some "game-changing" innovations.

The message for Turkish policymakers is to stay abreast of what is likely to be an emerging energy technology picture that will be changing as we move past the time horizon of the TEO Reference and Alternative Scenarios. This means supporting energy technology research at the many fine Turkish universities and research institutions as well as distilling the emerging knowledge into new ways that Turkey can best develop its clean energy future. As emphasized throughout the *Turkey Energy Outlook*, an important benefit of such a strategy is localization: Turkey becoming an industrial participant and partner in the global energy revolution rather than a technology or equipment importer. As will be discussed below (Section 9, "CCUS and Challenges: Power Sector vs. Hydrogen Production"), hydrogen produced from Turkish coal with CCUS could be a particularly important pathway to a clean energy future with strong Turkish localization. But there will be many other avenues to be explored as global and Turkish energy technology research proceeds, each benefitting from the other.

6.3 Energy Efficiency

Energy efficiency has proved to be the most potent weapon to achieve energy security and to reduce CO_2 emissions. As described in Chapter 2, while the benefits of vehicle fuel technologies were largely spent on increasing consumer appetite for larger and more powerful vehicles, passenger car fuel efficiency gains have helped stall the growth of oil demand that, going forward will be driven by truck transport and petrochemicals.

Appliance energy efficiency standards, along with efficiency labels, have dramatically reduced the electricity and natural gas consumption of household white goods, furnaces, and air conditioners. Standards have been particularly effective in reducing the consumption of electricity by light bulbs and also the relatively small electric consumption of transformers, set-top boxes, computers, and other electronic equipment. The electricity used by these devices is invisible to consumers so standards are particularly important to motivate manufacturers to consider efficiency in designing this equipment. The collective consumption of these devices has been increasing to over 10% of household electricity consumption and, in the United States, this is equal to lighting electricity consumption (EESI, 2017). As discussed in Chapter 5, significant energy efficiency potential exists in a variety of applications such as building envelopes, electric motors in the industry and irrigation pumps in agriculture.

As we fast forward to a post-2040 pathway to net-zero, energy efficiency, despite its importance in the recent past and the role it still has to play, begins to fall away as a climate policy. Energy efficiency will remain an important economic priority but as the use of fossil fuels without carbon capture declines to very low levels, efficiency produces negligible reductions in CO_2 emissions, especially in the power sector, just as the energy efficiency of Norway's electric appliances has had no bearing on Norway's GHG emissions. Transport and industry are among the hard-to-abate sectors due to continued reliance on fossil fuels without the cost-effective deployment of clean energy technologies such as BEVs, HFCVs, and hydrogen-based high-grade heating as discussed in Sections 6.6 and 6.7 below.

6.4 Renewable Energy and Electric Storage Systems

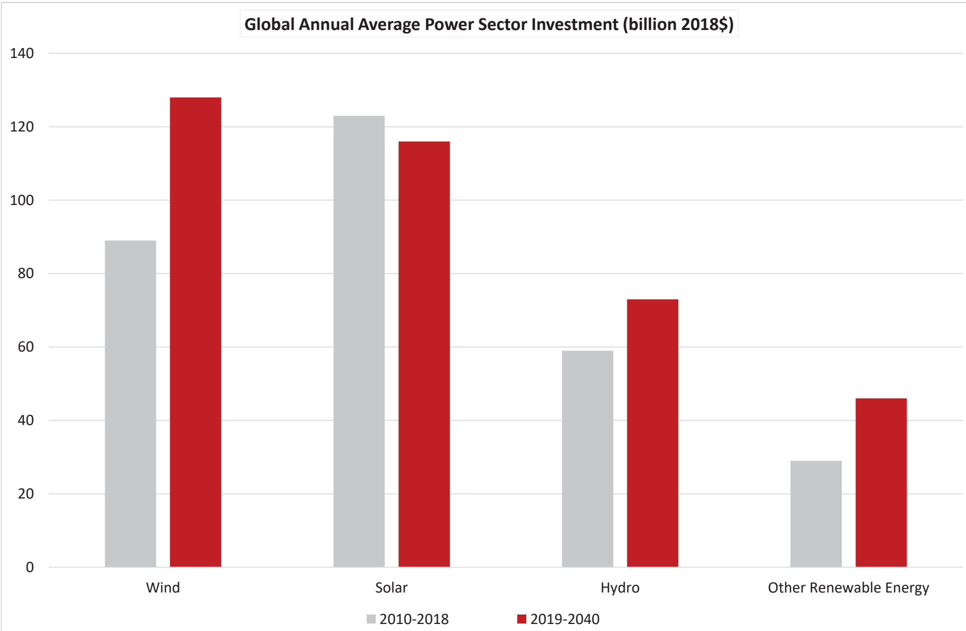
As discussed in Chapter 1, the cost reductions in wind energy have made it one of the least expensive ways to generate electricity in areas that have reasonably good wind resources. Similarly, solar PV, once expensive, has come down in cost so rapidly that it is on the threshold of becoming the least expensive source of electric power in regions with reasonable levels of solar radiation. Power sector investment globally totals $20 trillion over the period to 2040, which is 20% higher than annual spending between 2010 and 2018. Renewables account for $360 billion per year over the period to 2040, most of it for solar PV and wind power, an increase of 20% from 2010-2018 period levels, and also given the declining costs mean that this investment also buys more capacity per unit of invested capital than in the past (Figure 6.1).

At all latitudes, solar and wind power combined are expected to outpace investment in all other forms of electricity generation by a factor of five (IEA, 2019a). The technical challenge for these technologies is no longer the wind turbines or solar panels, but cost-effective and market-based methods to store and release electric power when the wind is not blowing or the sun is not shining. The role of load-following fossil fuel power must necessarily decline in a net-zero world and carbon capture and storage faces additional technical and economic challenges when applied to load-following coal or natural at all latitudes, solar and wind power combined are expected to outpace investment in all other forms of electricity generation by a factor of five (IEA, 2019a). The technical challenge for these technologies is no longer the wind turbines or solar panels, but cost-effective and market-based methods to store and release electric power when the wind is not blowing or the sun is not shining.

The role of load-following fossil fuel power must necessarily decline in a net-zero world and carbon capture and storage faces additional technical and economic challenges when applied to load-following coal or natural gas plants (IICEC, 2020). Likewise, nuclear power is generally not well suited to a load-following role as a technology with high capital costs and low fuel costs[74]. Consequently, the biggest challenge to increasing the role of variable renewable energy is to develop cost-effective and efficient technologies to balance load over multiple time periods from very short to seasonal. While arbitrage and demand-side management can reduce the need for storage in the shorter time intervals, the need for storage and release capabilities over a wide range of time intervals will increase greatly as variable renewables grow to be a high share of power capacity and fossil-fuel plants are phased out.

[74] The baseload operation is the technically simplest and the most economical mode for nuclear power plants. However, the load following has become a more apparent feature in new designs.

Figure 6.1 Global Annual Average Power Sector Investment (billion 2018$)



Source: IEA, 2019

Pumped storage accounts for 95% of electricity storage capacity worldwide. It has desirable flexibility and, while it can be expensive, its cost parameters are known but strongly linked to local circumstances. While the widespread form of electricity storage today, pumped storage cannot continue to maintain this high market share due to the relatively limited availability of reservoirs and geography. The battery storage has been expanding with applications in the electricity system both at the grids and via behind-the-meter storage. The Li-ion remains the leading technology of choice in many battery applications, however an extensive array of R&D activities is ongoing to enable feasible deployment of different battery chemistries. All other approaches to energy storage are in the early stages of commercial development and they all face economic and technical challenges. While batteries are poised for more widespread commercial deployment they do not work for seasonal storage. Using electrolysis to convert excess electricity to hydrogen and then using the hydrogen in turbines or fuel cells to regenerate electricity is a widely anticipated technology that would serve a wide range of storage needs, including seasonal storage (IEA, 2019b). In addition, hydrogen storage would employ a combination of developed technologies such as electrolyzers, hydrogen storage tanks, and hydrogen turbines (or fuel cells with further development). Thermodynamic losses are large returning less than 40% of the generated electricity back into the grid and, especially considering these losses, costs are a factor. Nonetheless, compared to the alternatives, and the more general need to produce hydrogen as a new clean energy carrier (Section 1.5 below), hydrogen storage may well emerge as the leading technology to balance an electric grid with high percentages of variable renewables capacity and a low percentage of load-following fossil fuel capacity.

Besides batteries and hydrogen, there are several categories of electricity storage that are being studied including:

- Chemical (besides hydrogen)
- Gravitational Potential
- Electrochemical
- Electrical
- Mechanical
- Biological

The selection of the most appropriate energy storage technologies to accommodate high shares of variable renewable energy without load following fossil fuel plants will depend on the candidates' technological parameters. Storage systems must serve the complex needs of a modern power system. These include frequency control (primary, secondary and tertiary), frequency stability, voltage support, angular stability, transmission support, and contingency grid support. These considerations are all in addition to providing capacity support when variable renewables are not dispatching power, as discussed in Chapter 1.

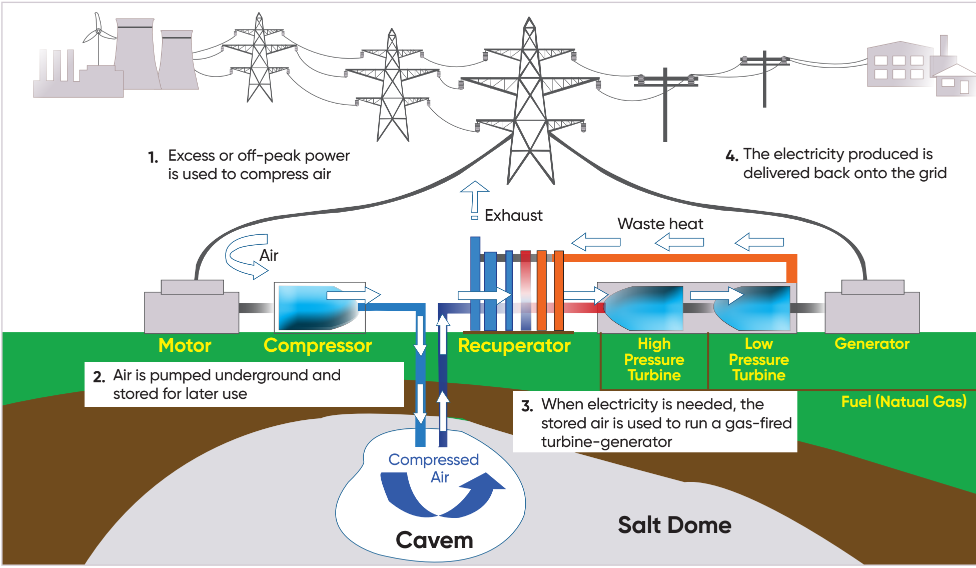
As the challenges to the replacement of natural gas-fired load-following power with current or emerging energy storage methods are very great, an interim solution may be required, even beyond 2040. Higher efficiencies can be achieved with gas hybrid systems consisting typically of one or more gas turbines, a heat recovery steam generator, a steam turbine and integrated battery storage. The result is a system that provides high-speed frequency regulation and voltage support while consuming no fuel between periods of dispatch. At least one version of this hybrid system is commercially available (IICEC, 2019a).

The storage cavity can potentially be developed in three different categories of geologic formations:

- Underground rock caverns created by excavating comparatively hard and impervious rock formations;
- Salt caverns created by solution- or dry-mining of salt formations; and
- Porous media reservoirs made by water-bearing aquifers or depleted gas or oil fields.

In particular aquifers can be appealing as a storage media because the compressed air will displace water, setting up a constant pressure storage system while the pressure in the alternative systems will vary when adding or releasing air (Chen et al., 2013) (See Figure 6.2).

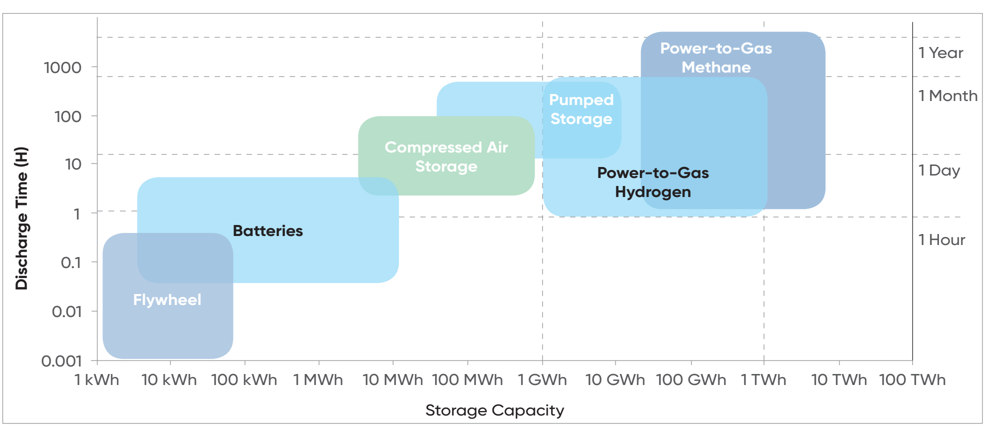
Figure 6.2 Schematic Diagram of a Gas Turbine and CAES System



Reproduced from Chen et al., 2013

Battery storage has been growing and the trend is anticipated to continue as IRENA projects an installed capacity of 14 GW in 2030. Despite this growth, battery storage has number of limitations regarding storage capacity which is not suitable for every application as shown in Figure 6.3 Large scale, long-term storage, which will be required for seasonal backup or as energy security reserves in the absence of fossil fuels, will require different technology. Hydrogen storage has the potential to fulfill this role and, that is why, the future grid is to be one where hydrogen plays a considerable role along with various other storage technologies, not in competition but in concert with other alternative technologies (Figure 6.3) (Moore and Shabani, 2016).

Figure 6.3 Comparison of Discharge Time vs Capacity of Different Energy Storage Technologies



Reproduced from Moore and Shabani, 2016

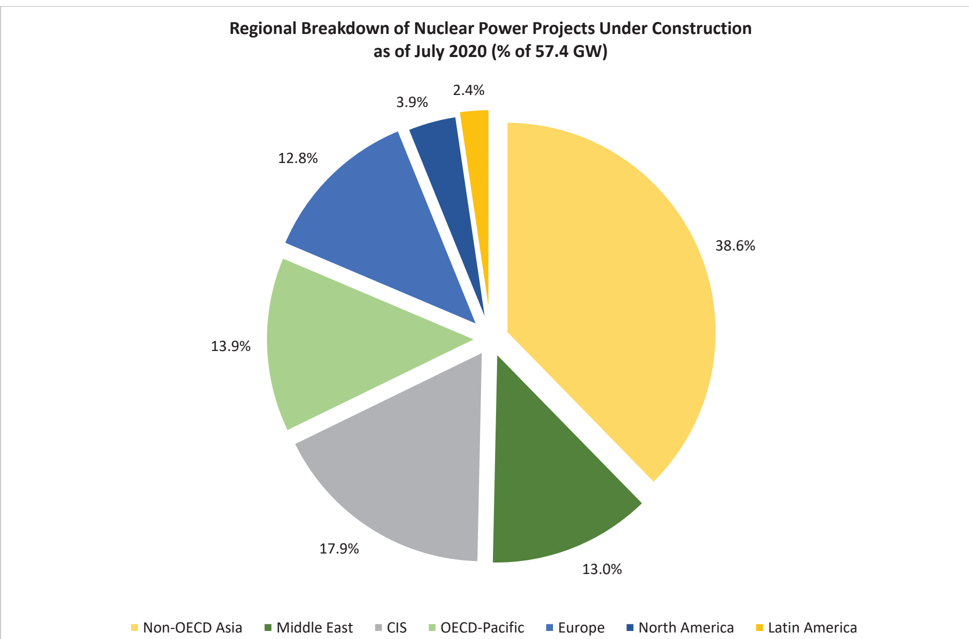
6.5 Nuclear Energy

Nuclear power was once anticipated to be the future of global power generation after the initial success in building the first commercial power reactor in 1956 (Calder Hall A, U.K.) and the many commercial projects that soon followed. While these included many different design concepts and orientations, eventually, the light water reactor, using ordinary water to cool the reactor, either with a secondary steam loop (Pressurized Water Reactor) or not (Boiling Water Reactor), came to dominate the world's nuclear fleet due to cost and other considerations. Nonetheless there are a large variety of other coolants including heavy water, sodium, various chemicals, molten metals as well as high temperature designs using gas. Reactor orientations include the nature of the spent nuclear fuel and whether the reactor is efficient for producing weapons' grade material (often referred to as a dual use reactor as was Calder Hall A). The vast majority of the current power reactor fleet has a single orientation for power generation and, for most plants, the spent nuclear fuel has not been reprocessed but is stored on the surface awaiting the construction of deep underground storage to keep the nuclear waste safe for many thousands of years.

The expectations for a vast expansion of world-wide nuclear power that prevailed during the 1960s led to a strong interest in fast breeder reactors whose orientation would be to produce plutonium as an endlessly available reactor fuel supply in the anticipation that natural uranium deposits would be fully exploited. This system of uranium reactors supplemented by fast breeders seemed to solve the world's energy security problem by, using nuclear fission reactions to produce an endlessly available supply of energy. And if that were not enough, work soon began on the concept of using nuclear fusion to harness and an even vaster potential supply of energy.

Despite the rapid growth of nuclear power plants in the 1960s and 1970s, especially the light water designs, confidence in these expectations began to wane. France, in particular, was successful in converting a large share of its electrical generating capacity to nuclear but it was an isolated example. While the U.S. nuclear fleet was larger than France's, nuclear power in the U.S. never reached more than 20% of U.S. power generation while, until more recently, U.S. electricity generation was dominated by coal. During the 1970s cost overruns and the 1977 Three Mile Island accident led to the cancellation of over 100 U.S. nuclear power projects that lasted into the 1980s. These cancellations and bankruptcies (as many of these reactors were already under construction) were a major factor behind the U.S. drive to replace the investor-owned regulated monopoly utility with a large variety of more competitive models in many U.S. States. At the same time, other OECD countries were abandoning their state-controlled power systems in an effort to make their energy economies more competitive. The net effect of "privatizing" the power system in the OECD away from integrated entities that had full responsibility for providing electric services to designated geography has had a particularly negative effect on investments in nuclear power. Because of its high cost and the large capacity of a single unit of nuclear power, the prospect for financing it is poor in competition to lowering renewable power generation costs and competitive gas prices. A single unit of nuclear power typically consists of two nuclear power units that, combined, provide 2.4 GW of electrical generating capacity and costs, under favorable expectations, over $10 billion and realistically take up to 10 years to build. Added to this, the recent experience of building nuclear power plants in the OECD has been plagued by cost overruns and delays. Because of the high cost to build a single nuclear power plant, along with the likelihood of delays and cost overruns, Moody's Investors Service has characterized a decision to build a nuclear power plant as a "bet-the-farm" risk[75] that is, essentially unacceptable (Difiglio and Wanner, 2012). This means that conventional nuclear power investments are within the domains of national governments. As shown in Figure 6.4., most current nuclear power projects are being constructed outside of the OECD where power demand increases are still persistent and competitive power markets are less common.

Figure 6.4 Regional Breakdown of Nuclear Power Projects Under Construction as of July 2020 (% of 57.4 GW)



Source: Adapted from IAEA data, 2020

New reactor vendors are emerging to serve this more divergent market in addition to or instead of the historic leaders, General Electric, Areva and Westinghouse. For example, while Rosatom has a long experience in building nuclear power reactors, its emergence as a major technology exporter is relatively new. Their VVER-1200 reactor possesses the latest advanced safety features and is now a tested design. Likewise, China, who is gaining experience building their own nuclear reactor fleet, is entering the export market.

[75] Bet-the-farm risks everything on a single investment.

These new vendors are also experimenting with ways to reduce the financial risk to their customers. For example, the "build, own and operate model", being employed at Turkey's Akkuyu nuclear power plant project, shifts the construction risk to Rosatom. Turkey's financial obligation is limited to fulfilling a power purchase contract. Rosatom is also responsible for the "fuel cycle" (refueling the reactor and returning spent fuel to Russia).

Nuclear energy currently represents 28% of global low carbon electricity generation. Despite the expansion of nuclear power outside of the OECD, the International Energy Agency expects that nuclear power will remain at about 8% of total global electricity supply through 2040 (IEA, 2019a). Prospects for more nuclear power will require a new generation of reactors that are less risky, more scalable with lower costs per kWh, and even greater levels of inherent safety than current large reactor designs. There are numerous projects worldwide to develop this potentially game-changing technology: the small modular reactor (SMR). Instead of undertaking a time-consuming on-site reactor build, the SMR would be produced in a factory and delivered to a power customer, vastly reducing their financial risk. A variety of SMR designs are being explored[76]. Many designs promise inherent safety (IICEC, 2019c).

The smaller reactors mean that there is less heat energy to manage and, for example, convection cooling is anticipated in many designs eliminating the need for backup power during a reactor shut down, a factor that was involved with both the Fukushima and, less directly[77], with the Chernobyl accident. SMRs could also have less frequent refueling and better options for waste disposal. The private sector, with government support to enable licensing and testing, is accepting the financial risk to produce this new generation of nuclear power technologies. Even without any new government policies, we should see in a few years whether or not the SMR can overcome economic and public acceptance challenges and grow the role of nuclear power in future decades.

6.6 New Clean Energy Carriers

Net-zero requires that all forms of energy production do not produce significant GHG emissions. This rules out the use of fossil fuels without carbon capture, utilization and storage (CCUS). CCUS is a technical and economic challenge in the power sector and in many industries that use coal for heat. CCUS is also only feasible for power plants and large industrial uses leaving out the significant consumption of oil and other fossil fuels by motor vehicles, ships, aircraft, households, commerce, and many industries. Achieving net-

[76] According to the latest IAEA data base as of the August 2020, there are 2 SMRs under construction (in Russian Federation and China). South Korea licensed an SMR plant. In addition, there are more than forty SMR projects under design efforts in a variety of regions.

[77] "Less directly", because the highly irregular test that led to the Chernobyl accident was designed to see how quickly the reactor could switch from its own power to its backup power during a reactor shut down. The Fukushima core meltdowns occurred because the backup power units were flooded by the same tsunami that caused the reactors to be shutdown. Consequently, the reactors became overheated.

zero will require that fossil fuels no longer be consumed to provide these energy services and instead be replaced by clean energy carriers. A clean energy carrier is not a primary source of energy, but instead, contains the energy derived from the primary source that can be easily transported and stored. Electricity is the predominant example of a clean energy carrier as long as it is produced without generating GHG emissions, for example, if produced by renewable and nuclear energy (disregarding the embedded CO_2 emissions used to produce the renewable or nuclear power plants). We take for granted the manifold stationary applications of electricity and the introduction of BEVs is becoming quite common. If fossil fuel use cannot be replaced with a clean energy carrier, then the resulting emissions will have to be offset by negative emissions, for example, applying CCUS to renewable fuels or direct capture of CO_2 from the air.

Fossil fuels can also be used to produce "clean" electricity if CCUS is applied. CCUS can typically reduce CO_2 emissions by 80% to 90% (IICEC, 2020). Further reductions, even negative emissions, can be achieved by mixing renewable fuels into the CCUS scheme. For example, woodchips can be combusted with coal in a steam power plant. Since the CO_2 removed from the atmosphere by photosynthesis to grow the trees used for the woodchips is not returned to the atmosphere, net-zero or negative emissions are possible depending on the ratio of coal to woodchips used in the power plant and the percentage of CO_2 emissions removed from the combustion process. Summing up, electricity produced by renewables, nuclear and certain CCUS-equipped fossil fuel plants is a clean energy carrier, at least with regard to CO_2 emissions.

Considering the rapid uptake of renewable energy, electricity is poised to become a widespread clean energy carrier. As noted in Chapter 1, share of electricity in total final energy consumption of Turkey is anticipated to increase from around 20% towards 30% until 2040 in the TEO Scenarios. By 2040, in many parts of the world, fossil fuel power plants will be phased out in favor of renewables with energy storage and nuclear power. Anticipating this, it makes sense to begin replacing fossil fuel end uses with electricity well before electricity has become a clean energy carrier considering the time it takes to make the switch. In addition, replacing these end uses, even with electricity produced from current sources, usually achieves significant CO_2 savings. For example, as shown in Chapter 2, a BEV provides meaningful CO_2 savings even in countries that have a significant share of fossil fuel power plants.

Electricity can make further inroads into final energy consumption. More conventional motor vehicles can be replaced by BEVs. Natural gas and oil furnaces can be replaced with electric heat pumps. Many industrial processes that now use fossil fuels can be replaced with existing electric alternatives so long as the temperature requirements are below 500 oC. However, as will be discussed below, electricity has inherent limitations that may require the more widespread use of other clean energy carriers.

6.7 Replacing Fossil Fuels with Clean Energy Carriers

6.7.1 Electric Vehicles

As noted in Chapter 2, the TEO Alternative Scenario has an ambitious outlook for electric vehicles. Nonetheless, electric vehicles do not greatly reduce Turkey's oil imports by 2040. Afterwards, the oil substitution will be greater with a growing BEV share of the fleet along with a declining stock of older vehicles. In addition, the improving carbon footprint of the Turkish power grid means that the CO_2 emission reductions of these vehicles becomes increasingly larger. With the expanded recharging network that would be put in place in the next two decades and advances in battery technologies, vehicle weight could be lower and driving range significantly extended making the "range anxiety" that people may currently have towards electric vehicles disappear entirely as intercity trips can be completed on one charge and recharging opportunities are ubiquitously available especially when the vehicle would be parked in any case such as at restaurants, motels, other way stations or destinations. With technological progress on battery technology, along with lower vehicle weight, the BEV purchase premium would be reduced providing clear cost-of-ownership benefits when taking account of the reduced recharging costs compared to refueling with diesel fuel or gasoline. There are numerous examples today of BEV models that have best-in-class performance characteristics especially aided by high power electric motors, instantaneous torque, and the low center of gravity due to battery placement, a feature that benefits cornering and handling[78].

Electricity also provides good prospects for wider use in city buses as it has been already demonstrated in many cities, including Turkish cities. Most heavy-duty vehicles remain a BEV challenge when the energy density requirements are more challenging than for light-duty vehicles or heavy duty vehicles used in centrally-fueled operations (buses, trash trucks, etc.). Over the road trucks can typically weigh 38 tons and travel 1,000 km on one tank of diesel fuel. With current battery technology, the freight capacity of an electric truck would be 28% lower than a diesel truck. Also, a typical electric truck would be 3 to 5 times more expensive although there would be fuel costs savings (Swedish Electromobility Centre, 2019). Advances in battery technologies could significantly improve these figures making the BEV heavy duty truck a more practical alternative than it now is. Nonetheless, the freight sector is largely seen to be in need of a new clean energy carrier such as hydrogen where the specific energy (energy stored per kg) compared to batteries is currently 4 to 6 times greater (IICEC, 2019b).

6.7.2 Hydrogen in the Industrial Sector

More than 90% of global hydrogen is produced and used for industrial feedstocks, especially for refining petroleum fuels and for the production of ammonia and methanol. Virtually all of this hydrogen is produced from fossil fuels. In order for hydrogen to be a clean energy

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[78] For example, the 'boxer" engine configuration used by Porsche to keep the weight of the heavier engine heads and cams in line with the crank shaft

carrier, it must be produced differently, for example, by using CO_2 capture (blue hydrogen, discussed in Section 9 below) or by using electrolyzers to produce hydrogen by splitting water molecules using carbon-free electricity (green hydrogen).

If blue and green hydrogen production expands along with wider distribution networks, hydrogen can be introduced into other industrial sectors to achieve a wider industrial decarbonization. Currently, fossil fuels (mainly coal, natural gas) and electricity provide the majority of industrial heat requirements. Decarbonization options for the industrial sectors include direct electrification, wider use of biomass, integrating CCUS to fossil fuel supplies, and utilizing hydrogen as an energy carrier for heating services.

Industrial heating is generally classified into three temperature ranges: low-grade heat up to 100°C, medium-grade heat between 100 to 400°C, and high-grade heat exceeding 400°C (Hydrogen Council, 2020). For low-grade heat applications, electrification remains the lowest-cost option to achieve emission savings. Biomass is applicable in mid-to-high grade applications but its use is limited by feedstock availability. Carbon capture and storage technologies, on the other hand are quite costly (see Section 9) and, to be practical, require much more fossil fuel use, such as in a large coal power plant, than fossil fuel combustion in most factories. Hydrogen is the most promising clean energy carrier to supplement electricity, especially for mid-grade and high-grade heat requirements. While the development of blue and green hydrogen use in general industry is some years away, there is already progress to use blue hydrogen in the chemical and refining sectors. Commercial blue hydrogen projects, using CCS are being established. Green hydrogen projects, using electrolyzers, are still limited to pilot applications.

There is also an opportunity to use blue or green hydrogen use in steelmaking. The reduction of iron ore (iron oxides) is the first step in steel production. The steel industry uses carbon in the form of coke as the main reduction agent in blast furnaces. It has been demonstrated that hydrogen, either in pure form or as present in syngas (CO and H_2) or methane (CH_4), can be injected in the blast furnace to act as the reducing agent (EC, 2018). Since the iron and steel industry is among the main industrial sources of global GHG emissions, and has seen little progress in reducing its emission footprint, more innovative approaches such as using blue or green hydrogen in blast furnaces, would be welcome to lower emissions from this industry[79]. Also, direct reduced iron and smelt reduction technologies can also employ blue or green hydrogen and achieve emission savings. Several projects are under development to advance these innovations and provide economically practical ways to use hydrogen as a new clean energy carrier[80].

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79 According to the IEA data, the direct CO_2 intensity of crude steel has remained largely constant during the past two decades.

80 The HYBRIT project in Sweden is developing hydrogen-based DRI production. In early 2020, the project announced its aim to produce the first fossil-carbon-free steel for sale in 2026,. Linde Gas AB and Ovako companies announced the world's first successful full-scale trial of using hydrogen to heat steel before rolling in a production environment. A pilot plant with hydrogen reduction is also under design in Germany. In Japan, COURSE 50 project targets developing low-emissions steel production, based on the blast furnace including a variety of GHG emissions reducing features such as recovering gases from the blast furnace to reduce fuel input needs, reforming coke oven gas into hydrogen to be used as fuel, and integrating carbon capture. A similar technology is in the test phase in France.

6.7.3 Hydrogen Vehicles

BEVs, by themselves, could provide sufficient emission benefits to achieve global climate targets *if the widespread consumer acceptance of BEVs could be assumed* and if BEV technologies prove to be applicable to heavy trucks. However, BEVs do not provide the range and refueling experience of a conventional vehicle yet, bringing into question whether they can achieve widespread acceptance in the private light-duty vehicle market. In addition, battery-electric technology is significantly less applicable to medium and heavy-duty trucks. Consequently, another low-emission vehicle technology and clean energy carrier may be needed that provides the same consumer experience as conventional vehicles and has broader applicability to heavier-duty vehicles. Nonetheless, BEV commercial uptake far exceeds HFCV sales because HFCVs are relative latecomers, they are currently expensive and, most of all, they rely on refueling infrastructure that is not available except in limited demonstration markets.

Technological and commercial progress will change the picture for HFCVs and BEVs as each type gains a larger share of the motor vehicle market. Government programs could bring about widespread hydrogen refueling infrastructure and HFCV costs will likely decline by a significant degree with lower fuel cell stack costs. Nonetheless, it will not be before 2030 that hydrogen refueling infrastructure is widely available except in a few places. Until then, BEVs and HFCVs will not be a static product as they each will undergo technological progress. BEV vehicle range and recharging time may significantly improve along with reductions in vehicle cost. Likewise, HFCVs will likely improve, particularly by reduced cost for the fuel cell stack. As a result, the relative consumer characteristics of BEVs and HFCVs may be significantly different than they are today. We do not know what the competitive comparison of HFCVs vs. BEVs would be in the future.

The *raison d'être* for developing HFCVs as a supplement or replacement for BEVs has been its potential consumer appeal compared to the BEV. Assuming widespread hydrogen refueling availability, an HFCV would provide consumers a more similar operating experience than a BEV since HFCV range and refueling time are much closer to what consumers are used to. The relatively high energy density of hydrogen storage (compared to batteries) would allow HFCV heavy duty trucks to have a driving range and load-carrying capacity similar to conventional trucks.

Widespread HFCV uptake will require continued government support. Compared to the recent experience to commercialize BEVs, HFCV uptake will require a more synchronized policy intervention as adequate retail refueling infrastructure will be required before motorists can be expected to purchase an HFCV. It was noted in Chapter 2 that HFCVs fueled from service stations that are producing hydrogen from electricity in most countries can have very high GHG emissions, even compared to conventional vehicles. As we look forward past 2040, this would be much less of a problem as the “carbon footprint” of the electric grid is dramatically reduced in most countries, certainly most countries that are making the efforts to reduce its GHG emissions by deploying hydrogen vehicles. Also, as noted in Chapter 2, hydrogen merchant plant production using renewable or nuclear electricity or fossil fuels such as coal or natural gas with carbon capture and storage would likely be developed to reduce costs once hydrogen transport and distribution systems are developed. Apart from road transportation, R&D efforts are also in place in the aviation and shipping sectors that both possess limited low-carbon fuel options.

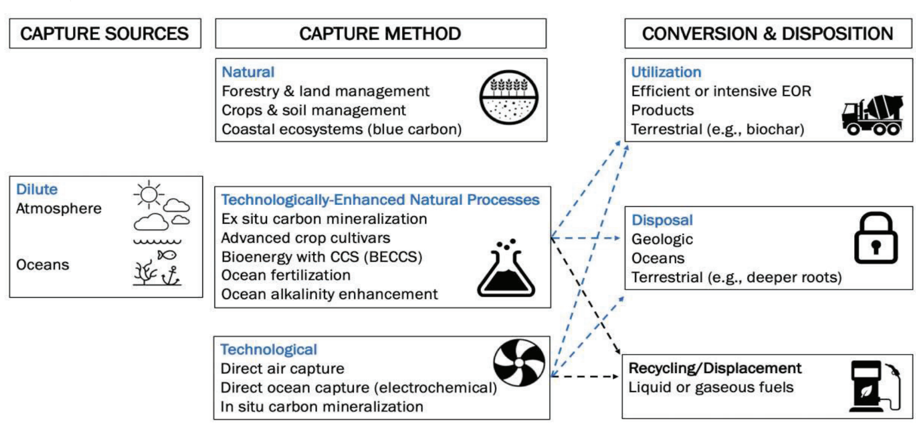
6.8 Carbon Capture from the Atmosphere

According to the Energy Futures Initiative (EFI), "Net-zero CO_2 emissions is not credibly achievable by midcentury without major contributions from negative-carbon technologies that would also make possible reversal of ever-increasing GHG concentrations in the atmosphere, thereby reducing the impact of past actions." (Energy Futures Initiative, 2019)

There are a variety of approaches to achieve negative carbon emissions. As shown in Figure 6.5, EFI categorizes them as:

- Natural methods (forestry and land management, etc.)
- Technologically-enhanced natural processes (bioenergy with CCS, ocean fertilization, ocean alkalinity enhancement)
- Technological including direct air capture, direct ocean capture, and in situ carbon mineralization.

Figure 6.5 Carbon Capture Pathways[81]



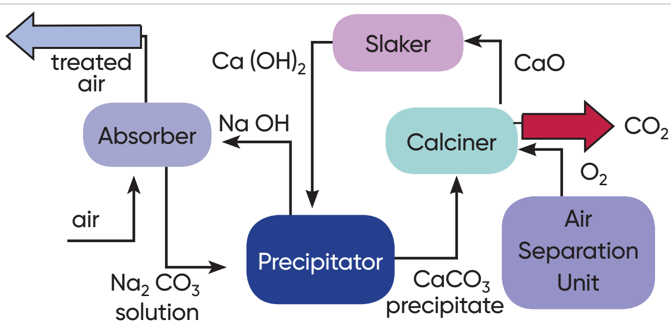
There are a variety of natural, technologically-enhanced natural processes, and technological pathways that can facilitate CDR through the capture of CO_2 from dilute sources. Source: EFI, 2019.

[81] Reproduced with the kind permission of the Energy Futures Initiative.

Avoiding deforestation or planting trees are often mentioned as natural methods to increase the uptake of CO_2 by the natural environment. The use of carbon capture with biofuels, mentioned above, falls into the second category, technologically enhanced natural processes, by geologically storing the carbon utilized during photosynthesis (to produce sugar molecules and oxygen) instead of allowing it to be released again into the atmosphere by combustion or decomposition. The third category involves the direct removal of carbon from the air or oceans, a process that is unrelated to the energy economy except insofar as it could compensate for the inability of the energy economy to make the necessary changes to achieve net-zero emissions.

Direct air capture uses heat and electricity to separate CO_2 from a moving stream of air with the use of sorbents or solvents permitting the CO_2 to be separated, transported and injected into deep saline aquifers. This sequestration process is the same as would be used for CCUS from fossil fuel power plants. An example process is shown in Figure6.6. This is just one of several systems that have been proposed. Carbon mineralization can also be used to convert CO_2 to carbonates permitting CO_2 to be stored as a solid. It should be noted that full-scale application of direct air capture could require giga-tons of CO_2 to be sequestered, at much higher volumes that would have been anticipated from the CO_2 captured from coal power plants.

Figure 6.6 Example of a Direct Air Capture Process



Absorber: $2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

$\Delta H^\circ = -109.4$ kJ mol^{-1}

Causticizer: $Na_2CO_3 + Ca(OH)_2 \rightarrow 2NaOH + CaCO_3$

$\Delta H^\circ = -5.3$ kJ mol^{-1}

Calciner: $CaCO_3 \rightarrow CaO + CO_2$

$\Delta H^\circ = +179.2$ kJ mol^{-1}

Slaker: $CaO + H_2O \rightarrow Ca(OH)_2$

$\Delta H^\circ = -64.5$ kJ mol^{-1}

Reproduced from Sanz-Perez et al, 2016

There are three significant obstacles to the application of direct air capture at a scale that would provide a significant level of negative carbon emissions to offset the growth of energy-sector emissions: technology development, cost, and required real estate. Keith, et al, 2018, estimates that a levelized cost of $94 to $232 per ton of CO_2 separated using the engineering concept presented in their paper. This is a surprisingly low cost considering that it is only 2 to 3 times higher than capturing CO_2 from sources where the CO_2 concentrations are roughly 300 times as high as they are in the atmosphere. It is quite possible that the costs could be considerably higher, such as the $550/ton estimated (APS, 2011) or even higher than that.

The real estate challenges are also significant as the plant envisioned by Keith et al, 2018, would have a plant face of 40 m high by 2 km by 400 m deep. In order to remove 40 billion tons of CO_2 per year from the atmosphere, 20 thousand plants like this would be required to consume 40 thousand km^2 of real estate not counting boundary areas and the real estate needed for transportation and other infrastructure. Due to the underlying thermodynamics required for moving air through the capture plant and for CO_2 absorption, the power requirements would be very significant, on the order of 0.49 MWh/tCO_2 captured (APS, 2011) or approximately 620 GW of dispatchable power generating capacity (as the CO_2 capture plants would be running 24 hours per day).

Were the electricity to be provided by burning coal, a powering a direct capture plant would add 0.5 tons of CO_2 for each ton removed unless CO_2 was captured post-combustion at the electrical generation plant. Using natural gas as the energy source would cut the emission to 0.25 tCO_2 generated for each ton removed. If renewable energy were used, the capacity requirements would be that much larger to reflect lower capacity factors; however, as the capture plant is sized for it maximum airflow, the lowest size and capital cost of the plant is realized by using constant base-load power.

In conclusion, the international research community should and will continue to explore these options to achieve carbon removal from the air. Nonetheless, it is quite likely that the costs and other practical factors make this approach a highly uncertain basis for planning a transition to a net-zero energy economy.

6.9 CCUS and Challenges: Power Sector vs. Hydrogen Production

Carbon capture, utilization and storage (CCUS) has been under serious discussion for over 2 decades with governments making significant pilot plant investments. However, currently, only two large-scale CCUS power projects are in operation worldwide. There has been continuing optimism that “clean coal” technologies would enable the continued use of the world’s coal resources in an environmentally acceptable manner. This has partly been encouraged by the significant progress that has been made in many countries to dramatically reduce many harmful pollutants using flue gas scrubbers, and supercritical combustion technologies, among others. These pollutants, sulfur dioxide, nitrous oxides, organic hydrocarbons, mercury, and others have a direct effect on human health and, in many parts of the world, for example, China, pose a major health problem despite the fact that these emissions have been significantly reduced from coal power plants in OECD countries. Removing CO_2 is much more difficult and expensive than controlling these other pollutants. Carbon capture adds between $30/MWh to $40/MWh to the LCOE for a coal or a natural gas plant (Global CCS Institute, 2017)[82]. As a result, despite considerable support in over two decades for carbon capture projects around the world, there has been no significant uptake of commercial carbon capture in the power sector.

If we return to Table 1.3, we note that the estimated LCOE's of Turkey's hard coal and lignite plants are from $55/MWh to $75/MWh (Table 6.1). Adding CCS would raise the LCOE for coal plants to $85/MWh to $105/MWh. This would cause coal fired power to be among the most expensive power sources along the entire suite of power technologies that are modeled in the TEO. In addition, even as the most expensive form of power generation in LCOE terms, these coal plants would remain a significant source of CO_2 emissions compared to renewable or nuclear power plants. A 750 MW coal plant with carbon capture would emit from 30 to 50 tons of CO_2 per hour of electricity generation, far less than without capture, but still significant in the context of achieving net-zero.

Table 6.1 Key Cost Figures for Power Generation Technologies

2019$	CAPEX ($/KW)		LCOE ($/MWh)		VALCOE ($/MWh) Reference Scenario	VALCOE ($/MWh) Alternative Scenario
	2019	**2040**	**2019**	**2040**	**2040**	**2040**
Nuclear	4800	4000	90-95	80-85	80-85	80-85
Hard Coal	1300	1300	50-55	55-60	55-60	55-60
Lignite	1700	1700	70-75	70-75	70-75	70-75
Gas CCGT	750	750	50-55	55-60	50-55	45-50
Hydro	1700	1700	75-80	80-85	75-80	75-80
Solar PV	550	400	50-55	40-45	45-50	50-55
Wind onshore	950	900	45-50	45-50	50-55	50-55
Wind offshore	3000	2400	80-85	65-70	75-80	80-85

These data suggest that carbon capture technologies, absent unexpected cost breakthroughs, are not likely to be part of Turkey's energy transition to net zero emissions. This calls into question how best to utilize Turkey's domestic reserves of lignite. Do they have an economically and environmentally sustainable role in Turkey's energy future? The answer appears to be yes, they do, since hydrogen will likely have a strong role in

82 Adding an equal cost penalty to the LCOE of a natural gas plant as a coal plant means that the cost per ton of CO_2 capture is twice as high for the gas plant compared to the coal plant. In addition, with natural gas plants reverting more and more to a load balancing role, especially in Turkey, carbon capture in a gas plant becomes even less economically feasible since carbon capture relies on a steady pressure of CO_2 removal for transport and injection (IICEC, 2020)

Turkey's energy transition towards and past 2040. Coal is among the least expensive ways to produce hydrogen having a cost range of $1 to $2 per kg of H_2 (IEA, 2018) compared to $1 to $3 for natural gas and $3 to $8 from electricity. Unlike a coal power plant that substantially increases the LCOE, adding carbon capture to a coal plant producing H2 has an insignificant impact on the cost of producing H_2, about $0.1/kg, a cost that essentially has no bearing on the competitiveness of coal compared to other methods of producing hydrogen (National Academy of Engineering, 2004). The reason for this is the fundamental difference of what happens in a coal power plant and what happens in a coal plant producing hydrogen. A coal power plant combusts coal to produce heat to produce steam that, in turn, is used to produce electricity. To produce hydrogen, coal is gasified and chemical processes are used to break down the heavier hydrocarbon molecules to CO_2 and H2. In this process, coal is partially oxidized in a gasifier producing CO and H_2 (syngas).

$$3C + O_2 + H_2O \rightarrow H_2 + 3CO$$

More hydrogen is gained with a water shift reaction and, more significantly, the CO reacts to become CO_2.

$$CO + H_2O \leftrightarrow CO_2 + H_2$$

Consequently, a high-pressure CO_2 stream already exists in a coal to hydrogen plant while in a coal power plant it has to be created using solvents to remove CO_2 from the flue gas or using other techniques that are equally expensive[83].

The consequences of these cost considerations are very significant. They strongly suggest that carbon capture is too expensive to apply to coal power plants and, at the same time, realize a new coal power plant investment with an LCOE that is competitive with any other power generating technology, including the most expensive options such as nuclear and hydropower. The data also show that the cost of carbon capture applied to a coal plant producing hydrogen would have a very small impact on its cost of producing hydrogen, for example, an increase from $2.0/kg H_2 to $2.1/kg H_2. Applying carbon capture to a coal to hydrogen plant has no bearing on its considerable cost advantage compared to producing hydrogen from electricity ($4/kg H_2 to $6/kg H_2).[84] Coupling conventional technologies with CCUS will likely lead the route for low carbon hydrogen production. As of the end of 2019, six projects with a total annual production of 0.4 million tons) were in operation. More than twenty new projects have been announced worldwide for commissioning during this decade (IEA, 2020a).

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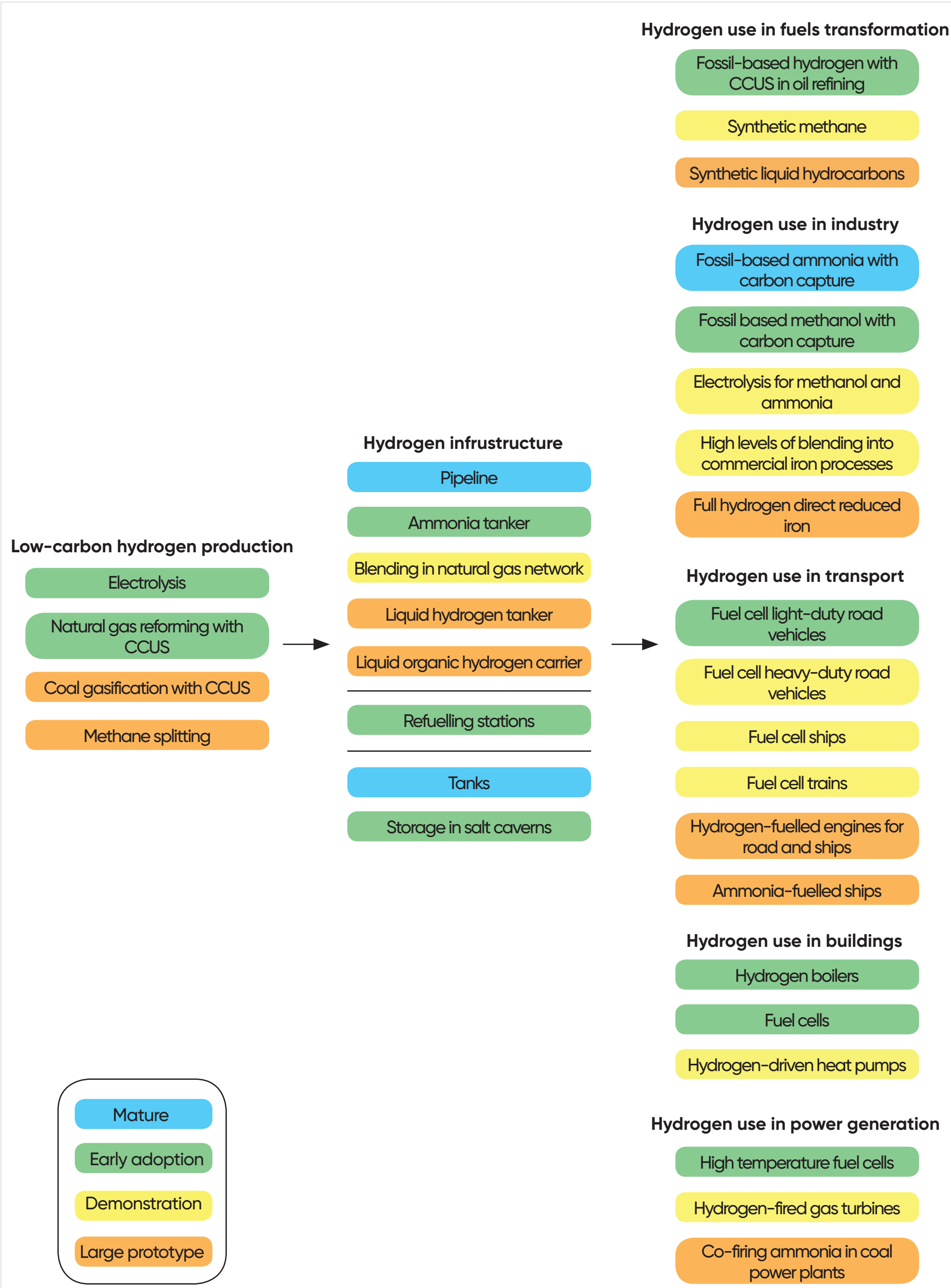
83 For example, it is possible to entirely replace the coal combustion steam plant with this same described chemical process to gasify coal to produce CO_2 + H_2. Then the CO_2 is sequestered and the H_2 is used in combustion turbines to produce electricity (similar to natural gas-fired turbines). However, compared to flue gas scrubbing, there are no cost savings to building this type of coal plant in lieu of a steam coal plant (IICEC, 2020).

84 Several reports suggest that the costs of hydrogen production from electricity could be significantly reduced by using excess renewable electricity. Nonetheless, it will be a challenge to bring the costs of electrolysis down to the cost of producing hydrogen from fossil fuels.

Figure 6.7 Current Technology Development Stages in Low-Carbon Hydrogen Production



Source: IEA, 2020

While it is too early for Turkey, or any other country, to establish hydrogen as a new widespread clean energy carrier, it appears that, before too long, this will be required in order to advance more rapidly to a net-zero energy sector, as electricity is not expected to be a satisfactory clean energy carrier for all applications. High-temperature applications in industry and other instances where combustion is necessary would require blue or green hydrogen.[85] In addition, in the transportation sector, it is anticipated that electricity cannot be relied upon as a clean energy carrier to fully replace fossil fuels, especially for road freight. For both heavy-duty vehicles and consumers requiring a private vehicle that has the same refueling features as a conventional vehicle, hydrogen fuel cell vehicles are likely to be necessary as a supplement to electric vehicles (IICEC, 2019b). Technology development in low carbon hydrogen is evident in each element of the energy sector with demonstration and early adoption in the most important areas as demonstrated in Figure 6.7 (IEA, 2020b).

There are important policy messages that can be drawn from these considerations. First of all, Turkey's current RD&D activities for hydrogen are farsighted and important. They are necessary first steps to ensure that Turkey stays engaged with global developments and maximizes the localization opportunities for hydrogen end-use technologies. In addition, above cost data suggests that Turkey's lignite reserves will be an important asset to Turkey's emerging hydrogen economy. They would ensure that cost-competitive supplies of blue hydrogen would be available as it develops the end-use technologies and hydrogen distribution and storage infrastructure. This would add further to Turkey's energy localization and energy independence as it greatly reduces reliance on imported fuels for every aspect of its energy economy. Therefore, it represents a perfect synergy along the macro objectives of environmental sustainability, socio-economic development and enhanced energy security.

[85] The literature has adopted the term "blue hydrogen' to refer to hydrogen produced from fossil fuels with carbon capture and "green hydrogen" to hydrogen produced from renewable energy (although some sources would also include nuclear energy).

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CHAPTER 7:

THE LONG TERM IMPLICATIONS of the Covid-19

7.1 Work Life and Consumer Behavior

The impact of Covid-19 has been one of the most drastic and rapid shifts to the global workforce in recent history. Pandemics have affected human behavior throughout history, most notably, the several Eurasian plagues during the Middle Ages to the Spanish Flu in the early 20th century. The Covid-19 pandemic has also brought social change. One difference between past pandemics and Covid-19 is 21st Century technology that has enabled more flexible responses to the way we work and live. Nonetheless, Covid-19 has brought unprecedented challenges especially in business models, ranging from remote working, consumer behavior, and digital business (Colleen, *et al*., 2020).

The Covid-19 pandemic has forced the adoption of new ways of working. The crisis required companies to embrace digital business models and forced customers and employees to give the Internet a larger role in the way they shop and work. Many companies have acted boldly to implement their digital strategies at a much faster pace than before, as a result of the outbreak (McKinsey, 2020a).

With the start of the pandemic, thanks to the digital transformation that took place in a matter of weeks, it has deeply transformed the nature and degree of human interaction throughout the world. Technologies such as videoconferencing and other forms of digital collaboration have been embraced rapidly and successfully. These technologies improved and saved lives by enabling human connections and also avoided a faster spread of the virus by making it easier for people to avoid social contact. For instance, the usage of video conferencing technologies such as Zoom, an almost vague brand name, burst out during the lockdown and it has become a household verb (Colleen, et al., 2020).

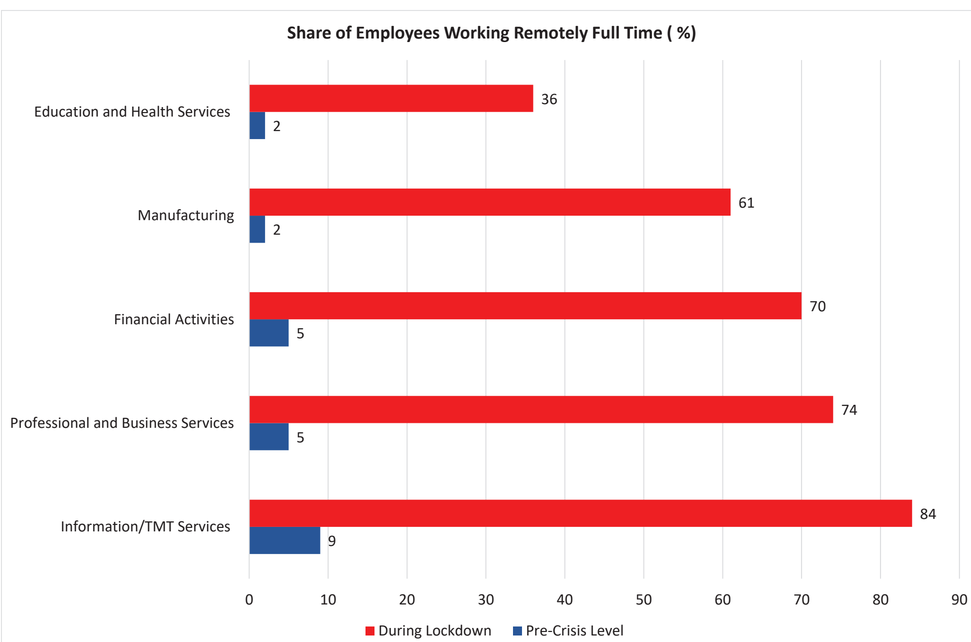
The latest study suggests that the world has vaulted several years forward in digital adoptions in a matter of months during the lockdown. Banks have shifted towards remote services and launched alternative digital operating systems in order to provide payment arrangements for loans and mortgages with more flexibility. Online ordering and delivery have become the primary business focus for grocery stores in addition to many other items that people were previously buying through the Internet instead of "brick-and-mortar" stores. Doctors have commenced delivery of telemedicine and schools have begun online learning and digital classrooms in many parts of the world. Manufacturers are vigorously working on strategies for more innovative supply chains (McKinsey, 2020b). Whether these changes continue after the Covid-19 pandemic is truly over (presuming that would be the case) will depend on many factors but it is likely that there will be some return to older models such as shopping in the supermarket or returning to the classroom. Nonetheless, we have reason to believe that many of the changes will be baked into our future. One survey found that 75% of the people who have used digital platforms for the first time say that they will continue to use them after the pandemic (Mc Kinsey, 2020c).

The Covid-19 pandemic has profoundly changed work environments with the priority being health and safety. This sudden change brought about by the pandemic has caused an unexpected and massive movement for many workers and companies. For many businesses, the shift to remote access embodied a very different way of working (Deloitte, 2020).

Together with social distancing and the 2020 economic shutdown that was common in many countries throughout the world, a large portion of the workforce has been pushed out of their offices into their homes in a matter of weeks beginning in March and April 2020. Before Covid-19, it was a usual practice for companies to have few or no remote employees. Many companies that provided remote work options limited them so employees could not substitute remote work for reporting to their offices. The pre-pandemic Future Workforce survey showed that a negligible share of the workforce performed their jobs remotely. Only, 2.3% of managers had fully remote teams (Ozimek, 2020). Nonetheless, the very existence of well-developed remote work technologies proved critical in dealing with the Covid-19 pandemic.

This unexpected shift to remote-working models during the lockdown has forced many companies to mobilize global expertise instantaneously, organize a project assessment rapidly, and respond to customer queries at a swifter pace by providing digital support for product sales and after-sales services. The pandemic propelled the faster execution of decisions as organizations figured out how to best respond to the new challenges. The discovery of new business models, as a necessary response to the pandemic, may cause a more permanent shift. For example, as shown in Figure 7.1, the share of employees working remotely has risen steeply during lockdowns and is anticipated to stay higher than pre-crisis level, at least, for a considerable period of time (Mc Kinsey, 2020c).

Figure 7.1 The Share of Employees Working Remotely Full Time (%)



Source: US Bureau Labor Statistics, 2020

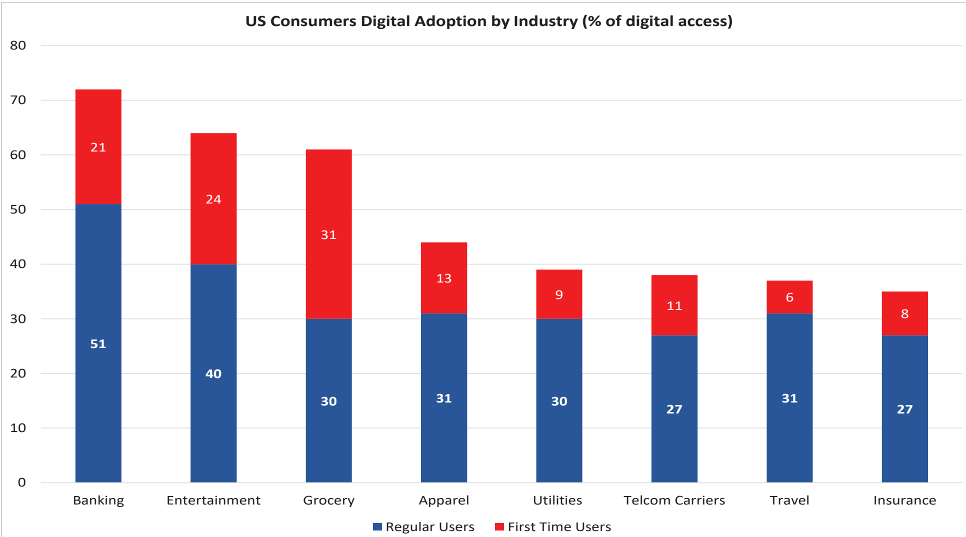
Since many employees have not been involved in long commutes as they were before, they have found more productive ways to spend that time, benefitting from greater flexibility. According to a survey conducted by McKinsey, 41% reported that they are more productive than before Covid-19 (McKinsey, 2020b). Also, 40% of respondents state that the greatest benefits of remote work have been no commuting and fewer unnecessary meetings. Face-to-face meetings have been substituted by video-chats and popping in at someone's desk or office has been switched to a short online message. The most important problems have been technological issues and most of these readily solved. One effect that has been observed is a blurring of the boundaries between work-life and home-life (Sheth, 2020).

The remote work experiment has gone better than many expected because employees were liberated from long commutes, adjusted well to work from home and businesses found that productivity was, in general, not adversely affected. Until the Covid-19 pandemic is truly over, the office environment will not remain the same and working spaces will have to be redesigned to ensure physical distancing and limit movements particularly in congested areas. Therefore, even after the reopening under the "new normal" attitudes, offices will continue to evolve. The long-term impact of the remote work experiment and what it will bring still remains ambiguous (McKinsey, 2020b).

Another major impact of the Covid-19 pandemic has been on customer preferences and behaviors. Consumers have changed their behavior rapidly moving from "brick-and-mortar" shopping to online shopping. Consumer habits of buying and shopping have been disrupted with lockdowns, mandates of social distancing and closed retail establishments. Covid-19 has unleashed the creativity and resilience of consumers. They have discarded past habits and created new habits of consumption. Out of sheer necessity, consumers have improvised and adopted several new technologies and their applications (Sheth, 2020).

As illustrated in Figure 7.2, the use of digital services by consumers for the first time for different industries have shown an upward trend across many fields, ranging from banking to grocery to utilities and insurance (Mc Kinsey, 2020c).

Figure 7.2 US Consumers Digital Adoption by Industry, % of Digital Access



Source: McKinsey 2020

It is unavoidable that some newly acquired habits under the lockdown condition will continue because the consumer has discovered more affordable and convenient alternative options. For instance, instead of going to theatres, consumers have become more familiar with streaming services such as Netflix. In particular, Netflix has challenged the traditional film industry by producing "major" films and distributing them online, even before the Covid-19 pandemic. This is another example of how the responses to Covid-19 benefitted from business trends that were already underway. Online purchase behavior has moved strongly to new types of purchases, especially groceries as consumers have sought to avoid Covid-19 exposure in grocery stores. Another example is Amazon which has experienced strong growth during the lockdown because its package delivery systems successfully respond to the challenge. Of course, Amazon had already established a massive platform to do this, another example of how recent online business developments enabled a much more flexible response to the pandemic. In addition, many retail businesses have been forced to shut down requiring purchases to be accomplished on-line. The most successful stores have been able to shift some of their sales to their on-line platforms but this typically required that the on-line platforms existed before the pandemic. One of the industries that suffered the most were restaurants as the revenues from meal deliveries were not sufficient to avoid closing down (Sheth, 2020).

It is expected that many of these newly adopted behaviors, in particular remote working, online shopping and others that will be discussed below, will continue after any fear of a pandemic has receded. More specific long-term impacts of the Covid-19 pandemic cannot be reliably predicted, except that a quick return to the 'old normal' appears to be unlikely (Fenwick, et al., 2020).

7.2 Transport Sector

7.2.1 Public Transport

The Covid-19 pandemic crisis had dire consequences on the transportation and travel industries. The crisis was predominantly felt by the oil industry due to less automobile travel, fewer revenues to public transportation and, especially, an economic crisis for commercial aviation. With the implementation of strict lockdown measures around the world to limit the virus contagion, transportation activities have declined dramatically and resulted in modifications of the current trends in personal mobility patterns and user behaviors (WB, 2020).

One of the biggest impacts of the Covid-19 pandemic has been on passenger transport demand due to closing many businesses, retail outlets and restaurants, restrictions on movements and participation in gatherings and meetings and self-imposed behaviors because of the fear of contracting the virus. As more residents in affected cities isolated themselves in their homes, besides less automobile travel, public transportation experienced decreased demand and consequently, public busses and urban rail services run at less than normal capacity. Public transportation declined by 25% to 50% in most metropolitan areas (WB, 2020).

The desire to maintain social distancing affected public transportation more than private auto travel. People saw public transport as a likely way to contract Covid-19 since it is difficult to avoid close contact with other passengers. One of the longer-term trends that may persist after the pandemic is decreased demand for travel. There may also be a stronger reduction in public transport demand (DeVos, 2020). The longer-term trends may follow the patterns established in 2020. For example, the International Road Union projects that global road transport will be 20% lower by the end of 2020, and the impacts on public transport are expected to be greater (WB, 2020). In a post-pandemic setting, it is conceivable that a portion of the population could avoid public transport with more use of private cars, biking, micro-mobility and even walking (EC, 2020).

7.2.2 Aviation

Aviation has been one of the hardest-hit sectors from the Covid-19 crisis. Along with the suspension of international air travel and closed borders, aviation activity has fallen to very low levels: an 80% global decline in flights right after the stringent Covid-19 pandemic measures were put into place (OECD, 2020). Data from IATA showed an 89% year-on-year plunge in European scheduled flights in April 2020. Scheduled flights in other parts of the world have shown similar declines. At the end of April 2020, scheduled flights dropped by 43% in China and 56% in the United States (OECD, 2020).

The IATA estimation shows that pre-crisis cash reserves owned by airlines could perhaps permit them to stay afloat only an average of two months. Therefore, it is plausible to suggest that unassisted, many airlines could go bankrupt even before travel restrictions are lifted. That is why governments in France, the Netherlands, Scandinavia and the U.S. have already provided loans or alternatively, taken temporary equity stakes in airlines. Spending patterns of consumers in the post-crisis period could continue to weaken demand for air travel for an extended period of time (OECD, 2020).

While the aviation sector paints a bleak picture there was some positive news as freight flights have shown an upward trend. Since increased supplies of medical materials, equipment and pharmaceuticals were required for the pandemic response, as well as other priorities, air freight prospered. For example, pharmaceutical products carried during the lockdown have doubled (OECD & WB, 2020).

Table 7.1, from Gudmundsson *et al*., 2020, shows estimates of how long air travel recovery may take: on average, 2.4 years from mid-2020. Their analysis expects that the demand levels of 2019 will only be reached sometime between 2022 and 2023 in a best-case scenario. Under the worst-case scenario, the demand recovery stretches beyond 2024. Table 7.1 also shows how recovery patterns may vary across Europe, North America, the Asia Pacific and the world. While the projected minimum recovery time for the Asia Pacific is the shortest at 2.2 years, for North America and Europe, it is estimated to be somewhat longer, 2.5 and 2.7 years, respectively. The study anticipates a passenger demand recovery to pre-Covid-19 levels within 4 years both for North America and the Asia Pacific and 6 years for Europe (Table 7.1).

Table 7.1 Estimated Recovery Times (years) for World Passengers and Freight in Air Travel

Estimated Recovery Times (years) for world passengers and freight	**Min**	**Average**	**Max**
Passengers			
Europe	2.0	2.7	6.0
North America	2.0	2.5	4.0
Asia Pacific	2.0	2.2	4.0
World	2.0	2.4	6.0
Freight			
Europe	1.0	2.2	3.0
North America	1.0	2.2	3.0
Asia Pacific	1.0	2.1	3.0
World	1.0	2.2	3.0

The impact of the Covid-19 crisis on aviation is projected to be double the loss caused by the 2008 global financial crisis (April 2020 estimates). The IATA projects that airlines could lose as much as $113 billion passenger revenues at a global level. This has already resulted in layoffs among airlines and airport workers (WB, 2020).

Based on the experiences acquired from previous economic shocks, the disruption caused by the Covid-19 pandemic to the aviation sector will retard progress to a more fuel-efficient aircraft fleet by hampering investment (OECD, 2020). The possibility of being stranded in a foreign country, exposure to diseases when traveling through airports and in airplanes, the inconvenience required by additional airport controls have all focused attention on alternatives to travel. With positive experience and new behaviors using video conferencing, the potential decline for air travel could be more long-lasting than anticipated in the analysis presented in Table 7.1 (EC, 2020).

The Covid-19 pandemic would likely have a disruptive effect both on transport and mobility beyond the duration of the crises. As global economic slowdown takes its toll, demand and supply of transport and mobility services may become more complicated. Personal mobility choices and user patterns could change due to strong risk aversion and self-imposed social distancing. However, it is anticipated that once restriction measures are eased and activity steadily improves, demand for transport and mobility services will likely recover at least to some extent (EC, 2020).

There are many uncertainties in the next few years. While the aviation industry is expected to slowly recover, progress will depend on how quickly international travel restrictions and domestic confinement measures are relaxed. Other uncertainties include the availability and level of protection provided by new vaccines. These can greatly affect the rate of recovery (OECD, 2020). Nonetheless, the rate of recovery will differ across transport modes and depend on the pace of economic recovery. Irrespective of how quickly the Covid-19 threat is over, the ambiguity regarding the possibility of second or even third waves still remain. Most probably it will pave the way for increasing risk aversion towards transport and travel (EC, 2020).

It is yet to be seen how these travel behaviors change will evolve in the near future. Some of the changes in behavior caused by the Covid-19 pandemic may persist after the fear of pandemics has passed and thereby affect transport and mobility in the long-term. A clear picture of the future of transportation will not be available for quite some time. However, we should have a much more reliable set of expectations by the end of 2021 when some of the most important uncertainties may be better understood. Even then, the long-term repercussions of Covid-19 on transport are still likely to be uncertain (EC, 2020).

7.3 Energy Sector

The worldwide shock caused by the Covid-19 pandemic has significantly distorted the course of the global economy and has had a widespread effect on energy investment and energy demand, particularly on oil, transport and the power sector. The Covid-19 pandemic has overturned high 2020 expectations for energy investments and resulted in a record fall off in energy investment with $400 billion less capital spending compared to the year earlier. Under these current circumstances, and given the overcapacity in most energy markets, a precipitous decline in new energy investment is simply a necessary business reality. In addition, government-funded projects are declining since public budgets have been under strong pressure with the need to provide more economic relief and lower tax revenues (IEA, 2020a). At a time when greater innovation is in strong need, the Covid-19 pandemic has caused a setback for innovation progress. In the foreseeable future, innovation capacity to unveil new technologies will be slimmer due to the disruptions caused by the Covid-19 pandemic.

The Covid-19 pandemic has reduced the demand for energy, not only in the transport sector but also in industry and other sectors, with uncertainties about how long economic recovery will take. In the first quarter of 2020 global energy demand dropped by 4%, with most of the impact felt in March and April as strict lockdown measures were enforced across the world. Despite macroeconomic policy efforts accompanied by opening up economic and social activity, forecasts do not indicate that energy demand would resume past trends anytime soon (IEA, 2020b).

Global road transport activity in regions with lockdowns has plunged between 50% and 75%, by the end of quarter one (Q1) of 2020. As a result of global confinement measures, oil demand has come down at an unprecedented scale. Oil demand fell steeply during the lockdown period returning to the 2012 consumption levels, declined by 5% in 1Q 2020 and projected to plummet further reaching a 9% decline by the end of 2020, mostly due to lower road mobility and aviation, which account for 60% of global oil demand. Due to the extremely low short term price elasticity of oil demand (Difiglio, 2014), relatively small imbalances of oil supply and demand cause very large changes in oil prices. These were experienced in the Spring of 2020 and discussed in detail in Chapter 3 (Oil).

As global aviation activity shrunk, jet fuel experienced the largest drop in demand compared to 2019 and fell by 27% in March 2020 alone. Gasoline has been the fuel with the biggest absolute decline in demand. Gasoline is expected to stay under pressure through 2020 with a projected decline of 11%. Following the days after the world's largest cities applied lockdown restrictions, road traffic dropped drastically. In mid-March alone, peak congestion rates measured in metropolitan cities such as in Istanbul, Paris, Rio de Janeiro, Los Angeles, New York, Mexico City, Mumbai, Sao Paulo, and Toronto went down as much as 50% to 60%. The decline in gasoline demand could be even greater except for the unwillingness to use public transport. Diesel demand has also tumbled due to lower economic activity and containment measures for both rail and bus transport. Diesel demand is expected to decline by 7% overall for 2020 but not the same extent as in gasoline or jet fuel because trucks have continued to transport manufactured goods (IEA, 2020b). The oil outlook is inextricably linked to, first and foremost, to the duration of the Covid-19 outbreak and the timing of the economic recovery. Only through a strong rebound of the economy along with effective and widely available vaccines would it be likely that 2021 oil demand could begin to resume normal levels.

Global electricity demand declined significantly as full lockdown measures pushed down demand for power. During the period of full lockdown, electricity demand declined 20% on average but demand for 2020 is only anticipated to decline by 5%. The increase in residential demand, which was recorded 40% higher across Europe compared to a year earlier, was outweighed by reduced demand in the commercial and industrial sectors due to the pandemic.

Renewable electricity has been largely unaffected during the period when strict lockdown measures are being taken. Driven mainly by higher installed capacity and priority dispatch (due to its near-zero marginal cost), renewable energy has so far been the energy source most resistant and the only source that experienced growth during the period of the pandemic. The supply of renewables is anticipated to remain strong due to low marginal costs and preferential access for the remainder of 2020 and going into 2021. In the first quarter of 2020, the global use of renewable energy in all sectors rose by 1.5% compared to the first quarter of 2019. It is estimated that the total global use of renewable energy will rise by 1% by the end of 2020 (IEA, 2020b).

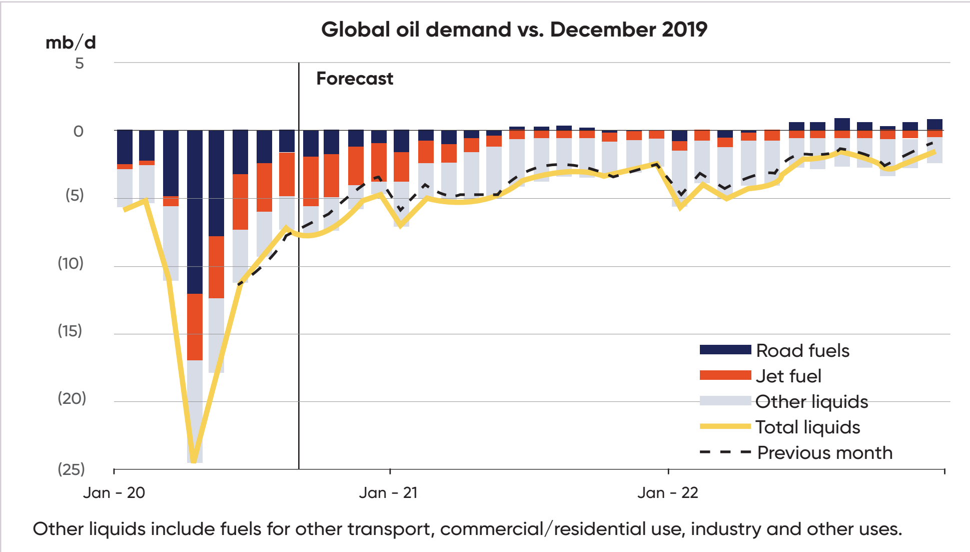
7.4 Long Term Impact of Covid-19: Uncertainties

The Covid-19 pandemic has dramatically changed people's daily lives and created uncertainties about how or when things might return to how they had been or whether they ever would. Anyone paying attention to the media has heard or read a wide variety of opinions. Various economists talk about "U" shaped, "V" shaped and "K" shaped economic recoveries, each with cogent arguments about why their favored "shape" will govern economic development. There are even a wider variety of opinions about how Covid-19 will change consumer behaviors or even more fundamental values. Many of the speculations defy normal methods of making projections based on past trends and understanding the relationships between causal variables and outcomes. It is especially difficult to speculate on what the longer-term impacts will be from a pandemic that has not yet ended. Much will depend on whether and when an effective vaccine will be distributed, how effective it is, how many people agree to take it, and whether the virus will then encounter too many immune people to spread further. In addition, we do not know whether Covid-19 mutations would render the vaccine to be ineffective after the first season it is used. If a new coronavirus strain emerged making previously infected and vaccinated people vulnerable, we could more or less be back to where we started in March 2020.

For the purposes of this energy report, we assume that medical progress is made to defeat the Covid-19 or related pandemics and that future pandemics do not again jolt the economies. Therefore, we restrict ourselves to considering behavioral changes that are continued because they are preferred. We make no claims that these medical assumptions are justifiable. They come to us out of necessity as IICEC does not have the expertise to consider scenarios that include continuing pandemics.

The full impact of the Covid-19 pandemic, as yet ambiguous, will be determined by the recovery pathways achieved around the world. The unprecedented challenges caused by the pandemic and the governments' responses to them are likely to affect the energy sector for years to come, with significant results for energy demand and investments. The energy sector that emerges from the Covid-19 crisis may perhaps appear considerably different from what has been before. Or it might not. If we turn to a recent study by the Oxford Institute of Energy Studies (OIES, 2020), we see a projection showing a fairly rapid return of transportation fuels, and associated transportation activity, to normal.

Figure 7.3 Recovery of Global Oil Demand with a Focus on Road Fuels and Aviation (OIES, 2020)



Source: OIES, 2020

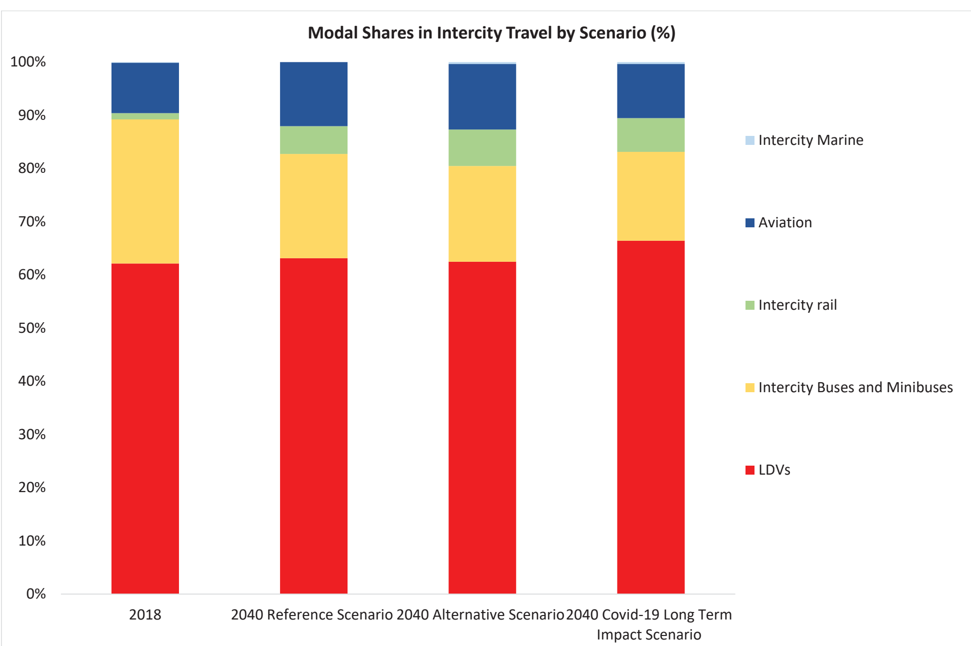
As shown in Figure 7.3, this projection shows a rapid return to pre-Covid-19 road and aviation fuel demand levels in 2021 with only modest growth in road fuel though 2022. While jet fuel demand returns close to its former level through this period, its growth appears stalled. The slower recovery of the “other fuels” category is notable as these fuels are used outside the transport sector. Their slow recovery reflects stalled economic growth in industry and construction activity and might also reflect trends away from petroleum fuels to electricity, natural gas and renewables in these sectors similar to trends shown in IICEC’s TEO Scenarios for Turkey. Nonetheless, it is interesting to note that transport fuels for highway and commercial aviation have made a more rapid recovery, at least according to this one study.

We cite these global projections partly because they are consistent with the slowdown of transport activity projected in the TEO Reference and Alternative Scenarios for Turkey compared to the IICEC projections that were prepared prior to the Covid-19 pandemic. As mentioned in previous chapters, our Scenarios are a “return-to-normal” projection during which 1-3 years of growth rates in pre-2020 levels have been lost, similar to what might have occurred after other severe economic downturns. However, it is possible that the Covid-19 downturn and recovery could be different and cause long-lasting changes to the global energy economy. If so, they are most likely to show up in the transport sector. The shifts to home-office and use of virtual meetings instead of physical meetings may live on as preferred ways of conducting business. Consequently, the oil industry, along with the airlines, which have been among the most adversely affected businesses, may see a slower recovery than others and have a lower trajectory of growth than before.

7.5 Turkey Energy Outlook Covid-19 Transportation and Oil Scenario

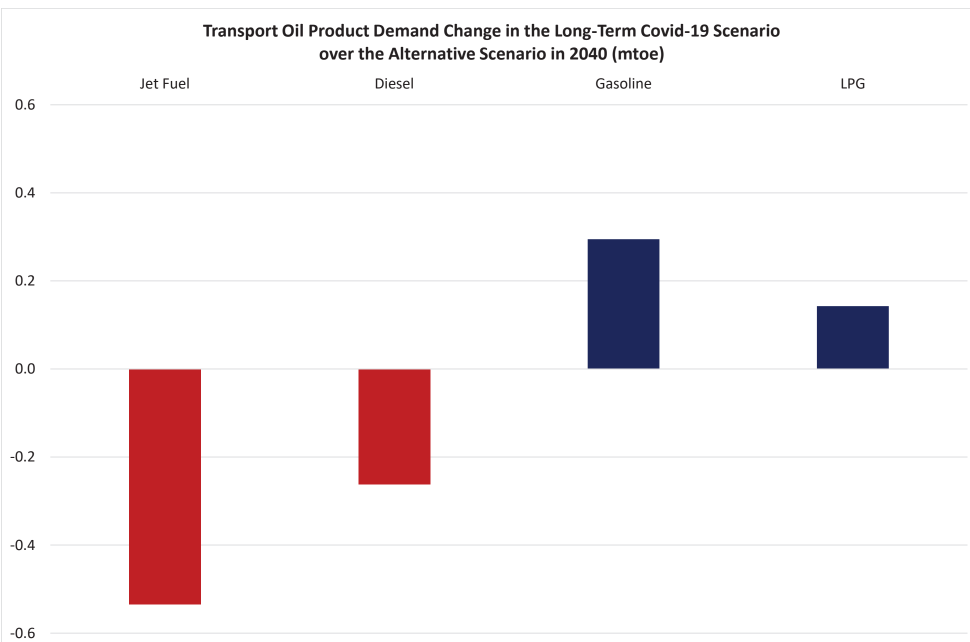
Turkish travel is anticipated to grow, as discussed in Chapter 2 (Transport). The Covid-19 related consequences elaborated above could also have longer-term implications on Turkey's travel patterns. IICEC's assessment suggests that a decline in air travel may be one of the more likely consequences of behaviors adopted during the Covid-19 pandemic but continued afterwards because they proved to be advantageous. These behavioral changes could affect other high-occupancy modes of intercity travel although they are not expected to affect private automobile travel to any significant degree. IICEC's assessment is that business travel would mostly be affected by the experience gained during the Covid-19 pandemic when the effectiveness. efficiency and reduced cost of virtual meetings were well demonstrated. However, these considerations would not deter family or vacation travel where the automobile is the preferred mode of transport. Another possible long-term impact involves a partial continuation of home office. While it is not expected that companies will abandon their offices for a virtual workforce, it is likely that management will be more accommodating of worker flexibility in using home office more often than has been the case in the past. Again, this would be reinforced by the often-positive experience many companies had with it during the pandemic. Increased home office would be more likely to affect the use of public transportation than private auto use especially since some of the time saved in commuting is likely to be spent traveling to other destinations that may be better served by automobile during time periods that are less congested.

Figure 7.4 Modal Shares in Intercity Travel by Scenario (%)



The TEO transport model was used to estimate plausible long-term changes in transportation patterns as a result of Covid-19. It is anticipated that inter-city travel could decline by 2-3% compared to the TEO Alternative Scenario through 2040 as tele-working becomes more prevalent as a result of the Covid-19 experience. With fewer business meetings, aviation's share of intercity travel could drop to 10% from 12% in both scenarios (2040). Rail passenger travel and intercity buses would also see a decline in their shares. Passenger cars, in contrast, would increase their share to over two-thirds compared to 62% in the Alternative Scenario by 2040 (Figure 7.4). These anticipated changes in passenger travel would also affect TEO fuel projections. Compared to the Alternative Scenario, total diesel demand is 0.3 mtoe lower but it represents a marginal decrease (1.3%). Gasoline demand increases by 0.3 mtoe (or 5.1%) and LPG consumption increases by 0.1 mtoe. Increasing electricity demand from electric vehicles is offset by reductions in intercity rail activity. Overall, total oil products demand by 2040 is not greatly affected: only by 0.4 mtoe, or 1%, less than the projected demand in the Alternative Scenario (Figure 7.5).

Figure 7.5 Transport Oil Product Demand Change in the Long-Term Covid-19 Scenario compared to the Alternative Scenario in 2040 (mtoe)



A modest decrease in rush hour commuting demand due to more home office could benefit public transportation by reducing somewhat the surge of travel demand during particular times of the day. While this would decrease revenues, with innovative urban transportation planning and investments, public transportation has the potential to offer more attractive and convenient multi-mode options that complement new urban designs such as pedestrian zones and green spaces.

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ANNEXES

- **ANNEX A.** Key Policy Documents and Data Sources
- **ANNEX B.** Key Macro Assumptions
- **ANNEX C.** Scenario Results Summary
- **ANNEX D.** Units
- **ANNEX E.** Conversion Factors
- **ANNEX F.** Definitions
- **ANNEX G.** Abbreviations and Acronyms

ANNEX A.

Key Policy Documents and Data Sources

- Presidency 11th Five Year Development Plan (2019-2023)
- New Economic Program (2021-2023)
- Strategic Plan of the Ministry of Energy and Natural Resources
- Ministry of Energy and Natural Resources Energy Balance Tables
- EMRA Monthly and Annual Sector Reports
- EPİAŞ Transparency Platform and reports
- Turkish Statistical Institute
- The Central Bank of the Republic of Turkey
- Strategic Plan of the Ministry of Transport and Infrastructure
- Strategic Plan of the Ministry of Industry and Technology
- Strategic Plan of the Ministry of Environment and Urbanization
- IEA data for Turkey and other regions and countries
- OECD statistics
- Emissions Inventory to the UNFCCC
- Sector Reports and statistics from the Ministries and other public institutions
- Sectoral NGOs' reports
- IICEC's modeling database and market intelligence

ANNEX B.

Key Macro Assumptions

	Population Forecast*	Real GDP Growth Forecast**
2018	81.9	2.6%
2019	83.2	0.9%
2020	83.9	0.3%
2021	84.9	5.8%
2022	85.9	5.0%
2023	86.9	5.0%
2024	87.9	4.2%
2025	88.8	3.9%
2026	89.8	3.7%
2027	90.7	3.6%
2028	91.6	3.4%
2029	92.5	3.3%
2030	93.3	3.3%
2031	94.2	3.2%
2032	95.0	3.1%
2033	95.7	3.0%
2034	96.5	3.0%
2035	97.2	2.9%
2036	97.9	2.9%
2037	98.5	2.9%
2038	99.2	2.9%
2039	99.8	2.9%
2040	100.3	2.9%

*Turkstat

**New Economy Program (2021-2023) and OECD

ANNEX C.

Scenario Results Summary

Total Final Energy Supply Summary

Total Final Energy Supply										
mtoe			Reference Scenario				Alternative Scenario			
	2000	**2018**	**2025**	**2030**	**2035**	**2040**	**2025**	**2030**	**2035**	**2040**
Natural Gas	12.5	41.2	28.1	30.1	33.8	36.8	28.5	31.2	35.2	38.1
Oil	33.6	41.9	46.5	50.8	54.7	56.0	44.5	47.3	48.7	46.6
Coal	23.0	40.8	48.8	52.5	50.0	50.9	45.9	41.8	34.6	25.7
Renewable	10.3	19.7	29.8	38.9	50.4	60.8	31.4	41.7	54.7	64.8
Nuclear	0.0	0.0	2.3	4.7	9.3	16.3	2.3	7.0	14.0	21.0
Total	**79.4**	**143.6**	**155.6**	**177.0**	**198.1**	**220.8**	**152.7**	**168.9**	**187.3**	**196.2**

Total Final Energy Demand Summary

Total Final Consumption by Fuel										
mtoe			Reference Scenario				Alternative Scenario			
	2000	**2018**	**2025**	**2030**	**2035**	**2040**	**2025**	**2030**	**2035**	**2040**
Electricity	8.3	22.1	26.0	31.2	36.6	42.3	25.7	30.0	33.9	37.2
Natural Gas	4.3	23.6	28.1	30.1	33.8	36.8	28.5	31.2	35.2	38.1
Oil	23.5	35.6	39.4	43.0	46.3	47.5	37.7	40.1	41.3	39.5
Coal	12.5	13.4	13.4	13.1	12.6	12.3	11.0	8.5	6.3	3.9
Renewables	8.9	7.8	8.5	10.1	12.0	15.6	8.8	10.6	12.7	16.7
Total	**57.5**	**102.5**	**115.4**	**127.5**	**141.3**	**154.6**	**111.8**	**120.4**	**129.4**	**135.4**

Total Final Consumption by Sector										
mtoe			Reference Scenario				Alternative Scenario			
	2000	**2018**	**2025**	**2030**	**2035**	**2040**	**2025**	**2030**	**2035**	**2040**
Industry	22.9	36.2	39.6	43.1	47.7	53.5	37.7	39.6	42.7	46.0
Buildings	19.6	33.4	39.0	43.4	48.3	53.7	38.2	41.8	45.3	48.4
Transport	12.0	28.4	31.9	35.6	39.2	41.0	31.0	34.0	36.0	35.5
Agriculture	3.1	4.6	5.0	5.5	6.1	6.3	4.8	5.0	5.4	5.5
Total	**57.5**	**102.5**	**115.4**	**127.5**	**141.3**	**154.6**	**111.8**	**120.4**	**129.4**	**135.4**

Total Final Consumption by Sector and Fuel

Industry										
mtoe			Reference Scenario				Alternative Scenario			
	2000	**2018**	**2025**	**2030**	**2035**	**2040**	**2025**	**2030**	**2035**	**2040**
Power	4.0	10.0	11.5	13.5	15.5	17.4	11.4	13.1	14.6	15.4
Natural Gas	1.6	9.4	10.8	11.7	14.0	15.8	11.0	12.2	14.7	16.2
Oil	5.1	3.8	4.1	4.3	4.4	4.5	3.8	3.8	3.6	3.3
Coal	10.6	9.5	9.5	9.4	9.0	8.8	7.8	5.9	4.4	3.3
Renewables	1.6	3.5	3.7	4.2	4.8	7.0	3.8	4.6	5.5	7.9
Total	**22.9**	**36.2**	**39.6**	**43.1**	**47.7**	**53.5**	**37.7**	**39.6**	**42.7**	**46.0**

Buildings*										
mtoe			Reference Scenario				Alternative Scenario			
	2000	**2018**	**2025**	**2030**	**2035**	**2040**	**2025**	**2030**	**2035**	**2040**
Power	3.9	11.3	13.6	16.6	19.8	23.3	13.3	15.6	17.7	19.7
Natural Gas	2.7	13.7	16.6	17.6	18.7	19.8	16.8	18.1	19.5	20.7
Oil	3.7	1.0	1.1	1.1	1.0	0.9	1.1	1.0	0.9	0.7
Coal	2.0	3.9	3.9	3.7	3.6	3.5	3.2	2.6	1.9	0.6
Renewables	7.3	3.5	3.8	4.4	5.2	6.3	3.9	4.5	5.3	6.7
Total	**19.6**	**33.4**	**39.0**	**43.4**	**48.3**	**53.7**	**38.2**	**41.8**	**45.3**	**48.4**

* including other services

Transport*										
mtoe			Reference Scenario				Alternative Scenario			
	2000	**2018**	**2025**	**2030**	**2035**	**2040**	**2025**	**2030**	**2035**	**2040**
Power	0.1	0.1	0.2	0.3	0.5	0.9	0.3	0.5	0.8	1.4
Natural Gas	0	0.1	0.1	0.2	0.3	0.5	0.2	0.3	0.5	0.7
Oil	11.9	27.8	31.0	34.6	37.7	39.0	30.0	32.7	34.2	32.9
Coal	0	0	0	0	0	0	0	0	0	0
Renewables	0	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Total	**12.0**	**28.2**	**31.6**	**35.1**	**38.8**	**40.6**	**30.7**	**33.7**	**35.7**	**35.2**

*excluding pipelines

Agriculture*										
mtoe			**Reference Scenario**				**Alternative Scenario**			
	2000	**2018**	**2025**	**2030**	**2035**	**2040**	**2025**	**2030**	**2035**	**2040**
Power	0.3	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Natural Gas	0.0	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Oil	2.8	3.0	3.2	3.1	3.2	3.1	2.8	2.6	2.6	2.5
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renewables	0.0	0.6	0.8	1.3	1.8	2.1	0.9	1.3	1.7	2.0
Total	**3.1**	**4.6**	**5.0**	**5.5**	**6.1**	**6.3**	**4.8**	**5.0**	**5.4**	**5.5**

* including farming and fisheries

Total Final Consumption*										
mtoe			**Reference Scenario**				**Alternative Scenario**			
	2000	**2018**	**2025**	**2030**	**2035**	**2040**	**2025**	**2030**	**2035**	**2040**
Total	**57.5**	**102.5**	**115.4**	**127.5**	**141.3**	**154.6**	**111.8**	**120.4**	**129.4**	**135.5**

Power Sector

Installed Capacity									
GW		Reference Scenario				Alternative Scenario			
	2019	**2025**	**2030**	**2035**	**2040**	**2025**	**2030**	**2035**	**2040**
Coal	20.3	22.6	26.6	27.4	26.6	22.3	23.4	21.4	17.4
Natural Gas	25.9	27.4	29.7	32.8	37.3	25.9	25.6	25.0	27.4
Liquid Fuels	0.4	0.2	0.0	0.0	0.0	0.2	0	0	0
Hydro	28.5	33.7	34.7	35.8	37.0	34.3	35.1	36.4	37.7
Nuclear	0.0	1.2	2.4	4.8	8.4	1.2	3.6	7.2	10.8
Wind	7.5	12.8	16.5	23.6	30.4	13.8	18.1	25.0	31.6
Solar	6.0	11.1	19.3	28.1	36.7	12.3	21.6	31.8	39.6
Geothermal	1.5	3.2	4.1	4.3	4.1	3.3	4.2	4.5	4.8
Biomass and Waste Heat	1.1	1.5	1.8	2.3	3.0	1.5	1.8	2.4	3.2
Total	**91.4**	**113.7**	**135.0**	**159.0**	**183.4**	**114.9**	**133.5**	**153.7**	**172.5**

Gross Power Generation									
TWh		Reference Scenario				Alternative Scenario			
	2019	**2025**	**2030**	**2035**	**2040**	**2025**	**2030**	**2035**	**2040**
Coal	113.0	139.5	161.1	160.7	166.1	137.4	138.7	121.9	94.0
Natural Gas	55.1	52.6	58.8	67.1	75.8	41.9	36.3	25.3	30.4
Liquid Fuels	0.9	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Hydro	88.6	73.8	69.9	72.1	68.1	75.1	70.7	73.3	69.4
Nuclear	0.0	8.9	17.9	35.7	62.5	8.9	26.8	53.6	80.4
Wind	21.4	38.0	50.5	72.2	93.2	41.1	55.5	78.7	99.7
Solar	9.6	19.4	33.8	51.7	67.5	21.6	37.9	58.4	74.7
Geothermal	8.2	18.4	24.3	25.6	24.4	18.9	25.0	26.9	28.3
Biomass and Waste Heat	4.0	6.6	7.7	9.9	13.0	6.7	7.8	10.6	14.2
Total	**300.8**	**357.5**	**423.9**	**495.1**	**570.6**	**351.9**	**398.7**	**448.7**	**491.0**

Net Electricity Demand									
TWh		Reference Scenario				Alternative Scenario			
	2019	**2025**	**2030**	**2035**	**2040**	**2025**	**2030**	**2035**	**2040**
Total	**258.2**	**303.4**	**363.7**	**426.5**	**493.8**	**300.4**	**350.0**	**395.4**	**434.4**

GHG Emissions from the Energy Sector

from the Major Energy Consuming Sectors					
million tons of CO_2-eq		Reference Scenario		Alternative Scenario	
	2018	**2030**	**2040**	**2030**	**2040**
Power	150.1	187.6	201.0	155.5	110.6
Transport	84.5	105.3	119.8	99.6	101.4
Industry	59.6	65.4	71.9	51.9	50.0
Buildings and Services	52.4	60.3	63.9	56.3	53.0
Agriculture	10.5	11.2	11.2	9.6	9.0
Other*	12.2	10.4	9.4	9.8	8.3
Total	**369.3**	**440.1**	**477.2**	**382.6**	**332.3**

*Other includes sectors such as refining, manufacturing of solid fuels and waste incineration from energy recovery

ANNEX D.

Units

Area

ha	hectare
km^2	Square Kilometer

Energy

ktoe	Thousand Tons of Oil Equivalent
mtoe	Million Tons of Oil Equivalent
MMBtu	Million British Thermal Units
kcal	Kilocalorie (1 Calorie x 10^3)
MJ	Mega Joule (1 Joule x 10^6)
GJ	Gigajoule (1 Joule x 10^9)
kWh	Kilowatt-hour
MWh	Megawatt-hour
GWh	Gigawatt-hour
TWh	Terawatt-hour

Power

kW	Kilowatt (1 watt x 10^3)
MW	Megawatt (1 watt x 10^6)
GW	Gigawatt (1 watt x 10^9)

Mass, Volume and Flow

mcm	Million Cubic Meters
mcm/d	Million Cubic Meters per day
bcm	Billion Cubic Meters
bcm/yr.	Billion Cubic Meters per year
tcm	Trillion Cubic Meters
Sm^3	Standard Cubic Meters
b/d	Barrels Per Day

kb/d	Thousand Barrels Per Day
mb/d	Million Barrels Per Day
kT	Kilo tons (1 Ton x 10^3)
MT	Million tons (1 Ton x 10^6)
GT	Giga tons (1 Ton x 10^9)

Emissions

ppm	Parts per Million (by volume)
g CO_2/kWh	Grams of Carbon Dioxide per kilowatt-hour of electricity
g CO_2/Pkm	Grams of Carbon Dioxide per passenger-km in transport
g CO_2/Tkm	Grams of Carbon Dioxide per ton-km in transport
t CO_2-eq	Tons of Carbon Dioxide Equivalent
t CO_2-eq/toe	Tons of Carbon Dioxide Equivalent Emission per tons of Oil Equivalent Energy

Other

Pkm	Passenger-Kilometers
RPK	Revenue Passenger Kilometers
Tkm	Ton-Kilometers
MPkm	Million Passenger-Kilometers
MTkm	Million Ton-Kilometers
toe/Pkm	Tons of Oil Equivalent Energy per Passenger-Kilometers
toe/Tkm	Tons of Oil Equivalent Energy per Ton-Kilometers

ANNEX E.

Conversion Factors

General Conversion Factors for Energy

Convert to:	**TJ**	**Gcal**	**mtoe**	**MBtu**	**GWh**
From:	*multiply by:*				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
mtoe	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11 630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3 412	1

ANNEX F.

Definitions

Agriculture: Includes all energy used on farms, in forestry and for fishing.

Biodiesel: A processed fuel made from the transesterification (a chemical process that converts triglycerides in oils) of vegetable oils and animal fats that can be blended into conventional diesel fuel. The permissible percentage of blending depends partly on how the biodiesel fuel is produced as well as other factors.

Bioenergy: The energy content in solid, liquid and gaseous products derived from biomass feedstocks and biogas. It includes solid biomass, biofuels and biogas.

Biofuels: Liquid fuels that are derived from biomass or waste feedstocks and include ethanol and biodiesel. They can be classified as conventional and advanced biofuels according to the technologies used to produce them and other features such as whether they are produced from food crops, cellulose or some other biomaterial. Unless otherwise stated, biofuels are expressed in energy-equivalent volumes of gasoline and diesel.

Biogas: A mixture of methane, CO_2 and small quantities of other gases produced by anaerobic digestion of organic matter in an oxygen-free environment.

Buildings: The buildings sector includes energy used in residential, commercial and institutional buildings, and non-specified other. Building energy use includes space heating and cooling, water heating, lighting, appliances and cooking equipment.

Carbon Capture and Storage: A process that captures up to 90% of the carbon dioxide emissions from combusting fossil fuels for electricity generation, pressurizing them, transporting them and injecting them into deep saline aquifers or other geological formations below the Earth's cap rock. Carbon Capture Utilization and Storage refers to the opportunity to use captured CO_2 emissions for various industrial or commercial purposes. Carbon capture and storage can also be applied to a variety of chemical processes, for example, those that use steam reforming and the water shift reaction to make syngas and then covert the syngas into CO_2 and H_2,

Coal: Includes both primary coal (including lignite, coking and steam coal) and derived fuels (including patent fuel, brown-coal briquettes, coke-oven coke, gas coke, gas-works gas, coke-oven gas, blast-furnace gas and oxygen steel furnace gas). Peat is also included.

Coal bed methane: A category of unconventional natural gas, which refers to methane found in coal seams.

Coal-to-gas: A process in which mined coal is first turned into syngas (a mixture of hydrogen and carbon monoxide) and then into "synthetic" methane.

Continuous Trade: The trading method in which the offers that comply in terms of price and amount are immediately matched.

Continuous Trading Platform: Transactions on the Platform are performed by a continuous trading technique. The weighted average of the purchase and sale matches formed by the bids of the market participants constitute the Daily Reference Price.

Coking coal: A type of coal that can be used for steel making (as a chemical reductant and source heat), where it produces coke capable of supporting a blast furnace charge. Coal of this quality is also commonly known as metallurgical coal.

Daily Reference Price: The natural gas price accounting for finalized bilateral settlements and delivery dates.

Direct Air Capture: Capturing CO_2 directly from the atmosphere. Some commentators believe that direct air capture may be necessary to avoid unacceptable increases in atmospheric greenhouse gases (see Chapter 6).

Demand side management: Often referred to DSM, it is a suite of programs and policies to adjust power demand to accommodate limitations in power supply (for example, when power demand is unusually high, power dispatch is constrained or both). DSM programs typically monitor consumption levels, time profiles of consumption, contractual conditions about supply, grid-related constraints, and market conditions.

Dispatchable: Dispatchable generation refers to technologies whose power output can be readily controlled (increased to maximum rated capacity or decreased to zero) in order to match supply with demand.

Electricity generation: Defined as the total amount of electricity generated by power only or combined heat and power plants including generation required for own-use. This is also referred to as gross generation.

Energy Service Companies: The companies that deliver energy efficiency projects that are financed based on energy savings.

Energy sector CO_2 emissions: CO_2 emissions from fuel combustion (excluding non-renewable waste).

Energy sector GHG emissions: CO_2 emissions from fuel combustion plus fugitive and vented methane and N_2O emissions from energy production and use.

Enhanced Oil Recovery: A suite of techniques to improve the recovery ratio from oil and natural gas wells. They are typically used to reverse or slow production declines in maturing fields.

Ethanol: C_2H_5OH. Used for a variety of purposes including being the active ingredient for intoxicating beverages. It can be produced in a variety of ways although it has, over the millennia, been produced by fermenting various grains and other food stuffs. It can also be produced from hydrocarbons such as petroleum. For this book, ethanol only refers to 100 % fuel ethanol. This must be produced from biological substances. Most fuel ethanol is produced from starches and sugars, but "second-generation technologies" have been under development for several decades to produce ethanol from cellulose and hemicellulose, the fibrous material that makes up the bulk of most plant matter. Commercial production of "second generation" ethanol at scale has not yet been achieved.

Flexibility: The ability of a power system to respond to changes in electricity demand and supply.

Heat (supply): Heat is obtained from the combustion of hydrocarbons, cogeneration, geothermal resources, sunlight and from electricity (that also can be produced from various energy sources. Commercial heat sold is reported in the TEO under total final **consumption with the fuel inputs allocated under power generation.**

Heat (end-use): Applications include space and water heating, cooking, desalination and many industrial processes.

Heat Pump: A device that pulls the energy out of air for the purpose of either heating or cooling a space. Heat pumps are, in effect, air conditioners that can operate in reverse.

Hydrogen: H_2. Disregarding its enormous role in almost all physical processes, hydrogen is the reason hydrocarbons produce energy when combusted (oxidized). However, free H_2 does not exist (as it is highly reactive or can escape from the Earth's atmosphere despite its abundance in the universe). Consequently, it requires energy to produce usually by reforming hydrocarbons, but it can be produced by separating H_2 from water (H_2O). Consequently, H_2 is an energy carrier, like electricity. If produced without combusting hydrocarbons, it can be used to reduce CO_2 emission and may be used for energy services that are not easily provided by electricity.

Green Hydrogen: Hydrogen produced from renewable energy typically using electrolysis.

Blue hydrogen: Hydrogen produced from reforming fossil fuels with carbon capture and storage of the CO_2. Unlike the typical technology that would be used to capture CO_2 from a coal power plant, a high-pressure CO_2 stream already exists in the fossil fuel reforming process causing the application of carbon capture to have only a slight cost impact on producing H_2 from fossil fuels (see Chapter 6 and the potential importance of blue hydrogen for Turkey).

Hydrogen fuel-celled vehicles: Referred to as HFCVs, these vehicles store hydrogen onboard the vehicle and use a fuel cell to convert the hydrogen to electricity that powers the vehicle's electric motor. It is similar to a battery electric vehicle (BEV) except that instead of storing electricity in a battery, it stores hydrogen that is converted to electricity onboard the vehicle. HFCVs can be an important complement to BEVs in fulfilling a variety of road transport needs, particularly freight travel where BEVs are technically challenged (see Chapters 2 and 6).

Hydropower: The energy content of the electricity produced in hydropower plants, assuming 100% efficiency. It excludes output from pumped storage and marine (tide and wave) plants.

Industry: The industry sector includes fuel used within the manufacturing and construction industries. Energy used to transform one form of energy into another (such as the production of motor fuels) is excluded.

Intermittent Electricity: Electrical energy that is not continuously available due to external factors that cannot be controlled. Sources of intermittent electricity include solar power, wind power, tidal power and wave power.

Investment: All investment data and projections reflect spending across the lifecycle of a project, i.e. the capital spent is assigned to the year when it is incurred. Investments for oil, gas and coal include production, transformation and transportation; those for the power sector include refurbishments, uprates, new builds and replacements for all fuels and technologies for on-grid, mini-grid and off-grid generation, as well as investment in transmission and distribution, and energy storage.

Levelized Cost of Electricity: Or LCOE, LCOE is a method to compare the costs of different types of power generating technologies on a comparable basis taking account of capital cost differences, fuel cost differences, operating cost differences and expected plant life. LCOE is an estimate of the average revenue per unit of electricity generation that can be compared among different generating technologies taking account of local circumstances such as capital costs, fuel costs and other factors.

Lignite: A type of coal that is mainly used in the power sector mostly in regions near lignite mines due to its low energy content and typically high moisture levels, which generally makes long-distance transport uneconomic. Lignite also includes peat, a solid formed from the partial decomposition of dead vegetation under conditions of high humidity and limited air access.

Liquids: Refers to the combined energy-equivalent volumes of petroleum, petroleum products and biofuels.

Middle distillates: Includes jet fuel, diesel and heating oil. They are called "middle distillates" because they are heavier products than, for example, gasoline and other, even lighter, petroleum products. One characteristic of being heavier is that they do not evaporate as readily because middle distillates have fewer volatile compounds.

Modern energy access: Refers to households having access to a minimum level of electricity services. Modern energy access makes households less dependent on traditional forms of energy supplies that are typically more polluting but can also require people, especially women, to spend time gathering traditional fuels such as wood and peat. Lack of access to modern energy services is called as energy poverty.

Modular Nuclear Reactors: Referred to as SMRs, they are much smaller than conventional nuclear reactors, with designs ranging from 50 MWe capacity to 300MWe (compare to 1,200 MWe for a typical conventional reactor). They would be manufactured in factories and delivered to reactor sites as opposed the current practice of having a time-consuming and financially risky on-site reactor build. Most designs under development have improved safety features not possible in larger reactors, such as convection cooling or other features. While still being developed and licensed, SMRs may provide power sector authorities a less risky, more cost effective and more scalable nuclear power plant than conventional reactors.

Natural gas: Gases mostly derived from geological sources that have a minimum percentage content of CH_4 (methane). Natural gas is available from wells that mainly produce natural gas ("non-associated" gas) or wells that are producing both natural gas and petroleum (associated gas). Methane can also be extracted from coal mines or from the decomposition of biological material, for example, municipal waste. TEO data does not reflect any vented or flared gas. TEO gas data in cubic meters are expressed on a "gross" calorific value basis (9155 kcal/m3) and are measured at 15 °C and at 760 mm Hg ("Standard Conditions"). Gas data expressed in tons of oil equivalent, mainly for comparison reasons with other fuels, are on a "net" calorific basis. The difference between the net and the gross calorific value is the latent heat of vaporization of the water vapor produced during combustion of the fuel (for gas the net calorific value is 10% lower than the gross calorific value).

Network Operating Principles (ŞİD): ŞİD lays down the general and detailed rules and principles governing the rights and obligations of the transporter and shippers regarding the transmission service, including system entry, capacity allocation, system balancing, metering and the conditions and characteristics of the use of transmission system. Access to the grid is governed by the Network Code.

Non-energy use: Mostly petroleum products used for chemical feedstocks and non-energy products. Examples of non-energy products include lubricants, paraffin waxes, asphalt, bitumen, coal tars and oils as timber preservatives.

Offshore wind: Refers to electricity produced by wind turbines that are installed in open water.

Oil: Oil is a heavy complex hydrocarbon that can be refined to produce a variety of fuels and other products. Petroleum fuels and other products include refinery gas, ethane, liquid petroleum gas, aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha, white spirit, lubricants, bitumen, paraffin, waxes, and petroleum coke. Oil is recovered from geological reservoirs. However, more recently, the largest increases in world oil supplies have come from "tight oil." (see definition below).

Organized Natural Gas Wholesale Market (OTSP): The purpose of the OSTP is to ensure the pricing of natural gas in the market under objective and transparent conditions. The principles and procedures set for the organized natural gas wholesale market allow market participants to trade and/or eliminate imbalances in the transmission system

Other energy sectors: Covers the use of energy by transformation industries and the energy losses in converting primary energy into a form that can be used in the final consuming sectors. It includes losses by gas works, petroleum refineries, blast furnaces, coke ovens, coal and gas transformation and liquefaction. It also includes energy used in coal mines, in oil and gas extraction, and in electricity and heat production. Transfers and statistical differences are also included in this category.

Power generation: Refers to the production of electricity from a variety of electrical generation technologies.

Power purchase agreements: It is a contract between two parties, one is the electricity generator and the other is the buyer.

Renewables: Includes bioenergy, geothermal, hydropower, solar photovoltaic (PV), concentrating solar power, wind and marine (tide and wave) energy for electricity and heat generation.

Refinery Product Slate: Refineries are typically configured to use particular grades of crude oil to produce the desired variety of petroleum products (product slate). There are relationships among the types of crude petroleum that are used for the refinery feedstock and the refinery units. These include its coking capacity (this refers to the ability to break down heavy hydrocarbons in the heavier grades of oil so higher-valued lighter products can be produced such as middle distillates and gasoline); its hydrogenation capacity (important for using higher sulfur crude grades - sour crude - and still make environmentally compliant products); and many other refinery units. Taken together, particular refineries can use their chosen feedstock supplies to make a range of products and can change the "slate" by making more products that happen to be commanding a higher price than when they are commanding a lower price. However, depending on the complexity of the refinery, there are limits to how much refineries can vary the slate of products they produce and, given relatively stable product prices, a refinery slate is simply the percentage of each and all petroleum products that a particular refinery is likely to produce.

Renewable Energy Resource Areas (YEKA): YEKA auctions resemble a market-based "auction" policy mechanism that is being increasingly implemented worldwide. YEKA auction model is preceded and complemented by a portfolio of other policy mechanisms to accelerate renewable energy investments. These policy mechanisms are the feed-in tariff mechanism and the pre-license auction model. YEKA model provides a Power Purchase Agreement and requires a certain amount of localization in the manufacturing of technologies.

Renewable Energy Resources Support Mechanism (YEKDEM): It is a feed-in tariff based support mechanism for electricity generators from renewable energy resources.

Residential: Energy used by households including space heating and cooling, water heating, lighting, appliances, electronic devices and cooking equipment.

Services: Energy used in commercial activity (e.g. hotels, offices, catering, shops) and institutional buildings (e.g. schools, hospitals, offices). Services energy use includes space heating and cooling, water heating, lighting, equipment, appliances and cooking equipment.

Shale gas: Is natural gas produced by hydraulic fracturing. Within the last three decades, technological progress enabled the economic recovery of natural gas from tight formations (where there is no open reservoir of gas but only gas permeating shales or other minerals). Horizontal drilling and hydraulic fracturing are used to bring the gas to the surface.

Steam coal: Type of coal that is mainly used for heat production or steam-raising in power plants and, to a lesser extent, in industry. Typically, steam coal is not of sufficient quality for steel making. Coal of this quality is also commonly known as thermal coal.

Tight oil: Within the last two decades, technological progress has enabled the economic recovery of oil from tight formations (where there is no open reservoir of liquid but only oil permeating shales or other minerals). Horizontal drilling and hydraulic fracturing are used to bring the oil to the surface.

Total final consumption: Total final consumption is the sum of consumption by the various end-use sectors. It is broken down into energy demand in the following sectors: industry (including manufacturing and mining), transport, buildings (including residential and services), agriculture and other (including non-energy use). It excludes international marine and aviation bunkers, except at the world level where it is included in the transport sector.

Total primary energy demand: Represents domestic demand only and is broken down into power generation, other energy sector and total final consumption.

Transparency Platform: Designed as a platform where the data of the electricity and natural gas markets can be seen by all the participants at the same time and the players operating in the market will reach the information on an equal basis.

Value Adjusted Levelized Cost of Energy: Or VALCOE. VALCOE is similar to LCOE except that it raises the "value adjusted cost" of intermittent sources of power and lowers the "value adjusted cost" of dispatchable load-following power. These cost adjustments reflect the system costs incurred by non-dispatchable power and system benefits of providing dispatchable power when needed. VALCOE reflects the cost implications of balancing the grid taking account of a number of specific assumptions such as the amount of intermittent renewable energy, their power profiles compared to demand profiles and several other factors, such as other load balancing opportunities. However, it does not reflect grid costs that are often required to accommodate particular renewable generators (see Chapter 1)

Variable renewable energy (VRE): Refers to technologies whose maximum output at any time depends on the availability of fluctuating renewable energy resources. VRE includes a broad array of technologies such as wind power, solar PV, run-of-river hydro, concentrating solar power (where no thermal storage is included), and marine (tidal and wave).

Variability: The changes in power demand and/or the output of a generator due to underlying fluctuations in resource or load

Waste storage and disposal: Activities related to the management of radioactive nuclear waste. Storage refers to temporary facilities at the nuclear power plant site or a centralized site. Disposal refers to permanent facilities for the long-term isolation of high-level waste, such as deep geologic repositories.

Waste Heat: It is the unused heat in the form of thermal energy by a heat engine in a thermodynamic process in which it converts heat to useful work.

ANNEX G.

Abbreviations and Acronyms

AIIB	Asian Infrastructure Investment Bank
ASEAN	Association of Southeast Asian Nations
BEV	Battery Electric Vehicles
BOO	Build, Own, Operate Contracts
BOT	Build, Own, Transfer Contracts
CAES	Compressed Air Energy Storage
CBM	Coalbed Methane
CCGT	Combined-Cycle Gas Turbine
CCUS	Carbon Capture, Utilization and Storage
CH_4	Methane
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP	Conference of Parties (UNFCCC)
CTG	Coal-To-Gas
DHC	District Heating and Cooling
DRI	Direct Reduced Iron
DSI	Demand-Side Integration
EBRD	European Bank of Reconstruction and Development
ECA	European Court Of Auditors
EESI	Environmental and Energy Study Institute
EFET	European Federation of Energy Traders
EIA	U.S. Energy Information Administration
EML	Electricity Market Law
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency (United States)

EPİAŞ	Energy Stock Exchange Company
ESCO	Energy Service Company
EU	European Union
EU ETS	European Union Emissions Trading System
EV	Electric Vehicle
FDI	Foreign Direct Investment
FSRU	Floating Storage Regasification Unit
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GIIGNL	International Group of Liquefied Natural Gas Importers
GRF	Daily Reference Price
HDD	Heating-Degree-Day
HDVs	Heavy-Duty Vehicles
HFCVs	Hydrogen Fuel Cell Vehicles
HGA	Host Government Agreement
HSR	High Speed Train
HTFs	Heavy Freight Trucks
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICE	Internal Combustion Engine
ICTT	International Council on Clean Transportation
IEA	International Energy Agency
IGA	Intergovernmental Agreement
IGU	International Gas Union
IMO	International Maritime Organization
IOC	International Oil Company
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IST	İstanbul International Airport

ISO	International Organization for Standardization
ITF	International Transport Forum
LCOE	Levelized Cost of Electricity
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LRT	Last Resort Tariff
MidSEFF	Mid-Size Sustainable Energy Financing Facility
MTFs	Medium Freight Trucks
NCI	Nelson Complexity Index
NBP	National Balancing Point
NEMP	National Energy and Mining Policy of Turkey
NGML	Natural Gas Market Law
NOC	National Oil Company
NOx	Nitrogen Oxides
OECD	Organization for Economic Co-operation and Development
OGIP	Original Gas in Place
OICA	International Organization of Motor Vehicle Manufacturers
OIES	Oxford Institute of Energy Studies
OOIP	Original Oil in Place
OPEC	Organization of the Petroleum Exporting Countries
OTSP	Organized Wholesale Natural Gas Market
PHEV	Plug-In Hybrid Electric Vehicle
PPA	Power Purchase Agreement
PSH	Pumped Storage Hydropower
PSA	Product Sharing Agreement
PV	Photovoltaics
R&D	Research and Development
RD&D	Research, Development and Demonstration
R&T	Royalty & Tax
SCT	Special Consumption Tax

SME	Small and Medium Enterprises
SMR	Small Modular Nuclear Reactor
SUV	Sport Utility Vehicle
ŞİD	Natural Gas Network Code
TEVMOT	The Project on Transition to Energy-Efficient Electric Motors in Industry
TFC	Total Final Consumption
TOGG	Turkey's Automobile Initiative Group
TOOR	Transfer of operating rights contracts
TPES	Total Primary Energy Supply
TTF	Title Transfer Facility
TuREEFF	Turkish Residential Energy Efficiency Financing Facility
TuRSEFF	The Turkey Sustainable Energy Financing Facility
UAE	United Arab Emirates
UITP	International Association of Public Transport
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
U.S.	United States
VALCOE	Value-Adjusted Levelized Cost of Electricity
VAP	Energy Efficiency Improvement Projects
VRE	Variable Renewable Energy
WB	World Bank
WEO	World Energy Outlook by the International Energy Agency
YEKA	Renewable Energy Resource Areas
YEKDEM	Support mechanism for electricity generation from renewable energy sources

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