SHURA Energy Transition Center

Optimum electricity generation capacity mix for Turkey towards 2030

About SHURA Energy Transition Center

SHURA Energy Transition Center, founded by the European Climate Foundation (ECF), Agora Energiewende and Istanbul Policy Center (IPC) at Sabancı University, contributes to decarbonisation of the energy sector via an innovative energy transition platform. It caters to the need for a sustainable and broadly recognized platform for discussions on technological, economic, and policy aspects of Turkey's energy sector. SHURA supports the debate on the transition to a low-carbon energy system through energy efficiency and renewable energy by using fact-based analysis and the best available data. Taking into account all relevant perspectives by a multitude of stakeholders, it contributes to an enhanced understanding of the economic potential, technical feasibility, and the relevant policy tools for this transition.

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Design

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This report and the assumptions made within the scope of the study have been drafted based on different scenarios and market conditions as of the end of 2019. Since these assumptions, scenarios and the market conditions are subject to change, it is not warranted that the forecasts in this report will be the same as the actual figures. The institutions and the persons who have contributed to the preparation of this report can not be held responsible for any commercial gains or losses that may arise from the divergence between the forecasts in the report and the actual values.

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Executive Summary

Efforts to restructure Turkey's energy sector over the past two decades have largely been successful in achieving the energy security for a growing economy with rapidly increasing energy needs. As a result, Turkey's installed power capacity has tripled in that period, reaching 92 gigawatt (GW) in May 2020. During the 2002-2018 period, 53% of the total investment of US$ 75 billion in electricity generation is directed to renewable resources, including hydroelectric power plants. While the share of renewables in the total power generation investments was 40% from 2002 to 2009, during the 2010-2018 period it increased to 58%[1]. Receiving one-third of total energy sector investments, renewables grew benefiting from the facilitating regulatory and financial environment, accounting for almost 50% of total installed capacity in 2019.

The share of renewable energy in electricity generation reached 44% in 2019 setting a new record[2]. This was due to several factors such as unusually high water in-flow, the increase in the installed capacity and generation of wind and solar energy sources and the relatively low electricity demand. As a result, the renewable energy generation target of 38.8% set for 2023 in the Tenth Development Plan has been reached as of 2019. Further record shares have been set during the COVID-19 pandemic due to the combination of low electricity demand and the usual high renewable energy generation in spring. In April 2020, around 66% of the electricity generation was accounted for by renewable energy sources[3].

On the other hand, the extensive build-up of power generation dramatically increased gas and other fossil-fuel imports, leaving the Turkish economy increasingly exposed to volatile prices, which has been further exacerbated by a weakened domestic currency. In 2019, the total of 41.1 billion USD spending on imported fossil fuels was a significant contributor of Turkey's 29.5 billion USD current account deficit. Reducing this deficit has become a top priority in policies. Increasing the utilization of domestic and renewable energy sources is one the most basic policies intended to achieve this goal. These policies have also been reiterated with the installed capacity increases foreseen in the "2019-2023 Strategic Plan" shared with the public on May 2020 by the Ministry of Energy and Natural Resources[4].

Turkey's energy transition is coming to a crossroads, as it has multiple goals: ensuring energy security and affordability of supply, while reducing the adverse environmental and economic impacts of fossil-fuel use. After 2023, there will be a need for an integrated long-term energy and climate strategy based on the foundations of the 2023 strategy vision. The impact of the ongoing COVID-19 pandemic has further laid bare the intricate links between energy and the economy. In the twelve weeks following the announcement of first cases in Turkey in early March 2020, electricity demand fell nearly 10% compared to the same period in 2019 with average day-ahead market prices dropping to 30 USD per megawatt-hour (MWh). Although focused on short-term recovery by design, the support plans aiming to revive stalled economies will have long-term impacts. This further highlights the need for integrated and forward-looking system planning and policies that minimize risks and engender investor confidence, especially given the current uncertainties and instable environs.

[1] SHURA Energy Transition Center, "Financing the Energy Transition in Turkey". Available at: https://www.shura.org.tr/eng/

[2] Turkish Electricity Transmission Company. Available at: https://www.teias.gov.tr/tr-TR/turkiye-elektrik-uretim-iletim-istatistikleri

[3] EPIAS Transparency Platform. Available at: https://www.epias.com.tr/en/

[4] Ministry of Energy and Natural Resources, "2019-2023 Strategic Plan". Available at: https://sp.enerji.gov.tr/

There are a number of strategic road maps to follow in order to meet these goals. A significant resource potential for wind and solar exists throughout the country. Additionally, domestic lignite reserves remain on offer, but these sources have low calorific values and require extensive mining operations. Meanwhile, nuclear energy remains a national strategic priority as well. Grid scale wind and solar energy, which are expected to play a significant role in Turkey's future energy mix, are now the cheapest power generating technologies and the decrease in their costs are expected to continue in the future. Recent SHURA studies have demonstrated the capability of the Turkish power system to integrate up to 50% renewables, including 30% wind and solar as early as 2026. Although this will require increased system flexibility, there will be no need for significant grid investments. The same studies have shown that system flexibility should be increased by using various options in order to integrate the new renewable capacity into the system with limited additional investment and limited operational impact. Net costs for adding system flexibility options on the levelized cost of electricity were estimated to be between 1%-5%[5].

Each strategy used to reach the energy targets includes different cost and benefit components which in some instances can contradict each other, depending on the projected price and developments in demand. **In this study, optimum capacity development is modeled for Turkey for the period between 2020 and 2030 under five different scenarios and how different policy choices can play a role in achieving energy goals.** The aim here is to contribute to the formulation of a long-term energy system planning strategy for Turkey. The analysis includes the impact of different scenarios on system cost, market prices, trade balance and carbon dioxide emissions.

Key findings:

- There are significant benefits in adapting a more holistic approach rather than trying to achieve the energy goals one by one. A coordinated approach for achieving Turkey's long-term goals: reducing imports, enhancing energy security and improving local air quality can yield enormous benefits for the climate and economy when renewable resources are fully exploited.

- Improving energy efficiency remains one of the most cost-effective (around 3 USD/MWh lower than the base-case scenario market price of 52 USD/MWh for 2030) policy options with multiple benefits that needs to be employed in the short-term. Increases in energy efficiency by reducing total electricity consumption (8.7% savings compared to all scenarios in 2030), reducing absolute carbon emissions by reducing the use of fossil fuels (9% less compared to the highest carbon dioxide emissions calculated for 2030) and reducing the amount of imports (20 billion USD less compared to the scenario with the highest import) will be possible, while at the same time playing a role in increasing energy security and flexibility in energy supply options. However, efficiency policies alone are not able to meet Turkey's energy transition goals without supporting policies for increased renewable energy generation and environmental protection.

- The establishment of a carbon pricing and trading mechanism in Turkey significantly reduces greenhouse gas emissions originating from electricity

[5] SHURA Energy Transition Center, "Costs and benefits of options to increase system flexibility". Available at: https://www.shura.org.tr/eng/

generation (average carbon intensity to decrease by 115 grams carbon dioxide (CO_2) per kilowatt-hour (kWh). It would exclude the low-efficiency coal plants from the supply and demand curves (with the installed capacity decreasing down to 8 GW) and increase the use of natural gas (by increasing the installed power to 33.9 GW), a source with less emissions, which, in addition, provides flexibility to the system, thus facilitating renewable energy integration. However, these reductions in emissions come at the expense of additional natural gas import costs (20 billion USD more in total) and higher electricity prices (20 USD/MWh more on average). Complementing carbon pricing with additional policies to incentivize the development of local renewable resources represents a balanced approach, reducing both power-related emissions, improving local air quality and decreasing imported fuels dependency.

- Wind and solar power remain the cheapest investment choice (the grid scale solar power plant levelized cost of electricity generation (LCOE) for İzmir is 63 USD/MWh, around 6% lower than coal and 10% lower than natural gas) of all power generation technologies across all scenarios and their role in the energy mix will continue to increase. Maintaining targeted market-driven regulatory mechanisms will continue to support this development. A competitive and cost reflective wholesale power market design will be crucial in integrating increasing VRE shares.

- Existing natural gas and hydropower projects are poised for delivering grid-scale flexibility, while scenario results show that the re-commissioning of gas power plants, which are not cost-competitive today, represents a least-cost additional flexibility option. On the other hand, this is set to increase the dependency on imported fuels and limit the CO_2 mitigation potential in the country for the long term. Because of this, the utilization of other flexibility options like energy storage can be realized through the active use of market mechanisms that recognize and incentivize flexibility.

- Distributed renewable energy generation, mainly small and rooftop solar PV, has some of the highest growth potential in Turkey, around 15 GW[6]. Market instruments that can support the development of these installations can complement the market-driven regulatory mechanisms that support renewable energy development as a whole.

- Nuclear energy's carbon neutral characteristics combined with its stable generation output and low fuel costs make it an attractive option to meet rising demand. However, its capital costs remain prohibitively expensive even under a considerably high carbon pricing environment. As nuclear power is considered a strategic asset in Turkey, especially due to its carbon neutral and baseload characteristics, the decision to build nuclear needs to incorporate an analysis of its long-term advantages and impacts.

The progress of Turkey's energy transition over the next decade will be shaped around today's policy decisions. Despite the current power supply surplus and short-term economic downturn due to COVID-19, the rapid rise in electricity demand is expected to require new investments in the electricity system as the economy recovers its upward trend. The question on how these investments can be optimized, and which policy

[6] SHURA Energy Transition Center, "Rooftop solar energy potential in buildings in Turkey". Available at: https://www.shura.org.tr/

instruments will be most appropriate in doing so remains open. Any policy decision taken today in this regard is set to have effects that may last for several decades with some outcomes that may be irreversible. Modeling studies enable policy and decision makers to ask critical what-if questions to assess and compare future outcomes of selected policies.

The outputs of this study's modeling work include indicators such as installed capacity development, generation mix, average wholesale power market prices, carbon intensity of electricity generation, cost of imported fuel sources and investment requirements. Each scenario developed under the scope of the study is compared and analyzed within these parameters in terms of benefits and costs.

New capacity engagement decisions are made by the dynamic engagement algorithm at the beginning of each year simulated in the model. For each energy technology, the algorithm calculated a specific LCOE value for each location, including LCOEs for certain specific pipelined projects. Commissioning is made based on these LCOE values for each source on an annual basis and the calculated wholesale market prices. Other cost items, such as system connection and transmission costs, are also included in the decision process. As a result of this process, it is possible to carry out commissioning decisions in each scenario in a cost-effective manner with a view to inflict the least costs on the energy system as a whole.

The ideal capacity scenarios developed within the study are listed as follows:

- **Purely Market Driven Scenario:** This baseline scenario arrives at an installed capacity mix by allowing the market to continue to operate under current policies until 2030.

- **Low Demand Scenario:** Reduced electricity demand growth is the only difference between the Low Demand and Purely Market Driven scenarios. Demand is significantly reduced due to the deployment and success of energy efficiency improvements throughout the energy system. The rate of efficiency improvement is assumed to be around 1% point per year as compared to the latest government projections.

- **Domestic Sources Scenario:** Under this scenario, several policies aimed at increasing the share of domestic energy sources are deployed. Policy instruments include purchase guarantees for renewable energies and a price-premium for power plants using domestic coal resources.

- **Carbon Pricing Scenario:** This scenario assesses the effects of a carbon pricing mechanism. The carbon price is initiated at a level around 7 USD/CO_2 in 2021 and increased gradually to 40 USD/CO_2 in 2030.

- **Balanced Policy Action Scenario:** This scenario represents a blend of the policies deployed in the Domestic Sources and Carbon Pricing scenarios. In this context, a comparatively lower carbon price is employed, reaching 25 USD/ton CO_2 in 2030, and additional purchase guarantees for renewable energy sources are introduced. The main aim of this scenario is to account for the different goals of the Turkish energy policy in a balanced manner such as carbon mitigation, the utilization of domestic sources and the supply of affordable electricity.

A summary of the results under each scenario is shown in the table below:

Summary of Key Results by Scenario

Parameter	Purely Market Driven Scenario	Low Demand Scenario	Carbon Pricing Scenario	Domestic Sources Scenario	Balanced Policy Action Scenario	2019 Year End Actual Figure
2030 Total Electricity Demand (TWh/year) (MENR Base Scenario: 482 TWh)	461	421	461	461	461	304
Annual Electricity Demand Increase (2020-2030) (%/year) (MENR Base Scenario: 3.9%/ year)	%3.9	%3	%3.9	%3.9	%3.9	%5 (2002-2018)
2030 Year-End Installed Capacity (GW)	133.3	129.2	130.7	138.1	139.3	91.4
2030 Year-End Coal Installed Capacity (GW)	22.3	22.3	8.8	25.3	15.0	20.3
2030 Year-End Natural Gas Installed Capacity (GW)	26.3	24.2	33.9	21.9	24.9	25.3
2030 Year-End Total Wind + Solar Installed Capacity (GW)	50.1	48.0	53.4	55.7	63.6	13.5
2030 Share of Domestic Sources in Total Demand	%58.3	%62.5	%52.3	%65.7	%59.6	%60.2
2030 Share of Renewable Sources in Total Demand (2023 target: 38.8%)	%43.5	%46.4	%45.6	%46.5	%51.5	%43.9
2030 Share of Variable Renewable Sources (Wind + Solar) in Total Demand	%23.9	%24.9	%25.7	%26.2	%30.1	%10.6
2030 Share of Natural Gas in Total Demand (2023 target: 20%)	%27.3	%22.4	%45.0	%20.3	%31.0	%18.6
Average Day - Ahead Market Price in 2030 ($USD_{Real2020}$/MWh)	52	49	69	48	57	46
Average Carbon Intensity between 2020-2030 (gram CO_2/kWh)	480.2	487.0	359.1	482.6	378.2	493.2 (2018)
Annual Average Carbon Emissions between 2020-2030 (million tonnes CO_2)	187.6	180.2	136.7	188.9	144.4	-
Cumulative Imported Fuel Costs between 2020-2030 (Billion $USD_{Real2020}$)	67.36	59.31	79.96	61.27	70.15	-
Annual Average Investment Costs between 2020-2030 (Billion $USD_{Real2020}$)	4.0	3.8	4.7	4.5	5.0	4.4 (2002-2018)

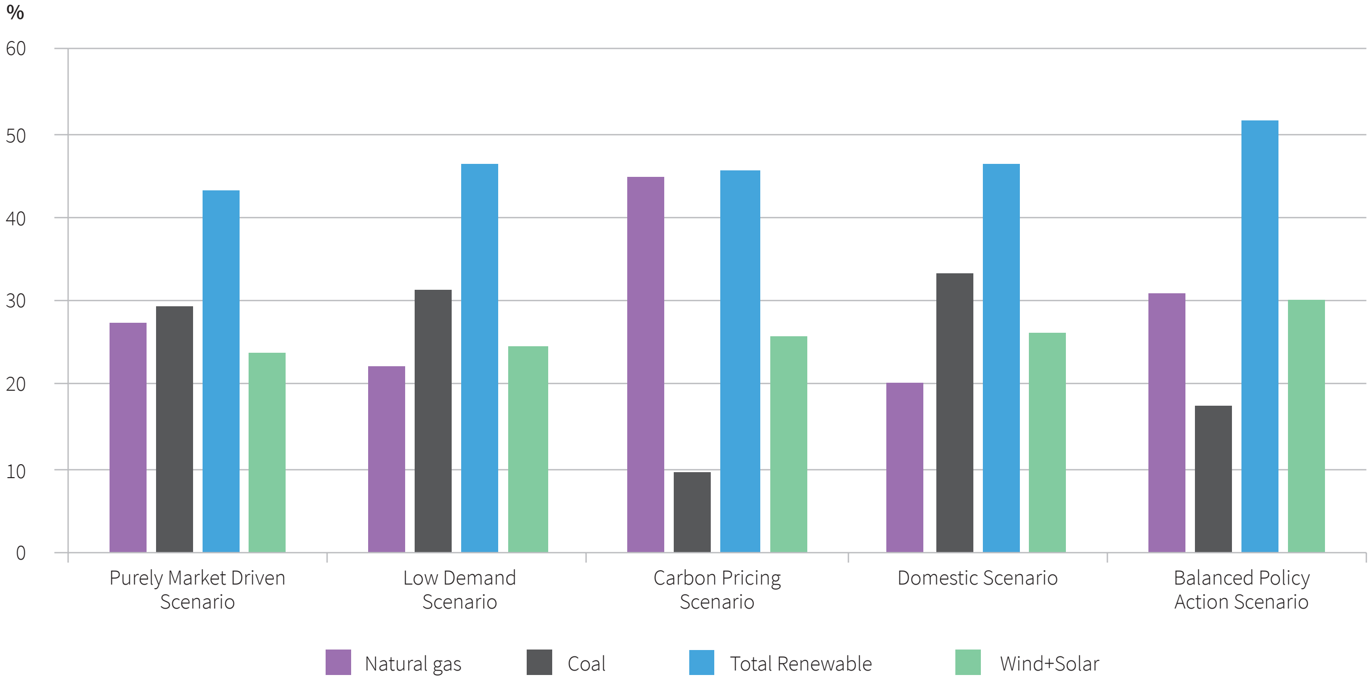
Turkey's current energy policy extending to 2023 puts energy efficiency improvements at the heart of its energy transition strategy. The National Energy Efficiency Action Plan released in 2018, targeted efficiency improvements across all energy sectors, recognizing the multiple co-benefits which are reflected in the Low Demand scenario results. By lowering total power demand further nearly by one percent per year compared to public base estimations, additional capacity increases of all technologies are avoided, leading to a USD 2 billion reduction in cumulative power sector investment compared to current policies. In this scenario where all factors other than demand are the same as the Purely Market Driven Scenario, relatively low cost renewables and coal investments are preferred over the natural gas option. Renewables growth however is also lowest, but its proportion in the power mix - 46.4% in 2030 production - remains high. As the coal proportion in the power mix remains high, carbon intensity of the power system is actually the highest in the low demand scenario. However, due to lower total production, total carbon emissions in 2030 (199 million tonnes (Mt) CO_2) are reduced by 15 Mt CO_2 compared to the baseline (214 Mt CO_2), representing 10% of total power sector emissions in 2017 which totaled to 150 Mt CO_2.

On the other hand, in the Purely Market Driven Scenario, a total of 3,500 megawatt (MW) of publicly owned natural gas power plants have been renovated with their efficiencies increased to 63%. The re-commissioning of these power plants after 2026 has made it possible for these power plants to be cost effective electricity generation options for the power system. This shows the importance of efficiency improvements on both the demand and supply sides. Another potential improvement in order to ensure a less costly and more efficient electricity system operation is reducing the technical losses in the transmission and distribution networks. Such potential improvements are excluded from the scope of this study. The electricity demand assumed under the scope of this study entails the gross demand. Any future benefits of reducing the network losses in the system should be evaluated in a detailed manner in future energy efficiency action plans.

Despite the broad evidence of energy efficiency policies' wide-reaching benefits, uncertainty and practical limitations regarding their implementation connote that efficiency policies alone do not represent a panacea for energy system transformations. For example, higher shares of renewable energy improve overall energy efficiency by reducing demand, especially when electrification displaces thermal processes. However, it was not possible to see the aforementioned effects within the scope of this study, as electricity demand was considered separately as an input. Policies targeting the electricity supply side remain important for a genuine transformation of the electricity system.

In this study, the effects of supply-side policies, which have the potential to conflict with each other, are most clearly seen in the development of natural gas and coal installed power under different assumptions. The introduction of carbon prices in the carbon price scenario expectedly leads to the decommissioning of the most inefficient lignite-fueled coal stations, only for the supply gap to be largely met by imported gas. Installed coal capacity decreases significantly, falling to just 9 GW in 2030, compared to 20 GW today, with gas increasing to 34 GW. This results in the highest cumulative imported fuel costs, over USD 12 billion over business-as-usual conditions. Day ahead market prices also increase as coal projects are decommissioned, further increasing consumer risk to international gas price volatility.

Comparison of Generation Share by Source in 2030 Across Scenarios[7]



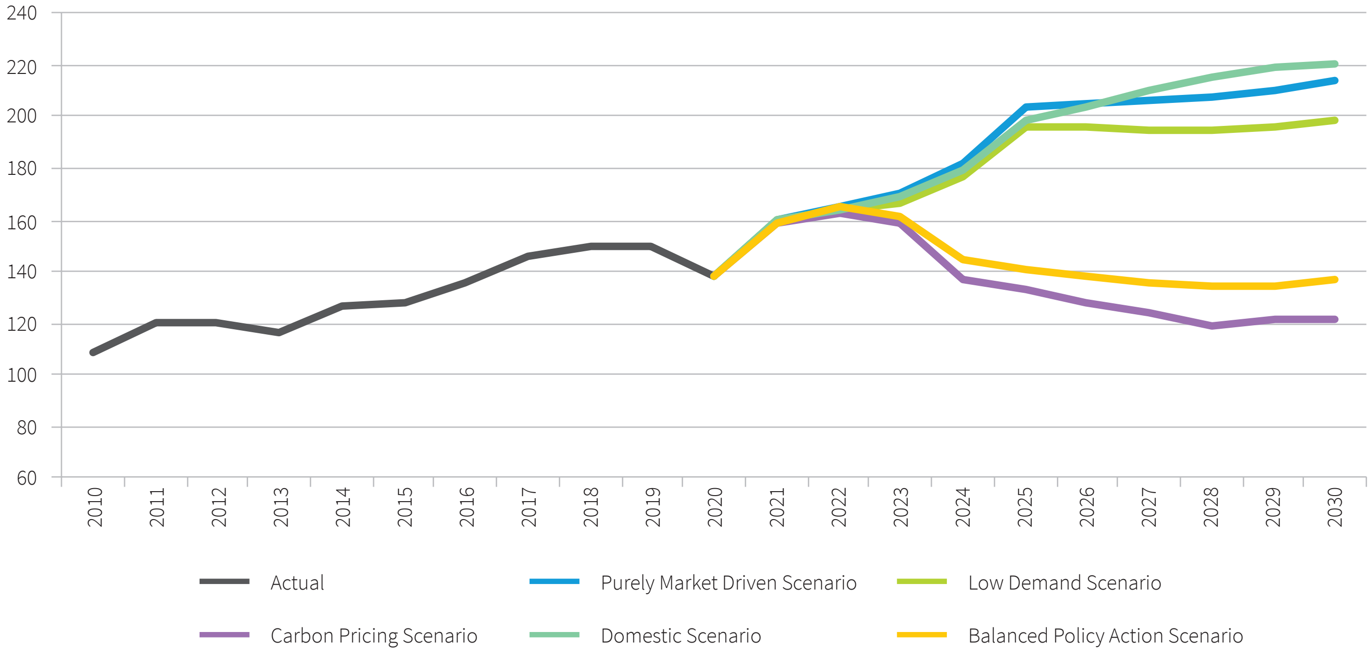
On the other hand, when the development of domestic resources is incentivized, the opposite occurs. In this scenario, it is assumed that a 20% price premium offered to domestic coal projects replaces the current policy of purchase guarantees. As a result, low marginal coal costs reduce power prices to a level where gas is unable to compete, resulting in a 3.4 GW reduction in gas capacity relative to 2019. Associated imports also decrease accordingly, i.e., cumulatively USD 18 billion less than in the Carbon Pricing scenario.

Driven by the high carbon price in the Carbon Price Scenario, the fuel switching from coal to gas results in clear short-term climate and local air quality benefits: carbon intensity of the power system drops from 480 g CO_2/kWh under current policies to 260 g CO_2/kWh in 2030, reducing total single-year emissions by 100 Mt CO_2 compared to Current Policies. Annual power sector emissions in 2030 in the Carbon Pricing scenario reach 121 Mt CO_2, a 20% reduction compared to current emissions. Adopting a temporal perspective beyond 2030, however, adds further complexity to the environmental case for building new gas infrastructure. Investment into new gas infrastructure runs the risk of technology lock-in over the lifetime of the projects, potentially up to 2050 and beyond. So, while switching to gas may result in relatively reduced emissions, this can increase absolute emissions by limiting emissions reduction potential in the future, thus running the risk of stranding gas assets. Yet, in the absence of a clear, long-term climate policy, coal power plants, especially those built in the upcoming years, similarly run the risk of becoming stranded assets, that is, if a climate policy is put into place at a later date.

[7] It should be considered that the share of total renewables also includes the shares from wind and solar.

Comparison of Carbon Emissions Across Scenarios[8]

Million tonnes CO_2/year



Meeting Turkey's long-term energy system goals concurrently is evidently a complex endeavor, especially given the inherent uncertainties regarding future economic growth, fossil fuel prices and technology costs. Wind and solar PV, in this respect, are more resilient than other technologies due to their decreasing costs, fast deployment times, modular nature and scalability.

The total share of wind and solar PV is rising significantly from 10% in 2019 for all scenarios and is between 24% and 30% in 2030. Existing Feed-in-Tariffs for renewable energy resources provided a strong incentive to wind and solar PV investments, and succeeded in raising combined installed capacity to 13.5 GW in 2019 from just 1 GW a decade ago. In order for renewable energies, and especially wind and solar PV to play a more important role in the energy system, these supports should be continued. As shown in the Carbon Pricing scenario, despite the relatively high penalties applied to fossil fuels, many renewable energy options including geothermal, biomass, hydropower and licensed solar were unable to breakthrough. These technologies all benefitted from direct support policies as in the Domestic Sources and Balanced Policy Action scenarios, reaching relatively higher total installed VRE capacities.

Distributed renewables, in particular unlicensed rooftop solar PV, play an important role throughout all scenarios. In addition to enhancing system efficiency, system benefits from the increased uptake of distributed solar PV include system support and power quality effects in the distribution network. Furthermore, expected cost decreases further increase the level of competitiveness vis a vis household electricity prices. In this respect, but not only limited to rooftop applications, smaller private investors can play a non-marginal role in overall power sector investments. Encouraging a shift towards increased solar and wind capacities also create positive impacts on local value creation in the forms of jobs and new manufacturing industries throughout the country.

[8] The latest figure published by Turkish Statistical Institute is for the year 2018. The 2018 figure is used for 2019 for demonstrative purposes. The forecasted reduction in 2020 is mainly due to the lower lignite-based electricity generation due to some local coal power plants that were shut-down with regard to the new environmental regulation. This reduction in 2020 emissions can be further than the forecast as a result effects of COVID-19 pandemic on electricity demand.

The results of the study display that the individual solutions to be used to achieve energy targets will pose various risks in terms of achieving all targets. Taking a holistic approach that combines multiple goals under a single policy roof presents a possible solution as evidenced in the Balanced Policy Action Scenario. Under this scenario, employing a less stringent carbon price and supporting this with direct incentive mechanisms for renewable energy sources, allowed the creation of a more diverse production mix while reducing carbon emissions. While wind and solar reach 30% of the total generation, capacity increases also occur for biomass and geothermal. Despite the decreased carbon price, significant emissions reductions are still achieved, declining to 137 Mt CO_2 in 2030, a 9% reduction from current levels. Renewables play a much larger role in displacing coal, at the expense of imported gas, even though some coal remains online. As a result, 60% of total generation is from domestic sources.

Given its carbon neutral characteristics, the stable baseload output and steady fuel costs, nuclear power is considered an important contributor to the decarbonization strategies of many countries worldwide, including Turkey. However, high capital costs and long lead times mean that nuclear LCOE values are on average nearly three times as expensive with respect to alternative technologies. Due to its high costs, nuclear power has not been installed in all optimum capacity development scenarios with dynamic commissioning algorithm. Nevertheless, as projects of national importance, these projects could contribute significantly to reducing imported fuels.

Achieving the energy system goals of Turkey's energy transition add up to a formidable and complex policy challenge. Energy system models allow for the study of long-term implications of different energy policies. Investment in sustainable energy will continue to move forward in Turkey as long as they are supported by a stable and targeted market-driven regulatory framework, which takes into account long-term energy policy goals and the decade-long impact of power system infrastructure investments.

About Istanbul Policy Center at the Sabancı University

Istanbul Policy Center (IPC) is a global policy research institution that specializes in key social and political issues ranging from democratization to climate change, transatlantic relations to conflict resolution and mediation. IPC organizes and conducts its research under three main clusters: The Istanbul Policy Center–Sabancı University–Stiftung Mercator Initiative, Democratization and Institutional Reform, and Conflict Resolution and Mediation. Since 2001, IPC has provided decision makers, opinion leaders, and other major stakeholders with objective analyses and innovative policy recommendations.

About European Climate Foundation

The European Climate Foundation (ECF) was established as a major philanthropic initiative to help Europe foster the development of a low-carbon society and play an even stronger international leadership role to mitigate climate change. The ECF seeks to address the "how" of the low-carbon transition in a non-ideological manner. In collaboration with its partners, the ECF contributes to the debate by highlighting key path dependencies and the implications of different options in this transition.

About Agora Energiewende

Agora Energiewende develops evidence-based and politically viable strategies for ensuring the success of the clean energy transition in Germany, Europe and the rest of the world. As a think tank and policy laboratory, Agora aims to share knowledge with stakeholders in the worlds of politics, business and academia while enabling a productive exchange of ideas. As a non-profit foundation primarily financed through philanthropic donations, Agora is not beholden to narrow corporate or political interests, but rather to its commitment to confronting climate change.

SHURA
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