COBENEFITS STUDY

October 2020

Securing Turkey's energy supply and balancing the current account deficit through renewable energy

Assessing the co-benefits of decarbonising the power sector

Executive report

İPM | IPC İSTANBUL POLİTİKALAR MERKEZİ SABANCI ÜNİVERSİTESİ ISTANBUL POLICY CENTER SABANCI UNIVERSITY

IASS POTSDAM

IET International Energy Transition

COBENEFITS

This study has been realised in the context of the project "Mobilising the Co-Benefits of Climate Change Mitigation through Capacity Building among Public Policy Institutions" (COBENEFITS).

IASS POTSDAM
renac renewables academy
UfU Independent Institute for Environmental Issues
epra
IET International Energy Transition
İPM | IPC İSTANBUL POLİTİKALAR MERKEZİ SABANCI ÜNİVERSİTESİ ISTANBUL POLICY CENTER SABANCI UNIVERSITY

This project is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag. The COBENEFITS project is coordinated by the Institute for Advanced Sustainability Studies (IASS, lead) in partnership with the Renewables Academy (RENAC), the Independent Institute for Environmental Issues (UfU), International Energy Transition GmbH (IET), and in Turkey the Sabanci University Istanbul Policy Center (IPC).

October 2020

Editors: Héctor Rodríguez, Sebastian Helgenberger, Pınar Ertör, Laura Nagel – IASS Potsdam and Sabanci University Istanbul Policy Center IPC

Technical implementation: Saeed Teimourzadeh, Gokturk Poyrazoglu, Osman Bülent Tör. EPRA – Engineering, Procurement, Research, and Analysis

We acknowledge the valuable inputs and reviews of the SHURA Energy Transition Center and its Director Değer Saygın in implementing the COBENEFITS Turkey studies.

Suggested citation: IASS/IPC. 2020. Securing Turkey's energy supply and balancing the current account deficit through renewable energy. Assessing the co-benefits of decarbonising the power sector. COBENEFITS Report. Potsdam/Istanbul. www.cobenefits.info

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag

INTERNATIONAL CLIMATE INITIATIVE (IKI)

Fostering energy independence as the backbone of economic recovery

Foreword in light of the COVID-19 pandemic

At the time this report is being published, Turkey along with many economies around the world has been severely affected by the spread and impacts of the global COVID-19 pandemic. Similarly to many countries worldwide, the Turkish economy, along with thousands of businesses and workers, has been deeply affected and substantial political efforts will be needed to rebuild national and local economies and job markets. The pandemic also reminded us how public health measures are equally important as a strong and resilient health system.

This report and the related COBENEFITS study series for Turkey suggest that the new energy world of renewables and the decarbonisation of Turkey's energy sector should have a strong role in reviving the economy and health system by boosting employment, fostering energy independence as foundation of economic resilience, and — importantly — unburdening national health systems by reducing the incidence of respiratory diseases. By providing the enabling policy environment necessary for unlocking these co-benefits, the Government of Turkey can provide important stimuli to recover from the impacts of the COVID-19 pandemic and revive both the health system and the national economy.

Turkey is in the midst of an energy transition, with important social and economic implications, depending on the pathways that are chosen. Independence from energy imports; economic prosperity; business and employment opportunities as well as people's health: through its energy pathway, Turkey will define the basis for its future development. Political decisions on Turkey's energy future link the missions and mandates of many government ministries beyond energy, such as environment, industry development, economics, foreign relations, and health.

Importantly, the whole debate boils down to a single question: How can renewables improve the lives and wellbeing of the people of Turkey? Substantiated by scientific rigor and key technical data, the study at hand contributes to answering this question. It also provides guidance to government ministries and agencies on further shaping and enabling the political environment to unlock the social and economic co-benefits of the new energy world of renewables for the people of Turkey.

Under their shared responsibility, the Istanbul Policy Center (IPC) of Sabanci University (as the COBENEFITS Turkey Focal Point) and IASS Potsdam invited the ministries of Energy and Natural Resources (MoENR), Environment and Urban Affairs (MoEU), Treasury and Finance (MoTF, formerly Ministry of Economics MoE), Foreign Affairs (MoFA), and Health (MoH) to contribute to the COBENEFITS Council Turkey and to guide the COBENEFITS Assessment studies along with the COBENEFITS Training programme and *Enabling Policy* roundtables. Their contributions during the COBENEFITS Council sessions guided the project team to frame the topics of the COBENEFITS Assessment for Turkey and to ensure their direct connection to the current political deliberations and policy frameworks of their respective departments.

We are also indebted to our highly valued research and knowledge partners, for their unwavering commitment and dedicated work on the technical implementation of this study. The COBENEFITS study at hand has been facilitated through financial support from the International Climate Initiative of Germany. The Government of Turkey has emphasised climate change as one of the most significant problems facing humanity, presenting wide-ranging threats to Turkey's future unless early response measures are taken. Within the scope of Turkey's National Climate Change Strategy, the government has laid out its vision for providing citizens with high quality of life and welfare standards, combined with low carbon intensity.

With this study, we seek to contribute to this vision by offering a scientific basis for harnessing the social and economic co-benefits of achieving a just transition to a low-carbon, climate-resilient economy and thereby also allowing Turkey to achieve a regional and international front-runner role in shaping the new low-carbon energy world of renewables, making it a success for the planet and the people of Turkey.

We wish the reader inspiration for the important debate on a just, prosperous, and sustainable energy future for Turkey!

Ümit Şahin
COBENEFITS Focal Point Turkey
Istanbul Policy Center

Sebastian Helgenberger
COBENEFITS Project Director
IASS Potsdam

Executive Summary

COBENEFITS

Increasing energy supply security and balancing Turkey's current account deficit through renewable energy

Turkey's socio-economic growth has been accompanied by increasing energy demand, thereby expanding the opportunities to enable multiple co-benefits involving both securing the country's future energy supply and utilising local and clean energy sources. The energy transition is inducing new investments in the electricity production and infrastructure sectors worldwide. By predominantly relying on fossil fuel resources to meet its increasing energy demand, Turkey faces significant risk of exacerbating the current account deficit in the energy sector's trade balance and also increasing its dependency on energy imports in the future. Electricity generation technologies that utilise local and renewable energy sources can contribute to reducing energy import dependency.

This study assesses the contribution of renewable energy sources to reducing demand for fossil fuels and thus associated fossil fuel imports. This research study has been carried out in the context of the COBENEFITS project, which assesses a range of socio-economic co-benefits[1] of renewable energy, in addition to the benefits of reducing energy sector greenhouse gas emissions, when compared to non-renewable energy systems.

The assessment consists of a series of quantitative analyses, including a renewable energy sources (RES) capacity penetration scenario analysis, a market and network simulation, and a levelised cost of energy (LCOE) analysis, based on investment and in the operation and management (O&M) cost of renewable energy under various weighted average cost of capital (WACC) assumptions.

KEY POLICY OPPORTUNITIES

- **Policy opportunity 1:** Turkey can foster its energy independence and ensure security of supply by increasing the use of its renewable energy sources. Increasing the share of renewable energy in power generation will contribute to increasing independence from fossil fuel imports and to reducing the current account deficit in the energy sector's trade balance.

- **Policy opportunity 2:** By the year 2028 Turkey can reduce its natural gas consumption by 16 % and 155 million MMBTU (million British Thermal Units) through scaling up renewable power generation without the need to increase foreseen investment in the transmission system.

- **Policy opportunity 3:** Annual economic savings on fossil fuels and fossil fuel imports can amount to USD 2.1 billion by the year 2028 by increasing the share of renewable energy in power generation and making the transmission system renewables-ready.

[1] The term 'co-benefits' refers to simultaneously meeting several interests or objectives resulting from a political intervention, private-sector investment or a mix thereof (Helgenberger et al., 2019).

FOUR POWER SYSTEM PATHWAYS FOR TURKEY

The co-benefits assessment for Turkey takes a policy-directed scenario approach, to connect with existing policy environments and learn from comparing the socioeconomic performance of various potential energy transition pathways in Turkey. In consultation with government and expert organisations, four scenarios were defined to assess the socio-economic implications of increasing the share of renewable energy in Turkey's future electricity generation mix in the year 2028 (see Figures ES.1 and ES.2 below): Building on the base year (2017) for this study, the four scenarios project an increase of total generation by one-third, from less than 300 TWh (2017) to around 400 TWh (2028).

1. **Base year (2017):** For the base year of the study the Turkish Electricity Transmission Corporation (TEİAŞ) reported 37.8 GW renewable energy installed capacity with a total generation of 85.1 TWh, accounting for 29 % of total power generation[2].

2. **Current Policy Scenario:** Based on projections by the Turkish Electricity Transmission Corporation (TEİAŞ) for 2026, proportionally adjusted for 2028. Under this scenario, in 2028 renewable energy installed capacity amounts to 61.5 GW, with a total generation of 142.0 TWh, accounting for 36 % of total power generation.

3. **New Policy Scenario:** Based on the Ministry of Energy and Natural Resources (MoENR) announcements of 1 GW annual increase in solar and wind capacity for 10 years, starting in 2018, as a part of its "National Energy and Mining Policy" (MoENR, n.d.). Under this scenario, in 2028 renewable energy installed capacity amounts to 69.5 GW, with a total generation of 167.1 TWh, accounting for 43 % of total power generation.

4. **Advanced Renewables Scenario A:** Under this scenario, in 2028 renewable energy installed capacity amounts to 77.5 GW, with a total generation of 181.5 TWh, accounting for 46 % of total power generation. This scenario is based on a report by SHURA (2018), which concluded that increasing installed wind and solar capacities to 20 GW each is feasible without any additional investment in the transmission system.

5. **Advanced Renewables Scenario B:** Under this scenario, in 2028 renewable energy installed capacity amounts to 97.5 GW, with a total generation of 217.0 TWh, accounting for 55 % of total power generation. This scenario is based on the same report by SHURA (2018), which concluded that increasing the solar and wind sector to 30 GW each is possible under the condition of a 30% increase in transmission capacity investment and 20 % increase in transformer substations investment.

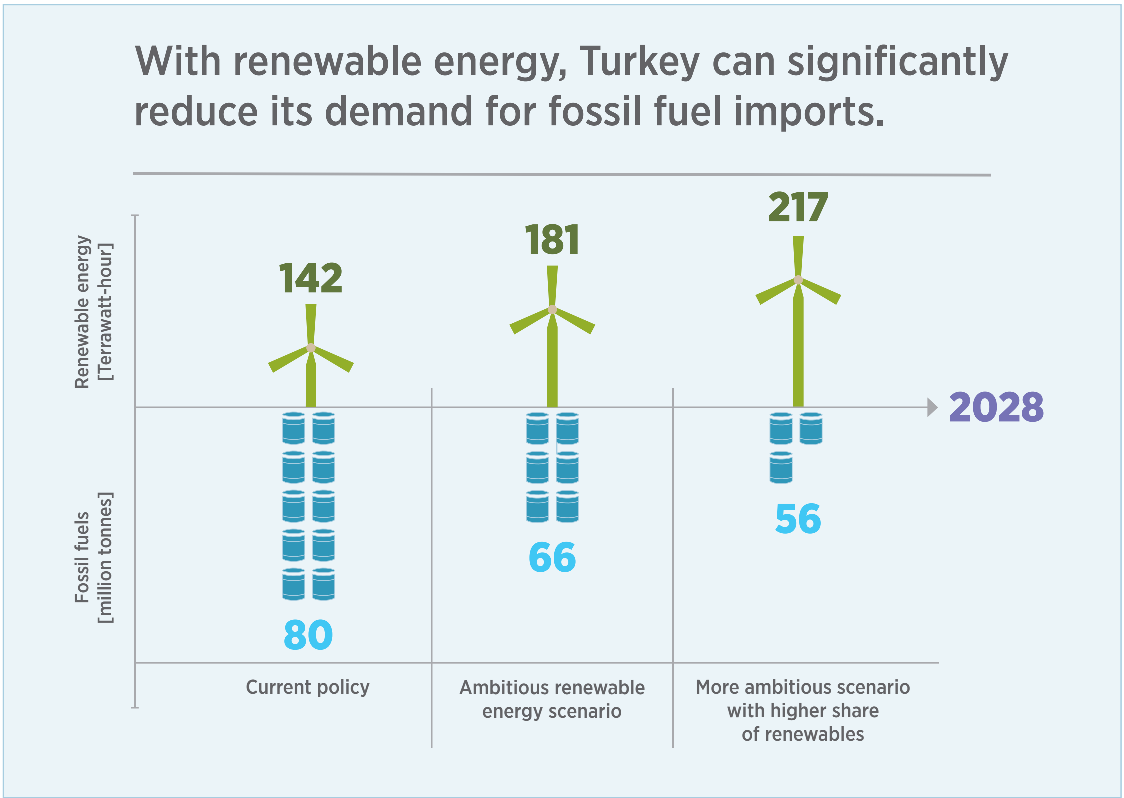
[2] The energy sources used to calculate the generation shares in this report cover 99 % of the power generated in the base year 2017. When including the remaining energy sources such as diesel or biomass, the rounded percentage of renewable energy sources (29 % for 2017) would remain unchanged. Hence, no major discrepancies are expected for the 2028 target year.

KEY FIGURES:

- Turkey is heavily reliant on fossil fuels imports: in 2017, more than 98% of the natural gas and 42% of the coal burned for electricity generation were from imported sources (EPDK, 2019).
- Turkey's coal reserves largely occur in the northwest of the country, and its natural gas resources are scarce[3]: 99% of natural gas used in the power sector was imported in the base year 2017. While lignite is available across the country, more than 90% of Turkey's domestic lignite reserves are of low calorific value with a heat rate of less than 3,000 Kcal/Kg.
- Renewable energy sources accounted for 29% of total power generation in 2017, increasing to 32% in 2018. Aside from hydro power (accounting for 20 GW), solar PV (3 GW) and wind power (6.5 GW) accounted for the highest non-fossil generation capacities. In 2018, solar PV capacities and wind power increased to 5 GW and 7 GW respectively (EPDK, 2019).
- It is feasible to more than double power generation from renewable energy sources, from 85.1 to 181.5 TWh (46% of total power generation), without any additional investment in the transmission system (own calculations; based on SHURA, 2018).
- The target for integration of renewables into the Turkish power system is 1 GW/year. However, current figures are not in line with this target (almost 0.6 GW/year in the Current Policy Scenario).

COBENEFITS
Securing Turkey's energy supply and balancing the current account deficit through renewable energy. Assessing the co-benefits of decarbonising the power sector

available on www.cobenefits.info



Key figure 1: Projected renewable energy generation and fossil fuels savings for Turkey in 2028

Source: own

[3] In 2017, the first natural gas production started in Çanakkale. In this province, the production amount was 1.48 million Sm3 in December 2017. (EPDK, 2018: 3)

KEY FINDINGS:

- Turkey can foster its energy independence and security of supply by increasing the use of its renewable energy sources: By the year 2028, Turkey can reduce its natural gas consumption by 16 % and 155 million MMBTU through scaling up renewable power generation without the need to increase foreseen investment in the transmission system (Advanced Renewables Scenario A, compared to the current policy pathway).

- By additional investment in transmission capacity (+30 % investment) and transformer substations (+20 % investment), renewable energy can allow Turkey to reduce its natural gas consumption by 38 % (300 million MMBTU) and overall fossil fuel demand in the power system by almost 30 % by the year 2028 (Advanced Renewables Scenario B, compared to the current policy pathway).

- Under the current policy pathway Turkey's power sector is expected to consume almost 80 million tonnes of fossil fuels in the year 2028. This total consumption can be reduced by 17% (to 66 million tonnes) and even by 30 %, by following the energy transition pathways Advanced Renewables Scenarios A and B respectively (see Key figure 1)

- Under the New Policy Scenario, economic savings on fossil fuels (including imports) are estimated as USD 728 million in the year 2028. Such savings could increase to more than USD 1 billion by increasing the share of renewable energy in power generation to 46 % (Advanced Renewables Scenario A). By additional investment in the transmission grid (Advanced Renewables Scenario B), allowing a 55 % share of renewable energy in power generation and reducing the levelised cost of electricity (LCOE) for renewable energy sources, economic savings can be almost doubled to USD 2.1 billion.

Fostering energy independence and ensuring security of supply with renewables.

© Dennis Schroeder/ NREL

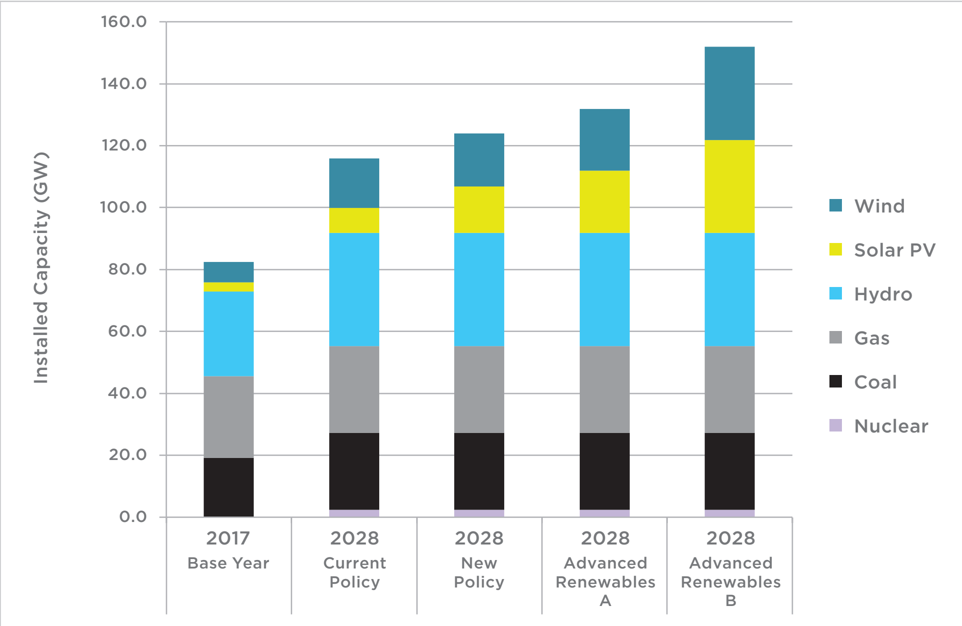


Figure ES.1: Electricity generation scenarios for different fuel types: installed capacities (GW)

Source: own, based on SHURA (2018), TEIAS (2018a), MoENR (2019)

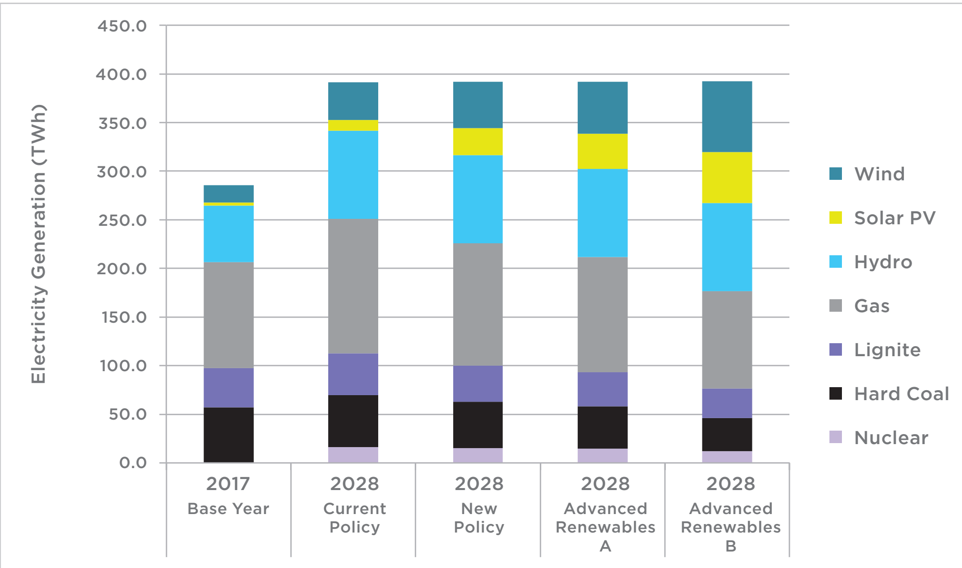


Figure ES.2: Electricity generation scenarios for different fuel types (TWh)

Source: own, based on SHURA (2018), TEIAS (2018a), MoENR (2019)

Contents

List of Tables

List of Figures

1. Status of Turkey's energy supply security under high dependency on fossil sources

KEY POINTS:

- Turkey is heavily reliant on fossil fuels imports: in 2017, 99% of the natural gas and 42% of the coal burned for electricity generation were from imported sources (EPDK, 2019). In 2017, 75% of electricity (206.4 TWh) was generated from fossil energy sources.
- Local reserves of fossil fuels in Turkey are insufficient to cover demand, and most of the resources are of low quality in terms of heat rate. Turkey's coal reserves are localised mainly in the northwest of the country, and natural gas resources are scarce[4]. While lignite is available across the country, more than 90% of Turkey's domestic lignite reserves are of low calorific value with a heat rate of less than 3,000 Kcal/Kg[5]. High dependence on fuel imports represents a threat to Turkey's future energy security while also increasing the country's current account deficit.
- Renewable energy sources accounted for 29% of total power generation in 2017, increasing to 32% in 2018. Aside from hydro power (20 GW), solar PV (3 GW) and wind power (6.5 GW) accounted for the highest non-fossil generation capacities. In 2018 solar PV and wind generation capacities increased to 5 GW and 7 GW respectively (EPDK, 2019).

Turkey's energy landscape and the issues of energy supply security and current account deficit

In the last 10 years, Turkey has diversified the national energy mix; installed capacities of renewables amounted to 2.7 GW (solar PV) and 6.5 GW (wind power) in 2017, the study's base year. In 2018 renewable energy installed capacities were increased to 5.06 GW (solar PV) and 6.99 GW (wind) respectively (TEİAŞ, 2019). Renewable energy sources (including hydro, geothermal, and waste) accounted for 29% of total electricity generation in 2017, increasing to 32% in 2018. However, Turkey's electricity generation is still heavily dominated by fossil fuels, accounting for 68% of total electricity generation in 2018. Natural gas generated 37.2% and coal 32.8% of electricity in the base year 2017 (TEİAŞ, 2019).

The energy transition in Turkey is inducing new investments in electricity production and energy in the country. The increasing relevance of renewable energies and climate change mitigation strategies is changing energy geopolitics, not only through changing patterns of demand for primary energy resources, but also in terms of energy independence and new local opportunities in clean energy generation.

While increasing the share of renewable energy resources in its energy mix, Turkey intends to reduce energy-related imports and to increase its energy security and energy independence. This motivated Turkey in implementing the Renewable Energy Resource Area (Yenilenebilir Enerji Kaynak Alanları – YEKA) scheme. In 2017, solar and wind tenders amounting to 2 GW capacity (1 GW each) were completed. The awarded consortiums were required to ensure that local content accounted for two-

[4] In 2017, the first natural gas production started in Çanakkale. Production in this province amounted to 1.48 Sm^3 (standard cubic metres) in December 2017 (EPDK, 2018: 3).

[5] Heat rate value for 2017, Average Tested Heat Rates by Prime Mover and Energy Source retrieved from eia.gov

thirds of the final project value. Such a policy framework is expected to support increases in domestic value-added and employment creation in the renewable energy sector.

The increased installed capacity of renewables in Turkey is insufficient to meet country's increasing energy demand. Turkey's demand for natural gas for electricity production increased by more than 24% within just one year (from 2016 to 2017) before showing a small 2% decrease in 2018 (Dünya, 2018a; EPDK, 2018). Natural gas consumption for electricity generation was around 16 billion m^3 in 2016 and reached 20 billion m^3 in 2017 (Bloomberg, 2019). Based on current natural gas consumption and electricity generation from gas-fired power plants, a conventional gas-fired power plant in Turkey consumes 220 m^3 of natural gas to generate 1 MWh electricity, which corresponds to 7,790 BTU/kWh heat rate (EIA, 2018).

The majority of fossil fuels burned for electricity generation in Turkey are imported: 99% of the natural gas[6] used in 2017 was imported from Russia (51%), Iran (16%), and Azerbaijan (11%) (City population, 2018). In 2017, 17% of electricity generation in Turkey's energy mix derived from imported coal. Of this, more than half of the hard coal was imported from Colombia, with almost another half from Russia, combined with comparatively modest imports from the United States (7%), Australia (5.3%), and South Africa (4.2%) (Euracoal, 2019). The total amount of Turkey's coal imports has increased significantly since 1980, mainly attributable to the low thermal value of domestic lignite and coal reserves and to the country's constantly increasing energy demand in recent years. The thermal value of a fossil fuel determines its efficiency. In 2018 Turkey reached an import threshold of around 72% dependence on fossil fuels (Euracoal, 2019).

Turkey's readily available reserves of hard coal are estimated to exceed 7 million tonnes and are found mainly in the northwest of the country close to the city of Zonguldak. On the other hand, readily available lignite reserves are estimated at around 12 million tonnes and are accessible throughout the country (Figure 1). Despite the availability of domestic hard coal and lignite, the currently available reserves have low thermal values compared with the equivalent fossil fuels available on international markets. The thermal value of the lignite reserves in Turkey ranges between 1,000 kcal/kg and 4,200 kcal/kg, and 90% of Turkey's domestic lignite reserves have a thermal value of less than 3,000 kcal/kg (EIA, 2018).

Figure 1: Major sites of lignite production in Turkey

Source: own

[6] Natural gas imports were from Russia, Iran, and Azerbaijan; Liquefied Natural Gas imports were from Nigeria and Algeria.

Securing Turkey's energy future

Fluctuations in the market prices of imported fossil fuels represent a threat in securing the energy supply future of Turkey. The increased deployment of renewables in Turkey will not only reduce the use of fossil fuels and generate economic savings by reducing fossil fuel imports, but can also create an impact by reducing energy dependence on imported fossil fuels.

Between 2013 and 2017, Turkey's total current account deficit was 220 billion USD (Figure 2) (Dünya, 2018b). More than 85% (188 billion USD) of that deficit derived from the energy sector. For the same period, imports from the energy sector were 213 billion USD while exports accounted for 25 billion USD. The deficit within the energy sector includes not only fuel imports, but all imports related to the energy sector and the energy supply chain. However, the increasing importation of fossil fuels is the main detriment to the present energy trade deficit and to Turkey's total current account deficit. Figure 2 shows the total current account deficit and energy imports related to current account deficit per year. Energy imports increased more than 40% from 2016 to 2017, accounting for 37.2 billion USD (Figure 2) (Dünya, 2018b).

Given Turkey's abundance of domestic renewable energy resources, these can be expected to generate positive co-benefits in balancing the country's current account deficit of the energy sector and in reducing the considerable energy dependency on imports from other countries. A recent study conducted by the SHURA Energy Transition Center provided technical evidence that it is feasible to almost triple power generation from renewable energy sources, from 68 TWh to more than 180 TWh (46% of total power generation), without any additional investment in the transmission system (own calculations; based on SHURA, 2018). Additional investment in Turkey's transmission system would enable renewable energy generation capacity of almost 100 GW relative to total generation of more than 200 TWh, thereby accounting for 55% of total power generation (own calculations; based on SHURA, 2018). In contrast, the target for integrating renewables into the Turkish power system is 1 GW/year. However, current figures are far from meeting this target (around 0.6 GW/year).

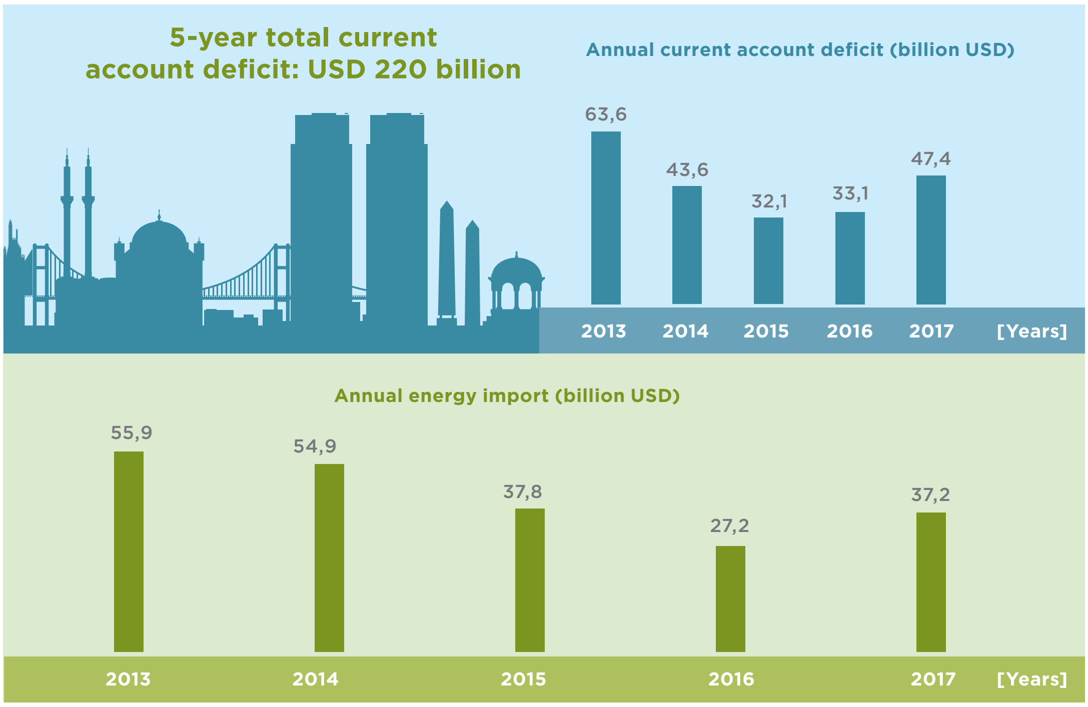


Figure 2: Yearly current account deficit and energy imports between 2013 and 2017

Source: Data based on: Dünya, 2018b

2. Study methodology and power system scenarios

This study assesses the contribution of renewable energy sources toward reducing the demand for fossil fuels and thus for associated fossil fuel imports. The assessment builds on a series of quantitative analyses, including a Renewable Energy Sources (RES) capacity penetration scenario analysis, a market and network simulation, and a levelised cost of electricity (LCOE) analysis, based on investment and in the operation and management (O&M) cost of renewable energy for different Weighted Average Cost of Capital (WACC) assumptions.

The co-benefits assessment for Turkey takes a policy-directed scenario approach, to connect with existing policy environments and learn from comparing the socioeconomic performance of various potential energy transition pathways in Turkey. The comparative approach reveals the impacts on Turkey's energy security by forecasting the market behaviours of fossil fuels and renewables. This approach also allows the results to be directly assessed against Turkey's current and future policy options.

In consultation with government ministries[7] and expert organisations, four scenarios were defined to assess the socio-economic implications of increasing the share of renewable energy (including hydro power) in Turkey's future electricity generation mix in the year 2028.

2.1 Reference policy pathways for Turkey's power sector

This study employs a comparative scenario approach to examine the opportunities and co-benefits available for Turkey to improve its energy security and also balance current trade deficits by adopting various policy pathways for expanding its renewable energy capacity. The reference policy pathways for Turkey's power sector were developed and selected in consultation with governmental and expert organisations, to allow for:

- Connectivity and comparability with Turkey's official climate and energy policies, strategies, or roadmaps (existing or considered), in order to ensure political relevance and usability of the assessment results.

- Suitability as calculation basis for scientifically sound, quantitative assessments of socio-economic impacts.

The co-benefits assessment for Turkey takes a policy-directed scenario approach, to connect with existing policy environments and learn from comparing the socioeconomic performance of various potential energy transition pathways in Turkey. In consultation with government and expert organisations, four scenarios were defined to assess the socio-economic implications of increasing the share of renewable energy (wind and solar) in Turkey's future electricity generation mix in the year 2028 (see Figure 3 and Figure 4). The 2028 reference year for the scenarios was set to address immediate socio-economic impacts and opportunities within this decade. Building on the base year (2017) for this study, the four scenarios project an increase of total generation by one-third, from less than 300 TWh (2017) to around 400 TWh (2028).

1. **Base year (2017):** For the base year of the study the Turkish Electricity Transmission Corporation (TEİAŞ) reported 37.8 GW renewable energy installed capacity with a total generation of 85.1 TWh, accounting for 29% of total power generation[8].

2. **Current Policy Scenario:** Based on projections by the Turkish Electricity Transmission Corporation (TEİAŞ) for 2026, proportionally adjusted for 2028. Under this scenario, in 2028 renewable energy installed capacity is 61.5 GW, with a total generation of 142.0 TWh, accounting for 36% of total power generation.

[7] The Ministries of Energy and Natural Resources (MoENR), Environment and Urban Affairs (MoEU), Treasury and Finance (MoTF; formerly Ministry of Economics, MoE), Foreign Affairs (MoFA), and Health (MoH) were consulted through their engagement in the COBENEFITS Council Turkey in 2018/2019.

3. **New Policy Scenario:** Based on the Ministry of Energy and Natural Resources (MoENR) announcements of 1 GW annual increase in solar and wind capacity for 10 years, starting in 2018, as a part of its "National Energy and Mining Policy" (MoENR, n.d.). Under this scenario, in 2028 renewable energy installed capacity is 69.5 GW, with a total generation of 167.1 TWh, accounting for 43% of total power generation.

4. **Advanced Renewables Scenario A:** Under this scenario, in 2028 renewable energy installed capacity is 77.5 GW, with a total generation of 181.5 TWh, accounting for 46% of total power generation. This scenario is based on a report by SHURA (2018), which concluded that increasing installed wind and solar capacity to 20 GW each is feasible without any additional investment in the transmission system.

5. **Advanced Renewables Scenario B:** Under this scenario, in 2028 renewable energy installed capacity is 97.5 GW, with a total generation of 217.0 TWh, accounting for 55% of total power generation. This scenario is based on the same report by SHURA (2018), which concluded that increasing the solar and wind sector to 30 GW each is possible under the condition of a 30% increase in transmission capacity investment and 20% increase in transformer substations investment.

The four reference policy pathways for Turkey's power sector have been defined for the COBENEFITS assessment studies in Turkey, based on government policy documents as well as the methodological approach developed in the SHURA Energy Transition Center report on Turkey's future renewable energy shares in electricity generation[9]. Electricity generation data for the 2017 base year and the 2028 scenarios are provided in Table 1 .

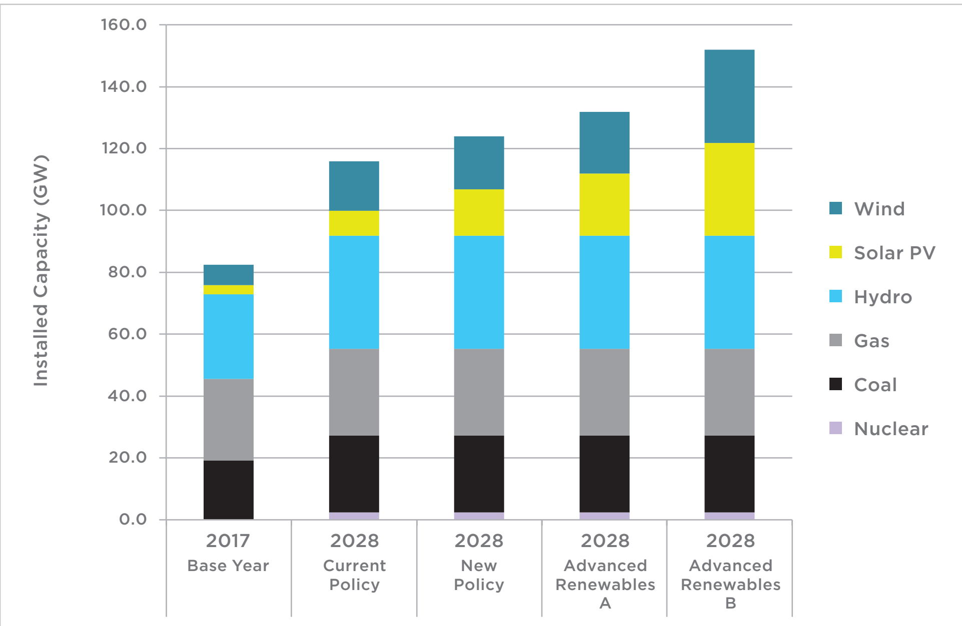


Figure 3: Installed capacities (GW): base year and projections under different scenarios

Source: own, based on SHURA (2018), TEIAS (2018a), MoENR (2019)

[9] Increasing the Share of Renewables in Turkey's Power System: Options for Transmission Expansion and Flexibility. SHURA Energy Transition Center, 2018.

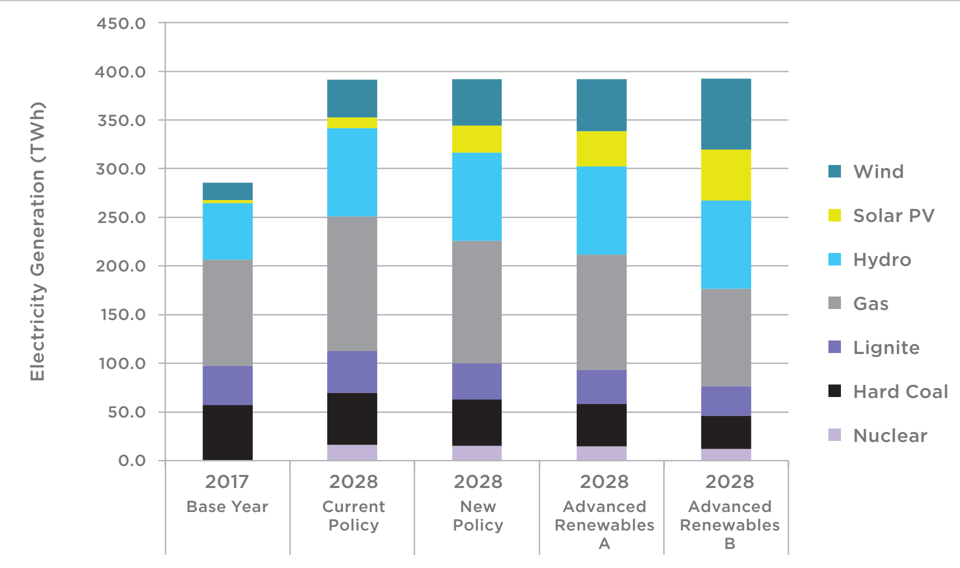


Figure 4: Electricity generation (TWh): base year and projections under different scenarios

Source: own, based on SHURA (2018), TEIAS (2018a), MoENR (2019)

Type of Fuel	Base Year 2017	2028 Scenario 1: Current Policy Scenario	2028 Scenario 2: New Policy Scenario	2028 Scenario 3: Advanced Renewables Scenario A	2028 Scenario 4: Advanced Renewables Scenario B
Hard Coal	57.0	53.5	47.5	43.6	34.0
Lignite	40.6	43.1	37.5	35.1	30.5
Natural Gas	108.8	138.3	125.5	118.3	100.1
Nuclear	0.0	16.1	15.3	14.5	11.9
Solar PV	2.9	10.8	27.8	36.4	52.5
Wind	17.9	38.9	47.3	53.2	72.9
Hydro	58.4	90.8	90.8	90.8	90.8

Table 1: Electricity generation (TWh): base year and projections under different scenarios

Source: own, based on SHURA (2018), TEIAS (2018a), MoENR (2019)

Base year 2017 data are based on TEİAŞ reports. 2028 Projections defined for the COBENEFITS assessment studies in Turkey, based on government policy documents as well as the methodological approach developed by the SHURA Energy Transition Center.

2.2 Multi-stage assessment methodology

Estimated heat rate of power plants and quality of fuel

Short-run marginal costs (SRMC) are estimated by calculating the heat rate of existing power plants and the quality of the burned fossil fuels. Heat rate is measured in units of BTU/kWh[10], expressing the thermal efficiency of the power plant when transforming fuel into electricity. Figure 5 shows the average heat rate for different fossil fuels (EIA, 2018).

The quality of the fuel is determined by its weight and energy potential. Hard coal includes coking and steam coal, which are among the most energy efficient fossil fuels with more than 5,700 kcal potential energy per kilogram. Low-efficiency coal with less than 5,700 kcal per kilogram is categorised as brown coal and is divided into subbituminous and lignite types.

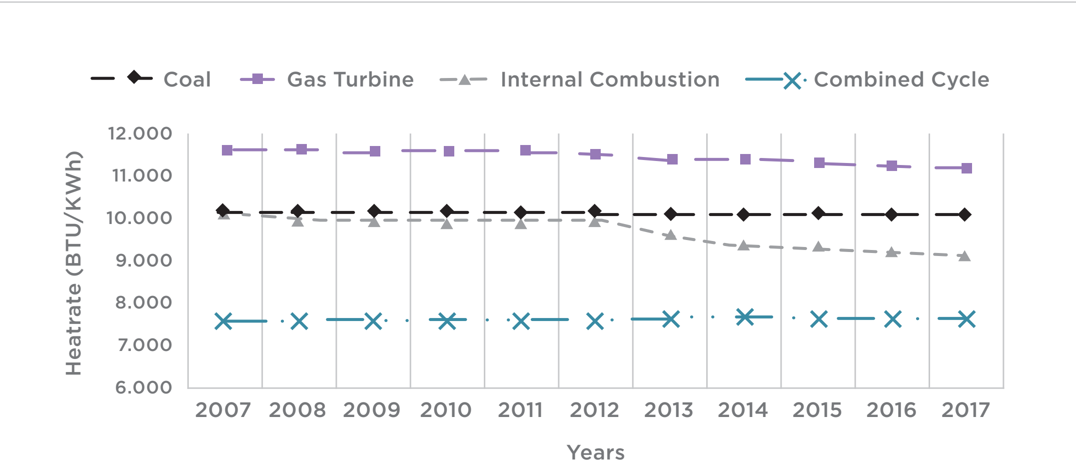


Figure 5: Average heat rate by fossil fuel technology (2007–2017)

Source: own

Fuel price forecasts

Fuel prices are forecast by calculating the price per one thousand British Thermal Units (MBTU), using the following equation:

$$\frac{\$}{tonne} * \frac{tonne}{quality\ (thousand\ kcal)} * \frac{7{,}000{,}000\ kcal}{1\ tce} * \frac{1\ tce}{27.7\ MBTU} = \frac{\$}{MBTU}$$

[10] Also frequently measured as MMBTU (1 million British thermal units) per MWh: Heat rate is a measure of the thermal efficiency of a power plant in converting fuel to electricity. It measures the amount of heat input (in units of BTU per hour) for each kWh of electricity generated. Although the common reference for heat rate is BTU/kWh, units of MMBTU/MWh are also commonly used in many reports. Power plants that burn coal or natural gas tend to have different heat rates. 1 MMBTU is equal to 1 million BTU (British thermal units). Natural gas is measured in MMBTU, where 1 MMBTU = 28.263682 m^3 of natural gas at defined temperature and pressure.

The conversion factors utilised in this equation are retrieved from the National Academy Press (NAP, 2007). The price forecast considers local and imported fossil fuels prices to 2028 based on a logarithmic regression of historical fossil fuels prices.

Fuel quality is measured according to the thermal value of the fossil fuel. The higher the thermal value, the more efficient the fossil fuel is in terms of power generation. The minimum thermal value assigned for local lignite is 1,600 kcal/kg (TTKGN, 2016), between 6,200 kcal/kg and 7,250 kcal/kg for local hard coal, and 6,600 kcal/kg for imported hard coal (TTKGM, 2016). Table 2 summarises the fuel cost, heat rate, and SRMC for lignite, local and imported hard coal, and imported natural gas.

Fuel Type	Market Price (USD/tonne)	Quality (thousand kcal)	$/MBTU	Heat Rate (MBTU/MWh)	SRMC (USD/MWh)
Local lignite	13.00	1,600	2.05	11.2	22.93
Local hard coal	95.51	7,000	3.42	10.4	35.57
Imported hard coal	82.21	6,600	3.14	10.2	32.02
Natural gas	–	–	7.33	8.5	62.31

Table 2: SRMC average forecast by fossil fuel in 2028

Source: own, based on TTKGN, 2016

Renewables forecast

Electricity price calculation requires the sum of fixed and variable costs such as land, labour, fuel, and investment costs. The annualised fixed cost (AFC) of electricity estimates the fixed cost of constructing a power plant over its expected lifetime, and is useful for supporting investment decisions and to calculate the electricity cost. The following equation is used throughout the assessment to calculate AFC:

$$AFC = \frac{C_{fix}\ x\ \rho\ x\ (1+\rho)^L}{(1+\rho)^L - 1}$$

Fixed cost (C_{fix}) is a technology-dependent cost generally categorised in terms of the fuel used to generate electricity. Alternative energy sources tend to have higher capital cost requirements attributable to the ongoing innovation surrounding the technology. Solar thermal towers with storage, fuel cells, and geothermal energy sources, as well as rooftop-type small-scale solar facilities, have two-three times higher capital cost compared to utility-scale wind and solar options. While capital costs for reasonably small-scale renewable energy source technologies currently exceed those of natural gas and some coal technologies, expected technological advances, in addition to the uncertainty of long-term conventional fuel costs, are closing this formerly wide gap in costs.

AFC is presented in currency per kW per year (Figure 6). The fixed cost in currency per KW at the time of investment decision (C_{fix}) is categorised in terms of fuel used to generate electricity. The discount rate (p) as the weighted average cost of capital (WACC), and the technical lifetime of the power plant is (L)[11].

[11] The discount rate may differ between countries depending on capital availability and capital risk.

The discount rate in calculating AFC is managed as the WACC. WACC is the return on investment that reflects the alternative costs of investment in related assets. It is calculated by country and by sector using the following equation:

$$WACC = \rho = (share\ of\ equity\ x\ the\ cost\ of\ equity) + (share\ of\ debt\ x\ the\ cost\ of\ debt)$$

Cost of equity reflects the foregone return that investors might otherwise have earned on an alternative investment. Meanwhile, the cost of debt is the interest rate paid by a company to its debtholders and creditors. This reports assigns 30% equity and 70% debt structure to its investments, based on the investor's report elaborated by the Akenerji electric company (Akenerji, 2016). The WACC is among the important factors that influence the levelised cost of electricity (LCOE) applied later in the market and network simulations.

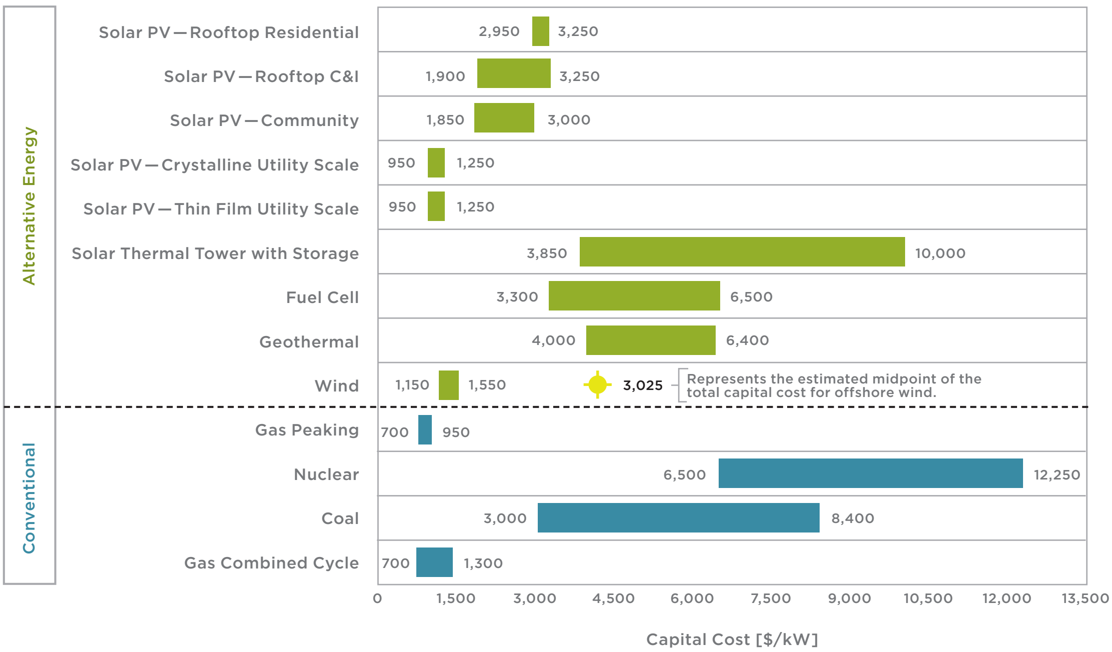


Figure 6: Capital cost comparison by technology

Source: LAZARD LCOE, 2018

Market and network simulation

The methodology is based on a consecutive [market simulation/network simulation] cycle conducted at hourly resolution throughout the entire target year 2028 (see Figure 7).

The market simulation platform developed by the Institute of Engineering, Procurement, Research and Analysis (EPRA) estimates a day-ahead power exchange (PX) electricity market for Turkey to 2028 (SHURA, 2018).

Figure 7: Consecutive market and network simulations

Source: own

Consecutive market and network simulations are the core of the methodology. In the market simulation, the supply–demand balance of the power system is satisfied hourly for the entire target year at a minimum total cost of generation and RES curtailment. Market simulation optimises the PX market clearing process. Network security and reliability (S&R) constraints and spinning reserve requirements are ignored in the market simulation, which is the case in the Turkish PX market. Market simulation indeed represents the role of the market operator (EPIAS) in the day-ahead PX market in Turkey, not only for a single day but for the entire target year. Market and network simulations for different scenarios essentially forecast the reductions in fossil fuel imports under different RES penetration scenarios. Impacts on current account deficit are calculated based on fuel price forecasts. The main outputs of the market simulations include:

- Market clearing for the target year (hourly resolution).
- Unit commitment (UC) of conventional generators (hourly resolution).
- Cost of generation (hourly resolution).
- Amount of RES curtailment, if any.

The outputs of the market simulation are used as inputs to the network simulation. Network simulation represents the role of the transmission system operator (TSO), TEİAŞ in Turkey, in determining a suitable transmission network and system operation that ensures S&R of the grid. The market simulation contains a high level of detail only with regard to temporal resolution (8760 hours per year), whereas the level of complexity is much higher in the network simulation as it also has high spatial resolution.

Figure 8 presents a flowchart showing the consecutive market and network simulation approach. As illustrated in the figure, the first step is the market simulation, which clears the PX market along the year based on a merit order. It is a mixed-integer programming (MIP) problem including dynamic unit commitment (UC) of power plants under short- and long-term operational constraints. UC in the market simulation provides market tendency in a PX-market. Although in a day-ahead market the clearing price (MCP) and commitment of the power plants are defined based on bids and offers from the market players, in a long-term planning problem, UC based on the SRMC of power plants is the widely accepted approach in the literature. Since the MCP is defined by the marginal plant in a marginal-based PX market, the main assumption in the study is that all market players are bidding based on their SRMC.

In the second step, load flow analyses are performed using the outputs from the market simulation. Load flow analysis indicates the amount of energy congestion and the duration of overloading in the transmission grid along the target year. The system is obviously required to function appropriately (i.e., to maintain standard voltages, acceptable currents, etc.). The third step is the assessment of transmission investment requirements based on the amount of energy congestion on the transmission grid. Cost–benefit analyses (CBA) are performed to identify cost–benefit-driven transmission grid investments. It is assumed that if the annual amount of congested energy *per km* on a transmission line exceeds a predefined threshold value, it is feasible to reinforce the corridor. The threshold is the annual investment cost of reinforcing the corridor *per km*. Unit cost values are taken from TEİAŞ[12]. The transmission grid model of the target year (2028) is updated by considering transmission investments driven by the CBA. This process continues until no additional grid investments are recommended by iterative market simulations and CBA.

[12] www.teias.gov.tr

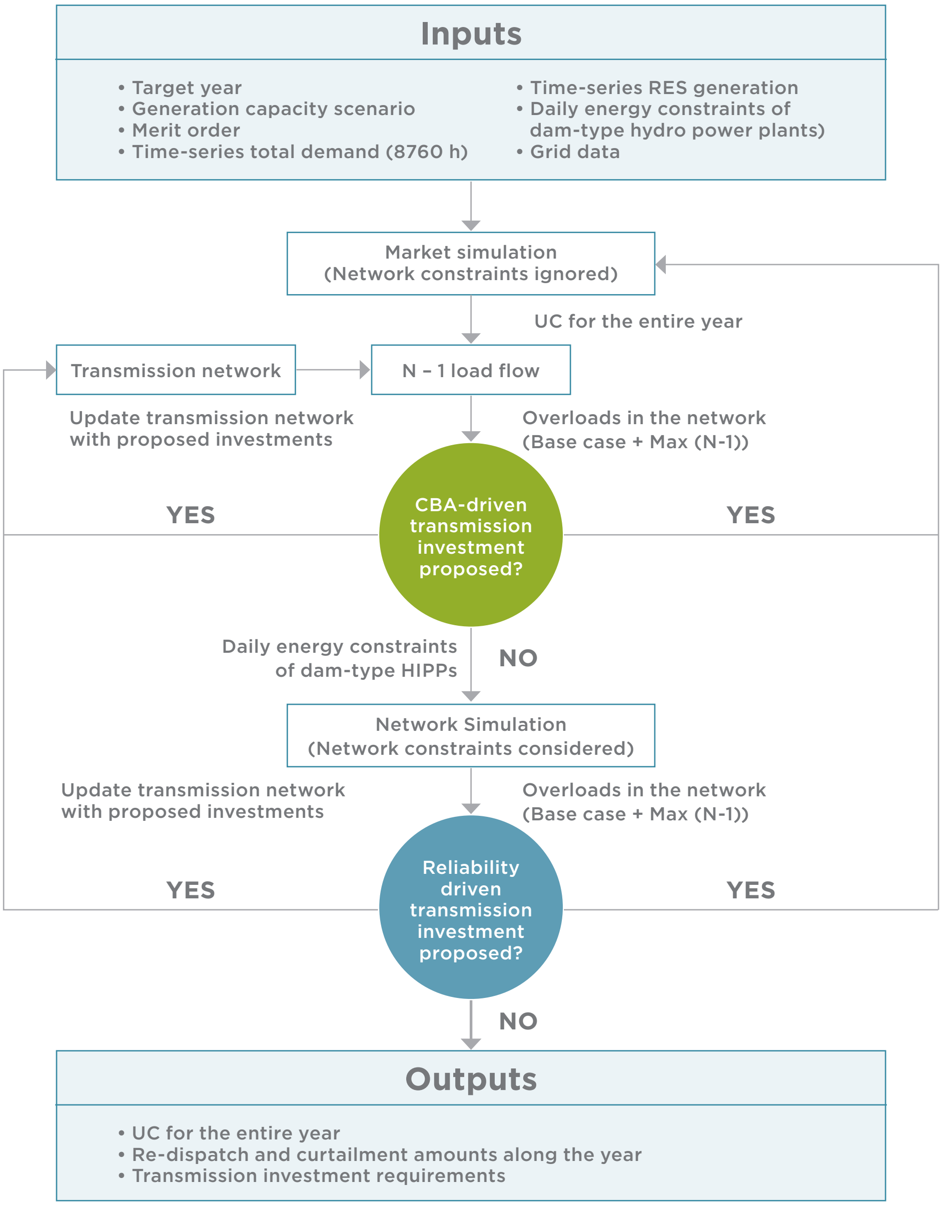


Figure 8: Flowchart of the simulation methodology

Source: own

Network simulations are performed in the fourth step using the market simulation results as the initial operating point of the power plants. Differently from the market simulation, the network simulations consider transmission network constraints. The constraints include security (overloading on the network branches) and spinning reserve requirements. Network simulations minimise re-dispatch amounts of power plants and curtailment costs while satisfying the network constraints.

The UC solution in the market simulation is considered as the reference for calculating re-dispatch amounts in the network simulations. UC in the network simulations provides optimum re-dispatch amounts if compared to this reference. It thereby enables trade-offs between short-term operational measures (re-dispatch, RES, and/or load curtailment, etc.) and long-term investment solutions.

Finally, reliability-driven transmission investments are defined based on *n-1* contingency analysis performed under network simulations. Transmission investments, which are identified to satisfy *n-1* contingency criteria, are included in the transmission model, as illustrated in Figure 7. Market and network simulations are run iteratively until no cost–benefit and reliability-driven transmission investments are required.

3. Increasing Turkey's energy supply security: fuel and economic savings from reducing fossil fuels

KEY POINTS:

- Turkey can foster its energy supply security and independence by increasing the use of its renewable energy sources: By the year 2028 Turkey can reduce its natural gas consumption by 16% and 155 million m^3 through scaling up renewable power generation. This can be achieved without increasing planned investment in the transmission system (Advanced Renewables Scenario A, compared to the current policy pathway).
- By additional investing into transmission capacity (+30% investments) and transformer substations (+20%), renewable energy can allow Turkey to reduce its natural gas consumption by 38% (300 million m^3) and the overall fossil fuels demand in the power system by almost 30% by the year 2028 (Advanced Renewables Scenario B, compared to the current policy pathway) (Table 4).
- Under the current policy pathway, total fossil fuel consumption (millions of tonnes) by Turkey's power sector will be almost 80 million tonnes in the year 2028. This total consumption can be reduced by 17% (to 66 million tonnes) under the Advanced Renewables Scenario A, and by 30% under Advanced Renewables Scenario B (Table 3).
- Under the New Policy Scenario, economic savings from reduced fossil fuel imports and consumption are estimated as USD 728 million in the year 2028. Such savings could increase to more than USD 1 billion by increasing the share of renewable energy in power generation to 46% (Advanced Renewables Scenario A). By additional investment in the transmission grid, allowing a 55% share of renewable energy in power generation and reducing the levelised cost of electricity (LCOE) for renewable energy sources, economic savings can be almost doubled to USD 2.1 billion (Advanced Renewables Scenario B).

Fuel	Total Generated Energy 2028 (TWh)				Total Amount of Fuel 2028 (Million tonnes)			
	Current Policy Scenario	New Policy Scenario	Advanced Renewables Scenario A	Advanced Renewables Scenario B	Current Policy Scenario	New Policy Scenario	Advanced Renewables Scenario A	Advanced Renewables Scenario B
Gas	138.3	125.5	118.3	100.1	31.45	28.54	26.9	22.76
Coal	53.5	47.5	43.6	34	8.42	7.47	6.86	5.35
Lignite	43.1	37.5	35.1	30.5	39.79	34.62	32.4	28.15
Sum	234.9	210.5	197.0	164.6	79.66	70.63	66.17	56.26

Table 3: Annual required amount of gas, coal, and lignite for each scenario by 2028

Source: own

The analysis suggests that by 2028 Turkey can reduce electricity generation from fossil fuels by 15% (from 138 TWh generation in the Current Policy Scenario to 118 TWh) without the need to increase foreseen investment in the transmission system (Advanced Renewables Scenario A). In order to further reduce dependency on fossil fuel imports, scaling up renewable energy sources in line with Advanced Renewables Scenario A would allow a 27% reduction in electricity generated from fossil fuels compared to the current policy pathway.

In view of gas imports, the analysis indicates that by the year 2028 Turkey can reduce its natural gas consumption by 16% and 155 million MMBTU through scaling up renewable power generation without the need to increase foreseen investment in the transmission system (Advanced Renewables Scenario A, compared to the current policy pathway). Additional investment in transmission capacity (+30%) and transformer substations (+20%) for renewable energy can allow Turkey to reduce its natural gas consumption by 38% (300 million MMBTU) and the overall fossil fuel demand of the power system by almost 30% by the year 2028 (Advanced Renewables Scenario B, compared to the current policy pathway) (Table 4).

At present, Turkey is highly dependent on imports for the natural gas that it utilises for power generation (in 2017, 99% of natural gas was imported. Main sources: Russia 51%, Iran 16%, Azerbaijan 11%, cf section 1). The results presented here indicate that renewable energy sources can play an important role of reducing Turkey's dependency on imported energy.

Natural Gas	2028			
	Current Policy Scenario	New Policy Scenario	Advanced Renewables Scenario A	Advanced Renewables Scenario B
Energy generation (TWh)	138.30	125.50	118.30	100.10
Volume equivalent (m^3)	30,426,000,000	27,610,000,000	26,026,000,000	22,022,000,000
Thermal unit equivalent (MMBTU)	1,074,037,800	974,633,000	918,717,800	777,376,600
Turkey's fossil fuels savings (MMBTU)	–	99,404,800	155,320,000	296,661,200
Turkey's financial savings (USD)[13]	–	728,637,184	1,138,495,600	2,174,526,596

Table 4: Fossil fuel generation, fuel, and savings for each scenario by 2028

Source: own

Under the New Policy Scenario, economic savings from reduced importation and use of fossil fuels are estimate as USD 728 million in the year 2028. These savings could increase to more than USD 1 billion by increasing the share of renewable energy in power generation to 46% (Advanced Renewables Scenario A). By additional investment in the transmission grid, allowing a 55% share of renewable energy in power generation and reducing the levelised cost of electricity (LCOE) for renewable energy sources, economic savings can be almost doubled to USD 2.1 billion (Advanced Renewables Scenario B).

As Turkey is currently a net energy importer despite abundant local and renewable energy sources (see section Status of Turkey's energy supply security), an accelerated energy transition oriented towards the Advanced Renewables Scenarios will have a positive impact on the current account deficit of Turkey's power sector.

Furthermore, Turkey can contribute to national and international endeavours to combat climate change, and the resulting global warming impacts for Turkey, by accelerating its energy transition. Choosing the Advanced Renewables Scenario B would replace more than 38.30 TWh of fossil fuel energy generation with a cleaner generation mix of wind and solar while also providing economic savings and benefiting energy security by reducing imports.

[13] A natural gas price of USD 7.33/MMBTU is assumed.

4. Creating an enabling environment to increase Turkey's energy security and independence

Impulses for furthering the debate

This COBENEFITS study shows that Turkey can significantly increase its energy supply security, reduce the current account deficit, and achieve cost savings in the power sector by scaling up renewable energies.

The renewable energy policy framework in Turkey should aim for increased installed capacity of renewables, building an independent domestic energy market, and enabling savings on fossil fuels and related imports.

Market fluctuations in the prices of imported fossil fuels represent a threat to Turkey's future energy security. The deployment of renewables in Turkey can reduce the use of fossil fuels and deliver associated economic savings. Furthermore, a shift away from fossil fuels can also create a positive impact by reducing uncertainty and energy dependence on imported fossil fuels. Additionally, renewables can simultaneously generate economic savings by reducing fuel imports while also contributing to balancing the current account deficit of Turkey's energy sector.

Turkey can substantially reduce demand for fossil fuels and consequently its fossil fuel imports. Turkey can reduce natural gas consumption to almost 300 million MMBTU in 2028 under Advanced Renewables Scenario B. By reducing its fossil-based energy imports, Turkey has the opportunity to achieve savings of USD 728 million, 1.1 billion, and 2.1 billion under the New Policy Scenario, and Advanced Renewables Scenarios A and B, respectively.

How can Turkey maximise the co-benefits of the assessment?

Maximising the co-benefits of energy security will depend on increasing the flexibility of the national power system. Enabling flexibility within existing energy supply technologies and mechanisms such as increasing the use of energy storage devices can reduce the impact of renewables intermittency and integrate renewables into the grid in more flexible ways. A lack of grid flexibility results in higher LCOE for renewables, due to renewable curtailment under ambitious renewable integration scenarios. Increasing system flexibility through storage, increasing the flexibility of existing power plants, and improving demand response can help further drive down grid-related costs.

What can government agencies and political decision makers do to create a suitable enabling environment to increase energy security in Turkey?

The integration of renewables to the power system requires that the Energy Market Regulatory Authority (EPDK) together with the Turkish Electric Transmission Corporation (TEİAŞ) create an enabling environment that incentivises the deployment of renewables and increases the security of the country's power grid. Turkey's electricity regulatory authorities can design mechanisms to incentivise and attract local and foreign investment on renewables within the structure of capital expenditure investments or operational expenditure investments.

[14] Green certificates are tradable commodities proving that certain electricity is generated using renewable energy sources (Renewable Energy World, 2020).

Green certificates for renewable generators, issued by the energy market operator EPIAS, could provide a positive incentive to scale up renewables[14]. Furthermore, building and expanding a capacity market for renewables can also act as an incentive to scale up renewables in Turkey. The Government of Turkey has successfully completed two tenders to build 1,000 MW wind and 1,000 MW solar PV plants (TEİAŞ, 2019).

A feed-in tariff mechanism has been already introduced in Turkey since 2013 by the electricity regulatory authorities to incentivise renewables. The tariff allows the sale of renewables at higher than market prices. However, with the proliferation of renewables, a feed-in-tariff might be regarded as less efficient, as it might reduce the competitive nature of the electricity market. For instance, Figure 9 compares LCOE for different technologies under the COBENEFITS assessment scenarios for renewable integration.

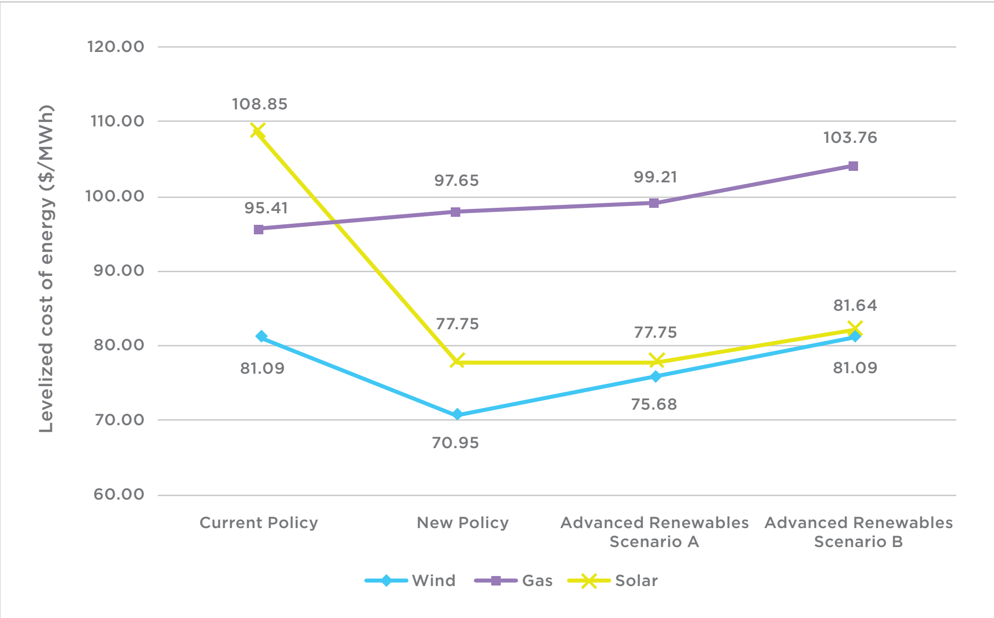


Figure 9: Levelised cost of electricity for each scenario by 2028

Source: own

As seen in Figure 9, a shift from the Current Policy to the New Policy Scenario may reduce the LCOE of renewables in comparison with gas, which implies that the LCOE of renewables is more competitive in the electricity market. However, shifting from the New Policy Scenario to Advanced Renewables Scenarios A and B increases the LCOE provided by renewables. This increase in LCOE is explained by the curtailment of renewables due to present constraints within the power system. Here, the electricity market regulatory authority should incentivise renewables at operational expenditure level to prevent a cost increase in the LCOE of renewables. Consequently, more renewables can be integrated into the system when competing in the electricity market. Investment at the level of operational expenditures can be incentivised through an accessible, predictive grid maintenance structure enforced by EPDK that can reduce operating expenses (OPEX) and improve the overall reliability of the grid.

Considering the power system operation capabilities and accountabilities, Turkey's energy planning should consider including intermittency of renewables at the planning stage. A common practice when undertaking energy planning in the power system is the implementation of peak and off-peak conditions. However, the generation profiles of renewables should be considered when increasing their share in the future electricity mix. Focusing on renewables planning will not only increase the potential for integrating renewables but will also reduce associated LCOE by easing curtailments.

References

Akenerji 2016. AKENERJİ ELEKTRİK ÜRETİM A.Ş. http://www.akenerji.com.tr/Dosya/Dokuman/investor_presentation-20160.pdf. Istanbul: Akenerji, 2016.

Basu, Sudip Ranjan. "Retooling Trade Policy in Developing Countries: Does Technology Intensity of Exports Matter for GDP Per Capita?" *Policy Issues in International Trade and Commodities* (56). New York and Geneva: UNCTAD/ITCD/ TAB/, 2011.

Bazilian, Morgan et al. "Model and manage the changing geopolitics of energy". Nature 569, 29–31 (2019). doi: 10.1038/d41586-019-01312-5.

Bloomberg 2019. Doğal gaz tüketimi 2018'de yüzde 8,28 azaldı. https://www.bloomberght.com/haberler/haber/2200741-dogal-gaz-tuketimi-2018-de-yuzde-8-28-azaldi. Bloomberg, February 2019.

City population 2018. *Natural gas imports turkey.* http://world.bymap.org/NaturalGasImports.html.

Dünya 2018a. Doğalgaz ithalatında rekor kırıldı. https://www.dunya.com/ekonomi/dogalgaz-ithalatinda-rekor-kirildi-haberi-403703. Istanbul: Dünya, February 2018.

Dünya 2018b. Türkiye'nin cari açığında 'enerji' yük oldu. https://www.dunya.com/ekonomi/turkiyenin-cari-aciginda-enerji-yuk-oldu-haberi-416032. Istanbul: Dünya, May 2018.

EIA, E. F, 2018. Annual electric generator report. *Energy Information Administration, Department of Energy.* Washington DC: EIA, 2018.

EPDK, 2018. Energy Market Regulatory Authority. Elektrik Piyasası 2017 yılı Piyasa Gelişim Raporu [Electricity Market 2016 Progress Report]. Ankara: TEİAŞ, 2018.

EPDK, 2019. Energy Market Regulatory Authority. Elektrik Piyasası 2018 yılı Piyasa Gelişim Raporu *[Electricity Market 2016 Progress Report].* Ankara: TEİAŞ, 2019.

Euracoal, 2019. Country profile Turkey. https://euracoal.eu/info/country-profiles/turkey/. Brussels: Euracoal, 2019.

European Centre for Medium-Range Weather Forecasts, 2020. "ECMWF," [Online]. Available: http://www.ecmwf.int/. 2018 data.

Helgenberger, Sebastian, Martin Jänicke and Konrad Gürtler. "Co-benefits of Climate Change Mitigation." In: Leal Filho, W., et al. (Eds.), *Climate Action: Encyclopedia of the UN Sustainable Development Goals.* Cham: Springer International Publishing, 2019. DOI: http://doi.org/10.1007/978-3-319-71063-1_93-1

IASS 2017a. *Generating socio-economic values from renewable energies: An overview of questions and assessment methods.* Potsdam: IASS Working Paper, July 2017. DOI: http://doi.org/10.2312/iass.2017.016

IASS 2017b. *Mobilizing the co-benefits of climate change mitigation: Connecting opportunities with interests in the new energy world of renewables.* Potsdam: IASS Working Paper, July 2017. DOI: http://doi.org/10.2312/iass.2017.015

IASS 2019. *Strengthening International Cooperation for a Global Energy Transition.* Potsdam: IASS Policy Brief, April 2019. DOI: http://doi.org/10.2312/iass.2019.011

IASS 2020. Reviving national economies and health systems following the COVID-19 pandemic. COBENEFITS Factsheet, May 2020 – accessible online: www.cobenefits.info

IASS/IPC 2019. Industrial development, trade opportunities and innovation with renewable energy in Turkey. Assessing the co-benefits of decarbonising the power sector. Potsdam/Istanbul: IASS/IPC, . www.cobenefits.info

International Energy Agency 2018. *Data and Statistics. Energy supply, Electricity generation by Source, Turkey.* https://www.iea.org/data-and-statistics?country=TURKEY&fuel=Energy%2supply&indicator=Coal%20production%20by%20type.Paris: IEA, 2018.

International Energy Agency 2019a. *World Energy Outlook 2018,* Paris: IEA, 2019.

International Energy Agency 2019b. *Global Energy and CO_2 Status Report 2018.* Paris: IEA, 2019.

International Renewable Energy Agency. *Renewable Energy Benefits: Leveraging Local Capacity for onshore wind.* Abu Dhabi: IRENA, 2017

Medina, Leandro and Friedrich Schneider. *Shadow Economies Around the World: What Did We Learn Over the Last 20 Years?* International Monetary Fund (IMF) Working Paper, January 2018.

Ministry of Energy and Natural Resources. “Milli Enerji Ve Maden Politikası Tanıtım Programı” [National Energy and Mining Policy Promotion Program]. Ministry of Energy and Natural Resources. 16 September 2019. https://www.enerji.gov.tr/tr-TR/Bakanlik-Haberleri/Milli-Enerji-Ve-Maden-Politikasi-Tanitim-Programi

National Research Council. 2007. Coal: Research and Development to Support National Energy Policy. Washington, DC: The National Academies Press. https://doi.org/10.17226/11977.

OECD. *Economic outlook, analysis, and forecasts.* 2015.

Porter, Michael. *The Competitive Advantage: Creating and Sustaining Superior Performance.* NY: Free Press, 1985.

Renewable Energy World 2020. What Is A Renewable Energy Certificate (REC)? https://www.renewableenergyworld.com/2015/08/24/what-is-a-renewable-energy-certificate-rec/#gref. 2020.

SHURA 2018. *Increasing the Share of Renewables in Turkey’s Power System: Options for Transmission Extension and Flexibility.* https://www.shura.org.tr/increasing-the-share-of-renewables-in-turkeys-power-system/ Istanbul: SHURA Energy Transition Center, 2018.

SHURA 2019. Energy pricing and non-market flows in Turkey’s energy sector. 2019. SHURA Energy Transition Center, 2019.

TEİAŞ 2018a. Turkish Electricity Transmission Corporation. Database https://www.teias.gov.tr/tr-TR. 2018

TEİAŞ, 2018b. Turkish Electricity Transmission Corporation. *Elektrik Piyasası 2017 yılı Piyasa Gelişim Raporu [Electricity Market 2016 Progress Report].* Ankara: TEİAŞ, 2018.

TEİAŞ, 2019. Turkish Electricity Transmission Corporation. *Elektrik Piyasası 2018 yılı Piyasa Gelişim Raporu [Electricity Market 2016 Progress Report].* Ankara: TEİAŞ, 2019.

Türkiye Taşkömürü Kurumu Genel Müdürlüğü 2016. Sektör Raporu. http://www.tki.gov.tr/depo/2017/KomurSektorRaporu2015.pdf. 2016

Annual economic savings on fossil fuels and fossil fuel imports can amount to USD 2.1 billion by the year 2028 by increasing the share of renewables.

Abbreviations

EPDK	Energy Market Regulatory Authority
EPIAS	Turkish Market Operator
FTE	Full-time equivalent
IASS	Institute for Advanced Sustainability Studies Potsdam
IEA	International Energy Agency
IPC	Sabanci University Istanbul Policy Center
LCOE	Levelised cost of electricity
MIP	Mixed-integer programming
MBTU/MMBTU	1 thousand British thermal units/1 million British thermal units
MoENR	Ministry of Energy and Natural Resources
MoEU	Ministry of Environment and Urban Affairs
MoTF	Ministry of Treasury and Finance (formerly Ministry of Economics MoE)
MoFA	Ministry of Foreign Affairs
MoH	Ministry of Health
MW	Megawatt
OPEX	Operational expenses
PV	Photovoltaics
RE	Renewable energy
SHURA	SHURA Energy Transition Center
SRMC	Short-run marginal cost
TEİAŞ	Turkish Electricity Transmission Corporation
TWh	Terawatt hours
TTKGM	Turkey Hard Coal Enterprises General Directorate
WACC	Weighted average cost of capital

Securing Turkey's energy future with renewables.

COBENEFITS

COBENEFITS
Connecting the social and economic opportunities of renewable energies to climate change mitigation strategies

COBENEFITS cooperates with national authorities and knowledge partners in countries across the globe such as Germany, India, South Africa, Vietnam, and Turkey to help them mobilise the co-benefits of early climate action in their countries. The project supports efforts to develop enhanced NDCs with the ambition to deliver on the Paris Agreement and the 2030 Agenda on Sustainable Development (SDGs). COBENEFITS facilitates international mutual learning and capacity building among policymakers, knowledge partners, and multipliers through a range of connected measures: country-specific co-benefits assessments, online and face-to-face trainings, and policy dialogue sessions on enabling political environments and overcoming barriers to seize the co-benefits.

Contact

COBENEFITS focal point Turkey
Ümit Şahin, Istanbul Policy Center Sabanci University
umit.sahin@sabanciuniv.edu

COBENEFITS project director
Sebastian Helgenberger, Institute for Advanced Sustainability Studies (IASS)
sebastian.helgenberger@iass-potsdam.de

DOI: 10.2312/iass.2020.052

www.cobenefits.info

@IKI_COBENEFITS

Supported by:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
based on a decision of the German Bundestag

INTERNATIONAL CLIMATE INITIATIVE (IKI)