COBENEFITS STUDY

June 2022

Increasing industrial competitiveness and hedging against fossil price volatility with renewables in Turkey

Assessing the co-benefits of decarbonising Turkey's power sector

Executive report

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

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Imprint

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Executive Summary

COBENEFITS

Prospects of decarbonising Turkey's power sector following ratification of the Paris Agreement

As of 6 October 2021, the Turkish Parliament has ratified the Paris Agreement. In line with the ratification, the Turkish Government announced its intent for a national net-zero target by 2053. This pledge needs to be formulated into bold actions in the next cycle of nationally determined contributions in order to support transformation of the power sector and industrial sectors, which are responsible for the majority of the emissions.

Aspiring to net-zero by 2053 not only recognises the opportunities facilitated by a climate-neutral economy and society but also anticipates the risks of continued dependence on fossil fuels. Turkey is heavily reliant on fossil fuel imports. In 2019, more than 98% of fossil gas and more than 97% of hard coal used by Turkey were imported. High dependence on fuel imports represents a threat to Turkey's future energy security while also exacerbating the country's current account deficit. Turkey spends around USD 45–50 billion each year on energy imports, which accounts for a quarter of total imports.

Recent record-high power prices in Turkey have again emphasised the economy-wide risks of dependency on fossil fuels, which ultimately manifests as high energy bills and severe electricity shortages for the industrial sector.

The average costs of the electricity sector are significantly affected by the import prices of fossil fuels. Exchange rate movements also affect trends and volatility in the markets, further increasing costs for industrial consumers. Nationwide electricity and fossil gas prices increased greatly during 2021, leading to surging energy costs for the industrial sector. In turn, this will push up prices for consumer goods and increase inflation rates.

Considering the present volatility of the energy market, the future development of electricity prices will have important implications for industrial competitiveness in Turkey. This research study shows how more ambitious deployment of renewable energy can both reduce electricity prices and mitigate the risks of price volatility associated with increasing gas prices and supply crises.[1]

Renewable energy technologies have emerged as the least-cost power generation technology in many markets around the world. In the past ten years, capital costs fell by 85% for solar photovoltaics (PV) and 56% for wind energy. By adding more renewable energy sources to the Turkish electricity system, electricity prices can be reduced, thus increasing economic competitiveness. This is especially important for the industrial sector, where energy frequently constitutes a high share of overall production costs. At the same time, greater renewable capacity can also avert price shocks arising from volatile prices for coal, oil, and gas.

Since most renewable energy technologies do not have any fuel costs – they have zero marginal costs and are therefore dispatched first – they push other, more expensive technologies out of the market. This reduces the wholesale electricity market price and consequently also the retail electricity price. This so-called 'merit order effect' has been observed in many countries around the world in the past decade. This study is among the first to quantify the merit order effect in Turkey.

This study analyses and quantifies how incorporating higher shares of renewable energies in Turkey's electricity mix can affect electricity prices for the industrial sector. The impacts are quantified for both wholesale and retail electricity prices. Moreover, additional positive socio-economic effects are also quantified in terms of job creation, GDP growth, and reduced inflation.

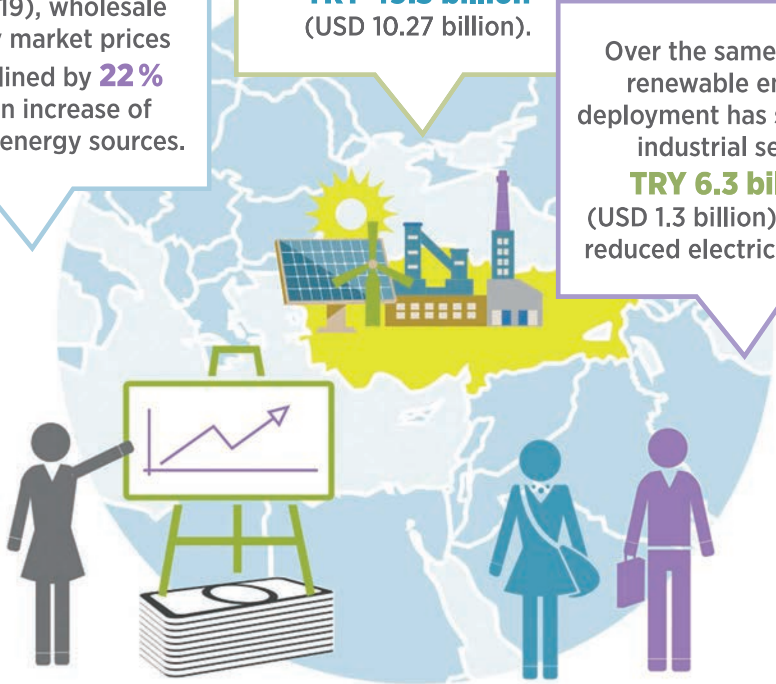
[1] The savings for the industrial sector expressed in this report are depicted as real-term values for the base year 2018. This is important, since Turkey has experienced high inflation in recent years. Accordingly, currency comparisons between TRY and USD are also based on 2018 conversion rates.

Key figures:

From 2020 to 2025, total accumulated electricity cost savings for Turkish industry can amount to **TRY 21.47 billion** (USD 4.45 billion). From 2020 to 2030 (comparing BAU with an Advanced Renewables scenario), total accumulated electricity cost savings for Turkey's industrial sector can amount to **TRY 49.5 billion** (USD 10.27 billion).

In the past five years (2015–2019), wholesale electricity market prices have declined by **22 %** due to an increase of renewable energy sources.

Over the same period, renewable energy deployment has saved the industrial sector **TRY 6.3 billion** (USD 1.3 billion) through reduced electricity costs.



Key policy opportunities:

- **Policy opportunity 1: A higher share of renewables can significantly reduce average wholesale electricity prices.** The industrial sector, in particular, can benefit from cost reductions, which in turn will improve the sector's economic competitiveness. Compared with the currently planned scale-up of wind and solar PV until 2030 (BAU scenario: business as usual), a scenario with a high share of renewables (Advanced Renewables Scenario) can reduce wholesale electricity prices by 2.4 % on average. This would amount to total savings of TRY 1.96 billion (USD 477 million) in 2030 alone. Compared with a market lacking any renewables, a high-renewables scenario can reduce wholesale market prices by 12.6 %, amounting to total cost savings of up to TRY 13.49 billion (USD 2.8 billion) in 2030 alone.

- **Policy opportunity 2: The average retail electricity price for the industrial sector can be reduced by 1.5 % in 2030 when comparing current renewable energy expansion plans with the more rapid expansion of wind and solar PV under the Advanced Renewables Scenario.** This would amount to total electricity cost savings of TRY 1.32 billion (USD 274 million) for the industrial sector in 2030 alone. Compared with an electricity market lacking any renewables, the Advanced RE scenario is predicted to reduce the average retail electricity price by 9 %. This can amount to electricity cost savings for the industrial sector of TRY 6.92 billion (USD 1.4 billion) in 2030 alone. For energy-intensive industries such as the metallurgical industries, savings can amount to TRY 2.15 billion (USD 446 million) in 2030 alone.

- **Policy opportunity 3: Renewable energy procurement can reduce the risks associated with fuel price volatility.** Assuming a 31 % increase in fuel prices (gas price) by 2030, this would increase average retail electricity prices for industrial consumers by 5 % based on current RE expansion plans, and by as much as 16 % in a market lacking any renewables. However, with high shares of renewables, the same increase in fuel price would only lead to a 3 % increase in average retail electricity prices, thus protecting industrial consumers from price shocks.

Key Findings:

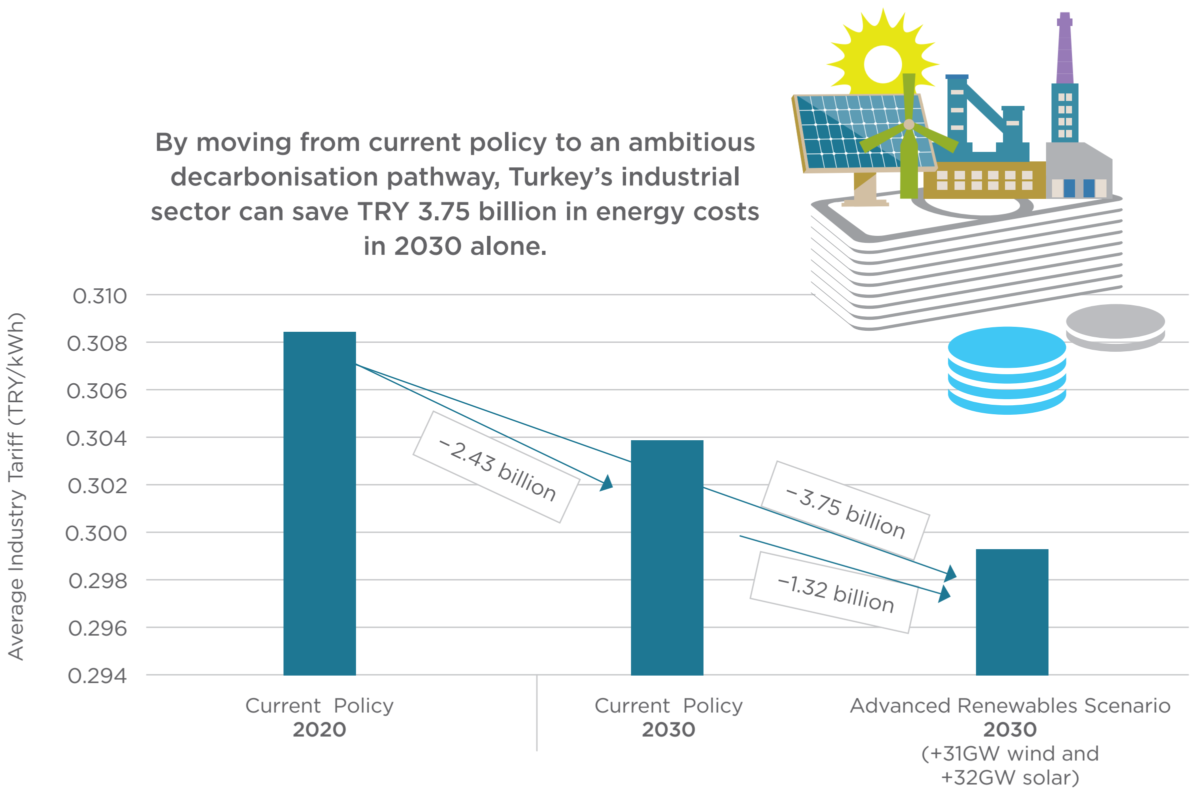
- **Historical savings: In the past five years, average wholesale electricity prices have declined by 22 %** due to an increase in renewable energy sources (with zero marginal costs). This results in annual savings of TRY 17.6 billion (USD 3.7 billion) compared with an electricity system lacking any renewables. When analysing the average retail electricity price, a reduction of 15.2 % was observed, resulting in total savings of TRY 9.47 billion (USD 1.96 billion).

- **Future savings potential: In the coming 10 years (2021 – 2030), renewable energy has potential to provide even greater savings in the industrial sector. By shifting from current deployment plans (BAU) to the Advanced Renewables Scenario, the average retail electricity price will decline by 1.5 %**, resulting in total savings of TRY 1.32 billion (USD 274 million) in the year 2030 alone. In a scenario with increased fuel prices (Case D), implementing a carbon pricing scheme could potentially deliver savings of TRY 8 billion (USD 1.95 billion) in 2030 alone.

- **Hedging against fuel price risk: Renewable energy procurement can reduce the economic and societal risks associated with fuel price volatility.** Assuming a 31 % increase in fuel prices (gas price) by 2030, this would increase retail electricity prices for industrial consumers by 5 % based on current RE expansion plans and by as much as 16 % in a market without any renewables. However, with high shares of renewables, this increase in fuel price would only lead to a 3 % increase in retail electricity price, thus protecting industrial consumers from price shocks.

- **Macro-economic benefits:** By reducing electricity prices and increasing the economic competitiveness of the industrial sector, **exports** are expected to increase by TRY 5.6 million (USD 1.16 million), amounting to a 0.13% increase in **GDP**. By making the Turkish industrial sector more competitive internationally, it can grow more rapidly, with the prospect of creating up to **19,000 new jobs**.

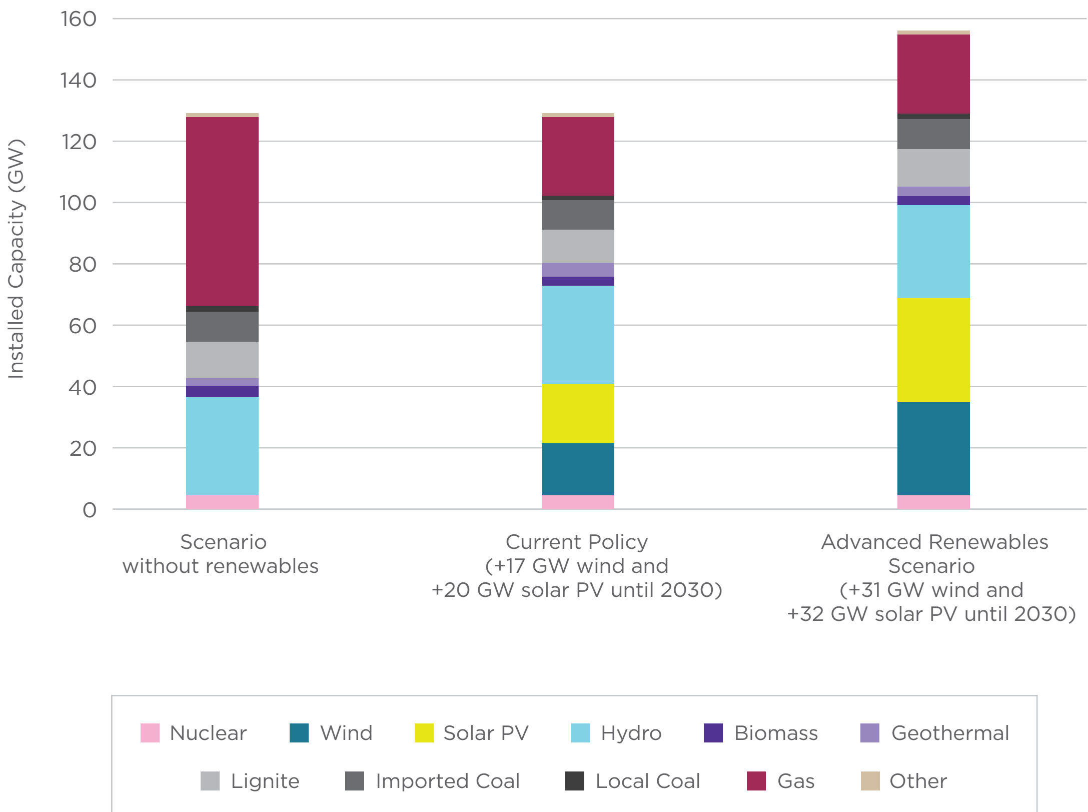
- **Climate benefits: By increasing the shares of renewables in Turkey's electricity mix, CO_2 intensity will decrease by 5%** with a shift from the currently planned BAU capacities (17 GW wind, 20 GW solar PV) to the Advanced Renewables Scenario (31 GW wind, 32 GW solar PV). Compared with an electricity market lacking any renewables, CO_2 intensity is reduced by 9%, amounting to 12 million metric tonnes less CO_2 emitted in 2030. This will likely increase export opportunities for Turkish industries, with the proposed EU Carbon Border Adjustment Mechanism (CBAM) looming on the horizon.



The study analyses both the real-world historical savings achieved between 2015 and 2020 as well as potential future savings based on various scenarios until 2030. Under the Current Policy Scenario (BAU), total capacity additions of 17 GW wind energy and 20 GW solar PV are assumed by 2030. This scenario is based on projections and assumptions made by various public stakeholders in Turkey, such as the Ministry of Energy and Natural Resources (MENR) and the Turkish Electricity Transmission Corporation (TEİAŞ). In the Advanced Renewables Scenario, capacity additions of 31 GW wind energy and 32 GW solar PV are expected up to 2030. This is based on a scenario developed by the SHURA Energy Transition Center as part of the report "Increasing the Share of Renewables in Turkey's Power System: Options for Transmission Expansion and Flexibility". Finally, a third scenario assumes that no renewables at all would be deployed in the Turkish electricity sector. In this case, it is assumed that all renewable capacity would be replaced with efficient gas-based power plants. The comparison with this hypothetical scenario can show the total cost savings associated with renewable energy deployment in Turkey.

The wholesale electricity market is simulated through a market simulation engine. The wholesale and retail electricity prices are calculated through statistical analysis. The macro-economic effects on the Turkish economy are based on a dynamic applied general equilibrium model with a horizon of 2030.

Installed power generation capacity in selected scenarios in 2030 (GW)



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1. The status quo: High electricity prices and import dependencies

KEY POINTS

Fossil fuel import dependency

- Turkey is heavily reliant on fossil fuel imports. More than 98 % of fossil gas and more than 97 % of hard coal that Turkey uses are imported. High dependence on fuel imports represents a threat to Turkey's future energy security while also exacerbating the country's current account deficit. Turkey spends around USD 45 – 50 billion per year on energy imports, which accounts for a quarter of total imports.

Increasing price trend due to fossil fuel imports

- Nationwide electricity and fossil gas prices increased dramatically during 2021, leading to large surges in energy costs for the industrial sector. In turn, this will lead to price increases for consumer goods and higher inflation rates.
- The average costs of electricity are significantly affected by the import prices of fossil fuels. Exchange rate movements also affect trends and volatility in the markets, further increasing costs for (industrial) consumers.
- The industrial sector accounted for around half of total invoiced electricity consumption (43 %, from a total of 233,436,615 MWh) in 2020.

Decreasing price trends due to renewable energy additions

- Domestic solar and wind generation increased sharply during the past five years, accounting for 11.8 % of total power generation in 2020. Overall, renewables account for a combined share of 42.4 %. Aside from hydropower (31 GW), solar PV (6.7 GW) and wind power (8.8 GW) accounted for the highest non-fossil generation capacities (EPDK, 2021).
- Electricity prices in the wholesale day-ahead market show a decreasing trend, from 51.05 USD/MWh in the year 2015 to 40.11 USD/MWh in 2020.
- The average electricity retail price for the industrial sector fell from 9.19 USD cent\kWh in 2015 to 8.19 USD cent\kWh in 2020.

1.1 Recent trends and developments in the Turkish energy sector

Fossil fuel import dependency and price volatility

Recent record-high power prices in Turkey have again emphasised the economy-wide risks of dependency on fossil fuels, which ultimately manifests as high energy bills and severe electricity shortage for the industrial sector. Considering the present volatility of the energy market, the future development and possible further surges in electricity prices will have important implications for industrial competitiveness. At the same time, GDP growth and inflation rates could be negatively affected in Turkey.

Meeting the objectives of the Paris Agreement and a net-zero target for 2053

As of 6 October 2021, the Turkish Parliament has ratified the Paris Agreement. In line with the ratification, the Turkish Government announced its intention to set a national net-zero target, to be achieved by 2053. This pledge needs to be formulated into bold actions in the next cycle of nationally determined contributions, in order to support the transformation of the power sector and industrial sectors, which are responsible for most of Turkey's greenhouse gas emissions. Aspiring to net-zero by 2053 not only recognises the opportunities facilitated by the climate-neutral economy and society but also anticipates the risks of continued dependence on fossil fuels.

Renewable energy capacity additions

Investments in the global energy transition have skyrocketed, amounting to more than USD 750 billion in 2021. In the power sector, total investment in renewables accounted for USD 366 billion in 2021, a new record high (BNEF, 2021). Today, renewable energy capacity additions are now the key countermeasure to reduce carbon emissions and mitigate climate change. Renewable energy technologies have emerged as the least-cost power generation technology in many markets around the world. In the past ten years, capital costs decreased by 85% for solar photovoltaics (PV) and 56% for wind energy.

In Turkey, solar and wind energy sources together accounted for 11.8% of total power generation in 2020. Overall, renewables (hydro and non-hydro) have a combined share of 42.4% of electricity generation. Aside from hydropower (31 GW), solar PV (6.7GW) and wind power (8.8 GW) accounted for the highest non-fossil generation capacities. The total installed capacity of all power generation plants (licensed and unlicensed) was around 100 GW and annual electricity consumption reached 305 TWh in 2020 (EPDK, 2021).

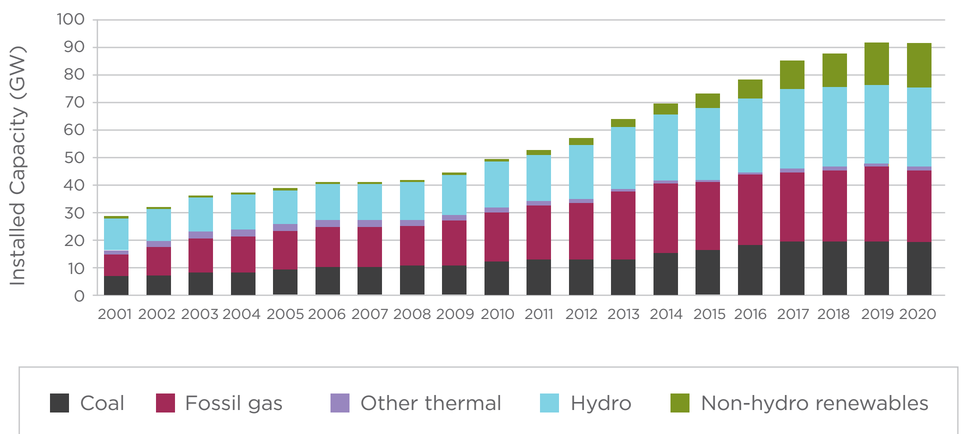

Figure 1: Installed capacity by energy source, 2001–2020 | Source: own

More than 50% of the newly installed capacity has been due to an increase in non-hydro renewables (wind and solar) since 2017. Additions to installed capacity have mainly been due to non-hydro renewables attracted by the US-Dollar-based feed-in tariff rates defined by the "Renewable Energy Resources Support Mechanism" (YEKDEM), which creates incentive structures for renewable energy investments in Turkey. The overall contribution of non-hydro renewables to newly installed capacity since the introduction of YEKDEM has been 35.9%.

The impact of renewable energy additions on industrial sector electricity prices

By adding more renewable energy sources to the Turkish electricity system, electricity prices can be reduced, thus increasing economic competitiveness. This is especially important for the industrial sector, where energy frequently constitutes a high share of overall production costs.

At the same time, greater renewable capacity can also avert price shocks arising from volatile prices for coal, oil, and gas. Since most renewable energy technologies do not have any fuel costs – they have zero marginal costs and are therefore dispatched first – they push other, more expensive technologies out of the market. This has reduced the wholesale electricity market price and consequently also the retail electricity price. This so-called 'merit order effect' has been observed in many countries around the world in the past decade.

This study is among the first to quantify the merit order effect in Turkey. It dissects the effects of renewables on Turkish electricity markets, and hence on prices. The research study shows how more ambitious deployment of renewable energy can both reduce electricity prices and mitigate the risks of price volatility associated with increasing gas prices. Moreover, additional positive socio-economic effects are also quantified in terms of job creation, GDP growth, and reduced inflation.

1.2 Prices for industrial consumers

A longer-term view of the electricity market provides information on several factors affecting supply/demand conditions as well as the prices in Turkish electricity markets. As more than 98% of fossil gas and more than 97% of hard coal that Turkey uses is imported (2019 data), the volume and average cost of the sector is also significantly affected by the import prices of these primary energy sources. Moreover, higher electricity prices for industry are reflected in final consumer prices and increased inflation.

Exchange rate movements, especially in the aftermath of 2015, as well as the world price of hard coal and fossil gas, are important factors influencing trends and volatility in the day-ahead market (DAM) in Turkey.

Turkish Electricity Markets

The Energy Exchange Istanbul (EXIST) (in Turkish, EPİAŞ: Enerji Piyasaları İşletme A.Ş.) is responsible for managing and operating energy markets, including power and gas commodities. EPİAŞ operates spot electricity markets, the power futures market, the Renewable Energy Guarantees of Origin System (YEK-G), and the Organized YEK-G market.

The spot electricity markets include the **day-ahead market (DAM)** and the Intraday Market (IDM), which EPİAŞ has operated since 2015. However, not all electricity demand is traded in the spot electricity markets. The DAM had a total electricity trading share of 41.5% in 2016, and has since shown an increasing trend, peaking at a record high of 62.3% in 2020.

EPİAŞ announces the hourly market clearing prices **(MCPs – wholesale market price)** for DAM based on bids from market participants.

The annual average **DAM clearing price (MCP – wholesale market price)** from 2015 to 2020 is depicted in Figure 2, where the average day-ahead market clearing price is 45.99 USD/MWh.

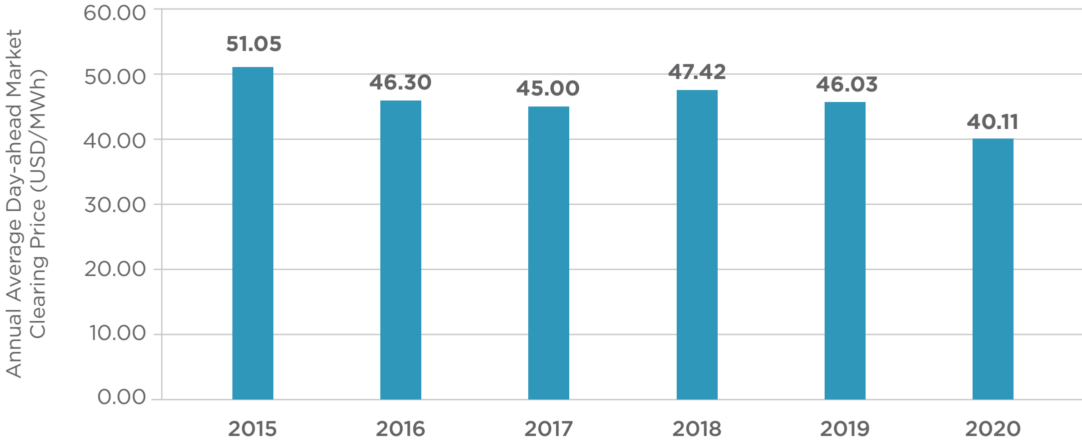

Figure 2: Annual average day-ahead market clearing price | Source: own

Regulated tariff for industrial consumers

The Electricity Market Law defines the rules for the nationally regulated tariff. The industry retail tariff comprises two main components, i.e., energy cost and utility cost components. Figure 3 shows historical industry retail tariffs (not including tax and levies) and their components.

The average electricity retail price for the industrial sector dropped from 9.19 USD cent\kWh in 2015 to 8.19 USD cent\kWh in 2020, averaging 8.23 USD cent\kWh over the same period.

Renewables can reduce electricity prices and mitigate the risks of price volatility.
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Industrial Retail Electricity Price Components

According to the Electricity Market Law, electricity users are grouped into five different consumer categories: household, commercial, industrial, irrigation, and lighting. Of these, industrial accounted for the highest share of consumption, at 43 % in 2020. In contrast to patterns seen in EU member states, electricity prices in Turkey are higher for industrial consumers than residential users. Turkey has the lowest relative ratio of household versus industrial electricity tariffs among the OECD countries. The industry retail tariff comprises two main components, i.e., energy cost and utility cost.

Industrial retail price = energy cost component + utility cost component

- **Energy cost component** = MCP + YEKDEM support

- **Utility cost component:** Grid costs (does not include taxes and levies)

The YEKDEM mechanism has a direct impact on electricity tariffs. It is incorporated within the energy component of the tariff as an additional cost on top of the market price of electricity.

The utility cost component of the industry tariff includes fees for: transmission, distribution, and retail services; and loss & leakage.

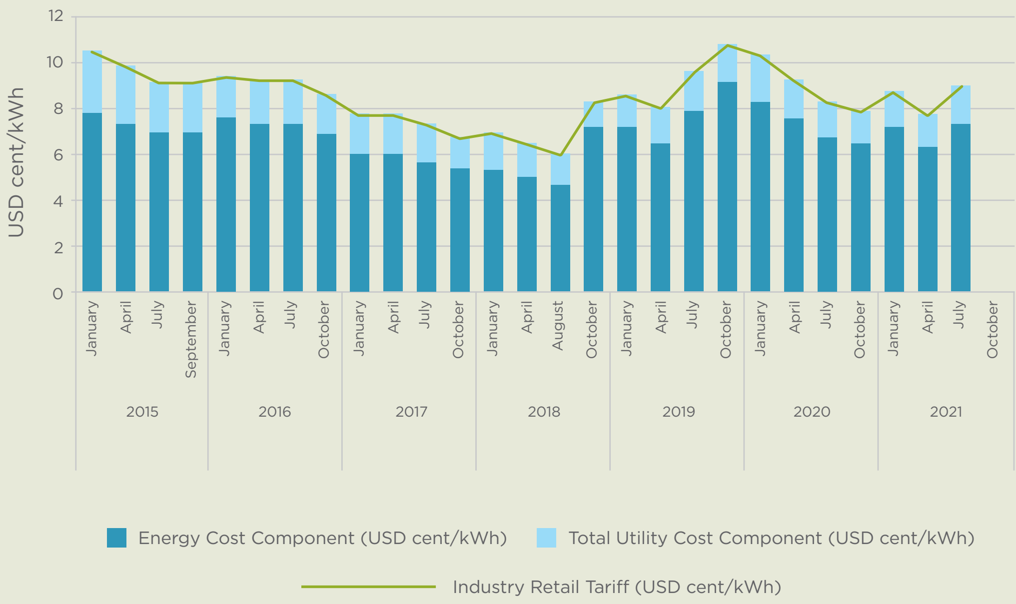


Figure 3: Historical overview of industry retail tariff and its components
Source: Turkish Energy Market Regulatory Authority

2. Methodology and scenarios: Quantifying the impact of renewables on electricity prices in the industrial sector

This section describes the reference power sector scenarios applied for this research study, and the selected approach and methodology for: i) quantifying the impact of renewables on electricity prices in the industrial sector, and ii) quantifying subsequent savings for the industrial sector in Turkey. In addition, the limitations of the selected research design and options for further research are laid out.

Scope of the study

This study analyses and quantifies how incorporating higher shares of renewable energies in the Turkish electricity mix may affect electricity prices for the industrial sector. The impacts are quantified for both wholesale and retail electricity prices.

In terms of renewable energy sources, the study considers the wind and solar sectors. Since most renewable energy technologies do not incur any fuel costs – they have zero marginal costs and are therefore dispatched first – they push other, more expensive technologies out of the market. This reduces the wholesale electricity market price and consequently also the retail electricity price. This so-called **merit order effect** has been observed in many countries around the world in the past decade.

This study is among the first to quantify the merit order effect in Turkey. It deconstructs the effects of renewables on Turkish electricity markets and hence prices. The findings show how more ambitious deployment of renewable energy can both reduce electricity prices and mitigate the risks of price volatility associated with increasing gas prices. Moreover, additional positive socio-economic effects are also quantified in terms of job creation, GDP growth, and reduced inflation.

2.1 Three reference scenarios for the power sector to 2030

The analysis of future cost saving opportunities is based on a policy-directed scenario approach, to connect with existing policy environments and learn from comparing the socio-economic impacts of various potential energy transition pathways in Turkey.

In total, three scenarios were defined to assess the potential cost savings associated with higher shares of renewable energy in Turkey's future electricity generation mix in the year 2030 (see Figure 4):

- Under the **Current Policy Scenario (BAU)**, total capacity additions of 17 GW wind energy and 20 GW solar PV are assumed by 2030. This scenario is based on projections and assumptions by different public stakeholders in Turkey, such as the Ministry of Energy and Natural Resources (MENR) and the Turkish Electricity Transmission Corporation (TEİAŞ).
- In the **Advanced Renewables Scenario**, capacity additions of 31 GW wind energy and 32 GW solar PV are expected up to 2030. This is based on a scenario developed by the SHURA Energy Transition Center as part of the report "Increasing the Share of Renewables in Turkey's Power System: Options for Transmission Expansion and Flexibility".

- Finally, a third scenario assumes that no wind and solar renewables **(scenario without renewables)** at all would be deployed in the Turkish electricity sector. In this hypothetical scenario, it is assumed that all renewable capacity would be replaced with efficient gas-based power plants.[2] The comparison with this hypothetical scenario can show the total cost savings associated with renewable energy deployment in Turkey.

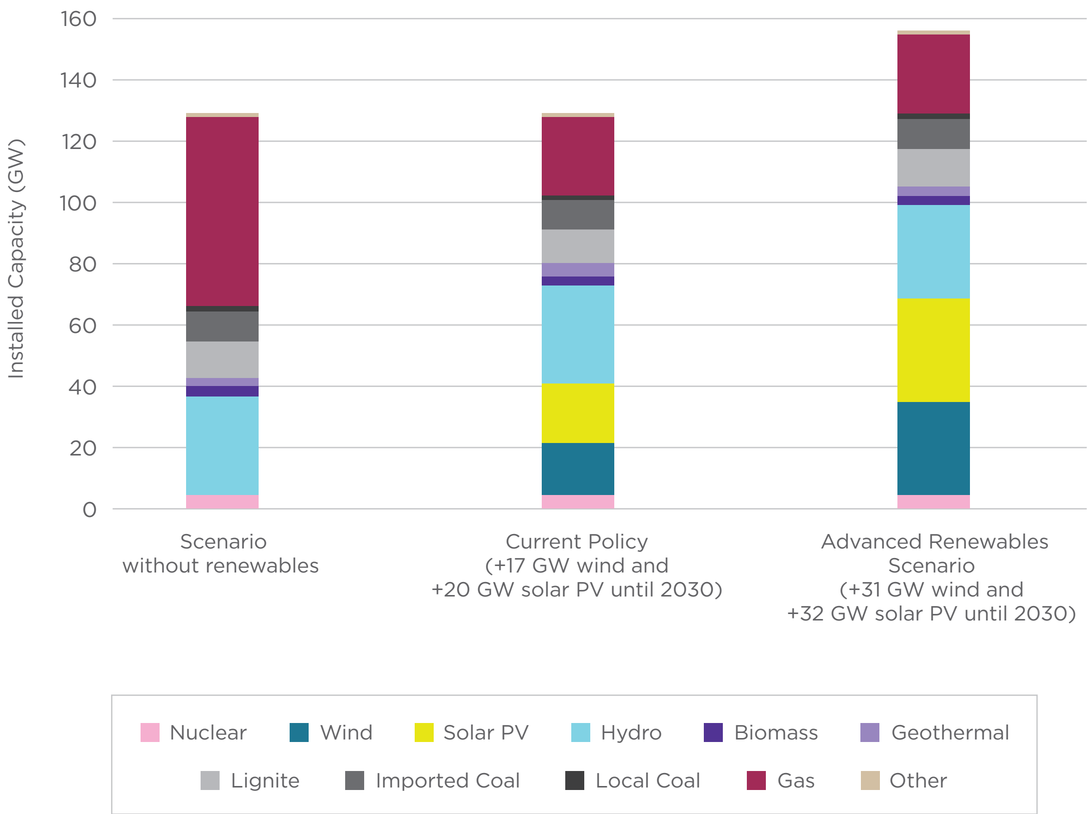


Figure 4: Installed power generation capacity in selected scenarios in 2030 (GW) | Source: own

Scenario configuration, and carbon- and fuel-price sensitivities

This study also models the effects of changes in fossil gas and carbon prices. Case A deals with a stable fuel price condition where the International Energy Agency (IEA) New Policies reference scenario is considered for fossil gas prices and no carbon price is taken into account. Cases B and C assess increasing fossil gas prices[3] and high carbon price factors, respectively. Case D considers the combined effects of increasing fossil gas prices and high carbon prices.

[2] At the time of writing, highly efficient fossil gas power plants were the most cost-effective replacement technology, and therefore it was assumed that all renewable energy capacity would be replaced by efficient gas plants in this hypothetical 'without renewables' scenario.

[3] https://heatroadmap.eu/wp-content/uploads/2020/01/HRE4_D6.1-Future-fuel-price-review.pdf

	Scenarios											
	2030 Case A – Stable Fuel Prices			2030 Case B – increasing Fuel Prices			2030 Case C – Stable Fuel Prices with High Carbon Price			2030 Case D – Increasing Fuel Prices with High Carbon Price		
Parameters	Without RES	BAU	Advanced RES	Without RES	BAU	Advanced RES	Without RES	BAU	Advanced RES	Without RES	BAU	Advanced RES
Fuel Price	Reference Price	Reference Price	Reference Price	31%	31%	31%	Reference Price	Reference Price	Reference Price	31%	31%	31%
Carbon Price (USD/tCO_2)	—	—	—	—	—	—	70.6	70.6	70.6	70.6	70.6	70.6
Wind and Solar Installed Capacity (GW)	0	17 and 20	31.1 and 31.2	0	17 and 20	31.1 and 31.2	0	17 and 20	31.1 and 31.2	0	17 and 20	31.1 and 31.2
RES Installed Capacity %	0%	28%	48%	0%	28%	48%	0%	28%	48%	0%	28%	48%
RES LCOE	High	Moderate	Low	High	Moderate	Low	High	Moderate	Low	High	Moderate	Low
Total Demand (TWh)	460 + Same NTC	460 + Same NTC	460 (600 MW Battery + 1000 MW pump storage)	460 + Same NTC	460 + Same NTC	460 (600 MW Battery + 1000 MW pump storage)	460 + Same NTC	460 + Same NTC	460 (600 MW Battery + 1000 MW pump storage)	460 + Same NTC	460 + Same NTC	460 (600 MW Battery + 1000 MW pump storage)
Conventional Power Plant Capacity	As forecast by TEİAŞ and 4 units at Akkuyu Nuclear Power Plant											

Table 1: Scenario configuration and carbon- and fuel-price sensitivities (Cases A to D)

Source: own

2.2 Approach and methodology

A combination of methods and models was used to quantify the impacts of renewable energy deployment on electricity prices in Turkey. The quantifications of wholesale market development are based on a market simulation engine and statistical analysis for retail price calculation (see sections A1.1 to A1.4 in Annex 1). The macro-economic effects on the Turkish economy are based on a dynamic applied general equilibrium model with a horizon of 2030 (see Section A1.5 in Annex 1).

Assessing electricity prices and savings for the industrial sector

In order to assess the cost savings[4] for the industrial sector, **a price calculation tool** was developed and applied. The tool consists of a **market simulation engine** (see Figure 5) that simulates the day-ahead power exchange across Turkey's electricity market.

The **merit order** is the main input for the market simulation engine, and determines the sequence for committing different technologies. To represent the Turkish electricity market, an initial assumption is made for the merit order and an iterative process is performed to derive an appropriate merit order set that accurately represents the Turkish electricity market (see Figure 5).

The results, in terms of total generation predicted for different technologies, are compared with actual energy generation and market prices and – if necessary – the merit order parameters are adjusted until the modelled results correlate with the real-world data from EPİAŞ. Once the proper merit order is attained, corresponding installed capacities for historical and future savings are inserted into the market simulation engine.

In another step, generation from renewables is excluded from the merit order and replaced with conventional sources in order to quantify the merit order effect and the impact on wholesale electricity prices. For both historical and future scenarios, the wholesale market prices are calculated (for more detail, see Annex 1 for "A1.2 Market simulation tool to quantify historical savings" and "A1.3 Market simulation tool to quantify future savings").

[4] The savings for the industry sector expressed in this report are depicted as real-term values for the base year 2018. This is important, since Turkey has experienced high inflation in recent years. The currency comparisons between TRY and USD are also based on 2018 conversion rates, where 1 EUR is assumed to be 5.67 TRY.

With the wholesale market prices in place, the retail electricity price for the industrial sector is calculated. The industry retail tariff in Turkey is constructed from two main components, namely **energy cost** and **utility cost components**. Next to the market clearing price, the costs associated with support for renewables (YEKDEM support) and the financial support for nuclear power plants were considered and projected until 2030. The detailed methodology is described in Annex 1.

Calculation of industrial retail electricity price

Industrial retail price = energy cost component + utility cost component

- **Energy cost component 2015 to 2020** = market clearing price (MCP) + YEKDEM support
- **Energy cost component 2020 to 2030** = market clearing price (MCP) + YEKDEM support + nuclear support
- **Utility cost component:** Grid costs (does not include tax and levies)

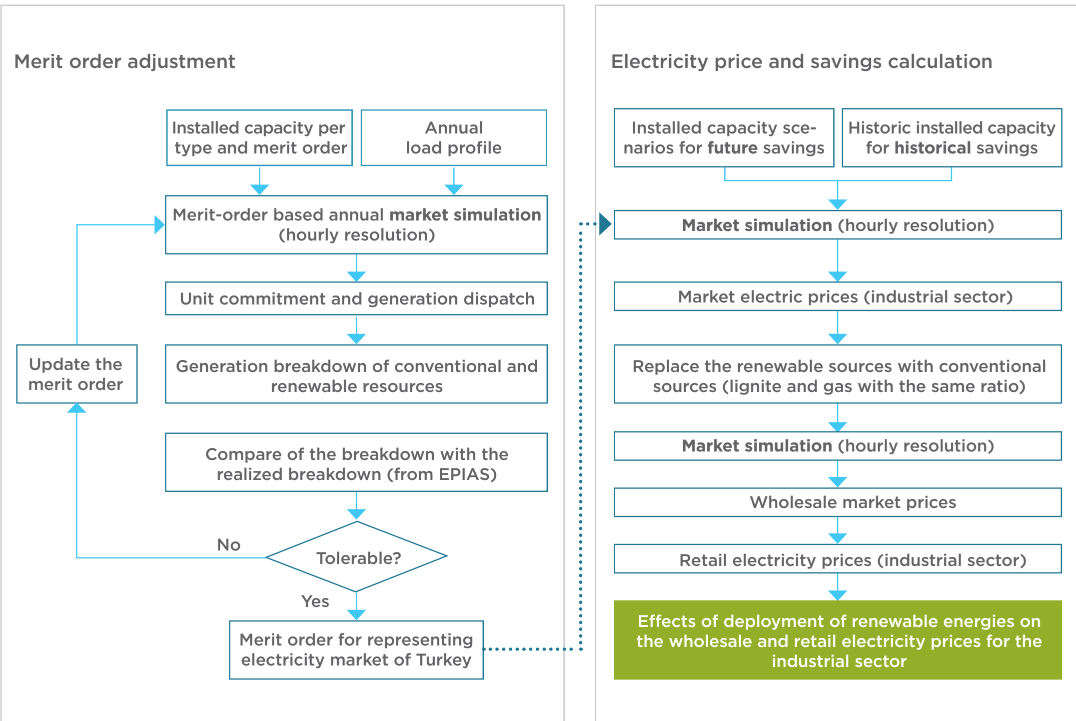


Figure 5: Methodology for calculating historical and future price savings | Source: own

Calculation of historical and future savings

Energy Balance Tables (2015 to 2019) from the Ministry of Energy and Natural Resources[5] were utilised to calculate the direct impacts (in terms of industry customer savings) of increased shares of renewable energy sources. The historical cost savings are calculated by deducting the industry retail tariff from the price that would have been realised in the hypothetical "without RES Scenario", (See Section A1.5 in Annex 1).

To assess the direct cost savings for industry during the period 2020–2030, the study utilises an economic growth path that is consistent with projections for total electricity demand. This growth path is then reflected in anticipated sectoral growth dynamics. A dynamic applied general equilibrium model (AGE) is utilised to calculate the future industrial cost-saving effects of increasing the share of renewable energy sources in the power market (See Section A1.5 in Annex 1).

Assessing the macro-economic effects of renewable energy deployment on the Turkish economy

To quantify the larger macro-economic effects (spillover effects) of renewable energy deployment on the Turkish economy, the study also applies a dynamic applied general equilibrium model. The model decomposes the overall economic activity into 23 sectors, and allows for **quantifying job creation**, domestic and foreign demand, and (relative) prices at the sectoral level to be further aggregated to **evaluate the impact on GDP**, overall **trade balance**, and inflation rate. The model is calibrated to the 2018 macro-economic/sectoral equilibrium of the Turkish economy. A more detailed description of the general equilibrium model and the methodology are included in Annex 1 under Section A1.5 AGE Model description.

2.3 Research limitations and options for further research

The study is carried out based on the transparent data acquired from the EPİAŞ platform, where the big picture of the Turkish electricity market is provided; however, much commercially sensitive data are not available. The effects of data omissions, particularly bi-lateral contracts and maintenance periods for power plants, are compensated by adjusting the merit order as described in Section 2.2. Additional details on methodological assumptions, limitations, and further research opportunities are provided **in Annex 5**.

Renewable energy deployment will have spillover effects on the Turkish economy, such as job creation and an increase in GDP. © Green Energy Futures CC BY-NC-SA 2.0

[5] Energy General Equilibrium Tables for Turkey. Ministry of Energy and Natural Resources. https://enerji.gov.tr/enerji-isleri-genel-mudurlugu-denge-tablolari

3. Reducing electricity prices for the industrial sector and generating macro-economic benefits

KEY FINDINGS:

- **Historical savings:** Over the course of five years (2015 – 2022), average wholesale electricity prices have declined by 22 % due to an increase in renewable energy sources (with zero marginal costs). This results in annual savings of TRY 17.6 billion (USD 3.7 billion) compared with an electricity system without renewables. When analysing the retail electricity price, a reduction of 15.2 % was observed, resulting in total savings of TRY 9.47 billion (USD 1.96 billion).
- **Future savings potential**: In the coming 10 years (2021 – 2030), savings in the industrial sector will be even greater. When comparing the Advanced Renewables Scenario with the current deployment plans (BAU), the retail electricity price will decline by 1.5 %, resulting in total savings of TRY 1.32 billion (USD 274 million) in the year 2030 alone.
- **Hedging against fuel price risk:** Renewable energy procurement can reduce the economic and societal risks associated with fossil fuel price volatility. Assuming a 31 % increase in fossil fuel prices (gas price) by 2030, this would increase retail electricity prices for industrial consumers by 5 % based on current RE expansion plans (BAU) and by as much as 16 % in a market without any renewables. However, with high shares of renewables, this increase in fuel price would only lead to a 3 % increase in retail electricity price, thus protecting industrial consumers from price shocks.
- **Macro-economic benefits:** By reducing electricity prices and increasing the economic competitiveness of the industrial sector, exports are expected to increase by TRY 5.6 million (USD 1.16 million), amounting to a 0.13 % increase in GDP. By making the Turkish industrial sector more competitive internationally, it can grow more rapidly, with the prospect of creating up to 19,000 new jobs.
- **Climate benefits:** By increasing the shares of renewables in Turkey's electricity mix, CO_2 intensity will decrease by 5 % with a shift from the currently planned BAU capacities (17 GW wind, 20 GW solar PV) to the Advanced RE (31 GW wind, 32 GW solar PV) scenario. Compared with an electricity market lacking any renewables, CO_2 intensity is reduced by 9 %, amounting to 12 million metric tonnes (1 t = 1,000 kg) less CO_2 emitted in 2030. This will likely increase export opportunities for the Turkish industrial sector, with the proposed EU Carbon Border Adjustment Mechanism (CBAM) looming on the horizon.

3.1 Historical savings in the industrial sector due to renewable energy deployment

Reduction of the wholesale electricity market price

The market simulation engine is used to calculate changes in wholesale electricity prices for the 2015–2020 period. The engine is capable of representing the Turkish electricity market with marginal error (maximum 1% error, See Annex 2, Section 6.2.1 comparison of simulated annual generation mix with actually realised historical values for the year 2015 and 2020).

Figure 6 shows the comparison of the actual wholesale market clearing prices in 2015 and 2020 with respect to the scenario without renewables (zero solar PV and wind capacity). The average annual wholesale electricity prices are 3.0% and 7.6% lower in 2015 and 2020 respectively, compared to the scenario without renewables.

From 2015 until 2022, average annual wholesale electricity prices have declined by 22% (see Figure 7) due to an increase in renewable energy sources (with zero marginal costs).

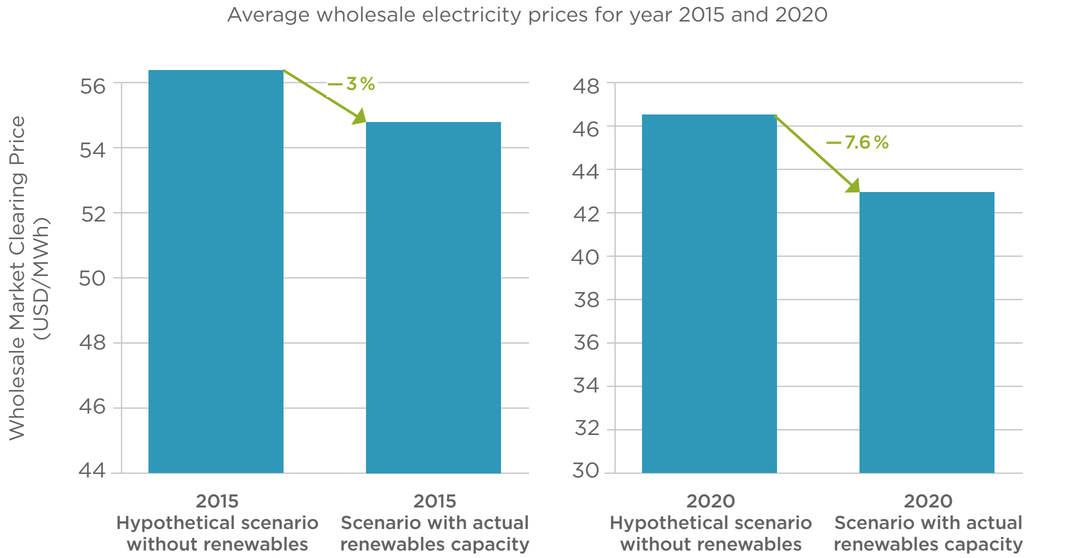


Figure 6: Comparison of wholesale market clearing prices in 2015 and 2020 (actual power generation mix with renewables vs scenario without renewables) | Source: own

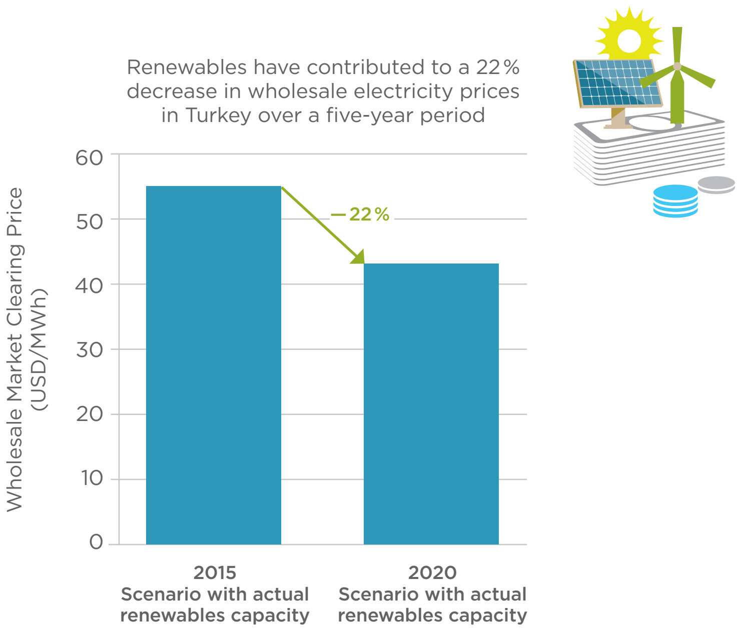


Figure 7: Comparison of average wholesale market clearing prices in 2015 and 2020 (actual power generation mix with renewables) | Source: own

Reduction of the wholesale electricity market price

To calculate the effects on the retail electricity price, the price component beyond the average wholesale market price needs to be taken into consideration, namely the "utility cost". The average industry retail tariff and associated components for the years 2015 and 2020 are depicted in Figure 8.

Comparison of the actual average annual retail electricity prices for industrial consumers with the hypothetical scenario shows that the addition of renewables (wind and solar PV) reduced retail electricity prices by 2.1% in 2015 and 5.5% in 2020.

Based on the calculations, the **annual average industrial retail electricity price for industrial consumers** was reduced by 15.2% in the period 2015 to 2020 by adding renewable energy sources to the Turkish electricity system.

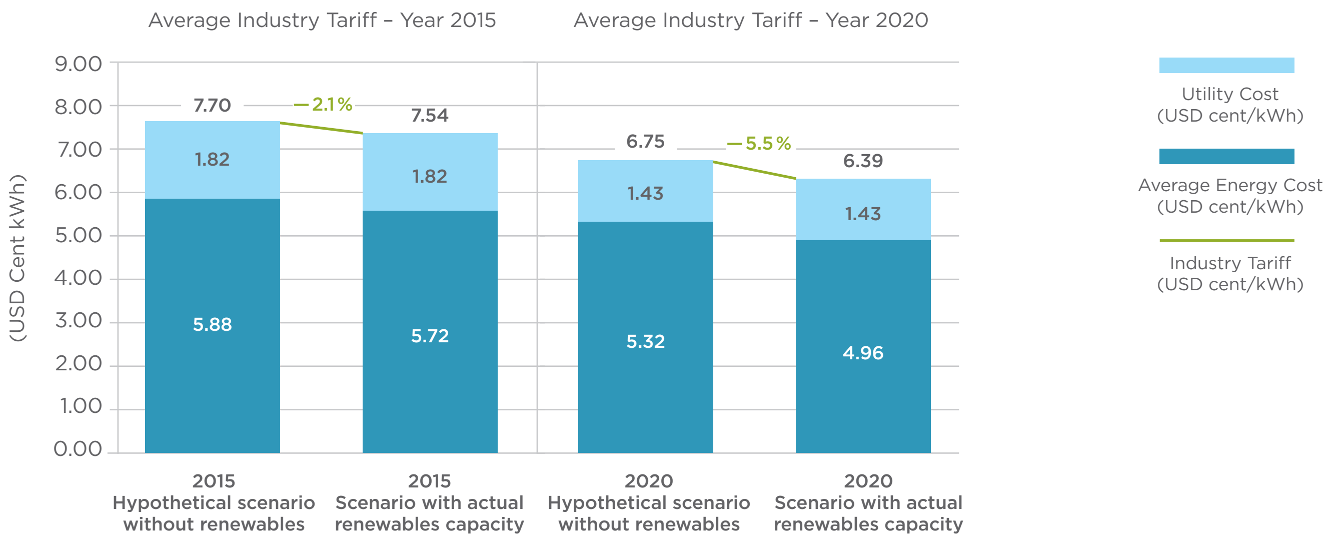


Figure 8: Average energy cost and utility cost changes for the years 2015 and 2020 (hypothetical scenario without renewables vs actual capacity) | Source: own

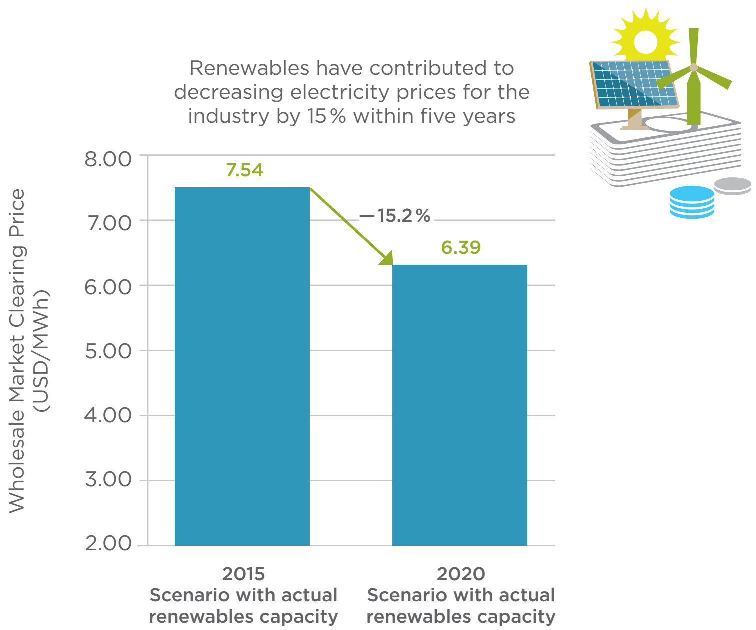


Figure 9: Average industry retail tariff from 2015 to 2020 | Source: own

Total electricity cost savings for the industrial sector

By utilising the differences between the industry retail tariff with actual renewables capacity compared with the hypothetical scenario without renewables (see Figure 8), the annual and the cumulative direct savings for the industry are calculated. The analysis shows savings for the Turkish industrial sectors amounting to TRY 9.47 billion (USD 1.96 billion) in the period 2015 to 2020 when comparing the actual costs with a hypothetical power market scenario lacking any renewables (See Table 2, cost savings for each industrial sector).

Statistical classification of economic activities		Electricity Demand (GWh)						Electricity cost savings (million USD)		
	Nace Rev. 2									
Industry		2015	2016	2017	2018	2019	2020	2015	2020	2015–20 cumulative
Paper & publishing	17-18	4.018	4.139	3.506	3.439	3.418	3.468	6,62	30,94	74,65
Non-metallic minerals	23	18.228	19.099	12.955	12.931	12.853	13.065	30,01	83,60	259,71
Metal industry	24	19.462	24.375	29.262	29.092	28.918	29.373	32,04	191,68	515,11
Other industry	16-31-32	5.885	6.388	18.928	18.552	18.441	18.591	9,69	27,03	204,66
Mining (excluding coal and gas)	07-08-09	10.229	2.271	1.402	1.593	1.584	1.605	16,84	13,94	48,15
Textiles & wearing apparel	13-14-15	24.022	17.892	17.022	18.077	17.967	18.298	39,55	103,55	326,93
Chemical, rubber, plastic products	20-21-22	8.190	15.610	12.449	13.146	13.067	13.297	13,48	77,77	230,36
Fabricated metal products	25	1.494	1.646	2.377	2.188	2.174	2.216	2,46	12,86	37,27
Transport equipment	29-30	1.910	2.736	2.635	2.589	2.574	2.765	3,14	5,76	36,06
Machinery, electric machinery & electronics	26-27-28	1.607	2.219	2.889	2.756	2.739	2.808	2,65	55,31	85,65
Food	10-11-12	7.777	7.313	7.483	7.805	7.758	7.809	12,80	55,32	146,98
TOTAL (USD)		102.822	103.687	110.907	112.167	111.493	113.293	169,3	657,8	1.965,5
TOTAL in TRY (millions)								816,2	3.171,3	9.476,67

Table 2: Electricity cost savings with existing renewables capacity compared to a scenario without renewables (million USD), 2015–2020

Source: own

3.2 Future savings potential for the industrial sector due to renewable energy deployment

Reduction of the wholesale electricity market price

Similarly to calculating historical savings, the market simulation engine is used to calculate future change in electricity prices with respect to the selected scenarios and assumptions (See Annex 1 for methodology and Annex 2 Section A2.4. for the market simulation of future power generation mix attained in 2025 and 2030).

In the year 2030, a comparison with the hypothetical case of a power market lacking any non-hydro renewables in the energy mix shows that the wholesale market price could be 10.46% higher than the Current Policy Scenario (17 GW wind and 20 GW solar PV). The wholesale market prices can be reduced by a further 2.4% in the Advanced Renewables Scenario (31 GW wind and solar PV, see Figure 10). This reveals the overall importance of renewables in reducing the wholesale market price.

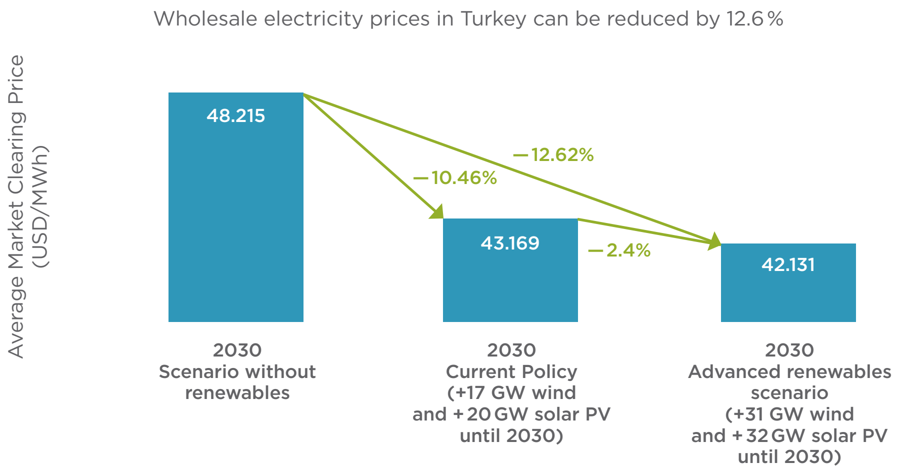


Figure 10: Comparison of annual average wholesale market clearing prices for 2030 | Source: own

Reduction of the retail electricity market price

Increasing the share of renewables in the Turkish electricity mix clearly reduces future retail electricity prices for industrial consumers.

For the year 2025, average retail electricity prices can be reduced by 6.6% when comparing the Current Policy Scenario with the hypothetical case without any renewables (see Figure 11).

The analysis for 2030 shows that retail electricity prices can be reduced even further: Compared with the Current Policy Scenario, the Advanced Renewables Scenario (with additional 14 GW of solar PV and 12 GW of wind energy) can reduce the retail electricity price by a further 1.6%. Compared with the hypothetical case (no non-hydro renewables in the mix), the Advanced Renewables Scenario has potential to reduce retail electricity prices for industrial consumers by **8.8 %** for the year 2030 (see Figure 12).

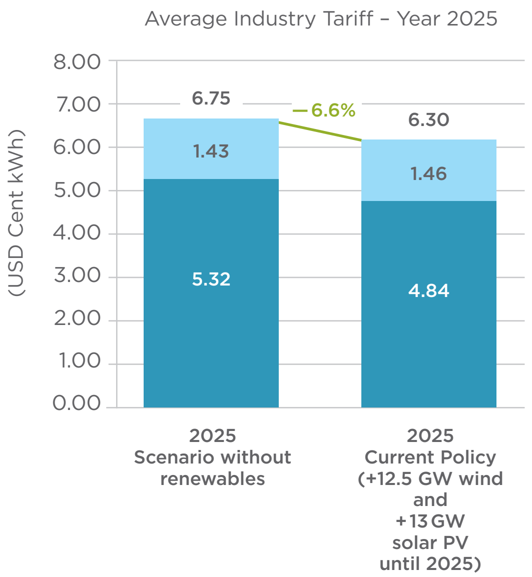


Figure 11: Average annual retail electricity prices for 2025 (Scenario without renewables vs current policy) Source: own

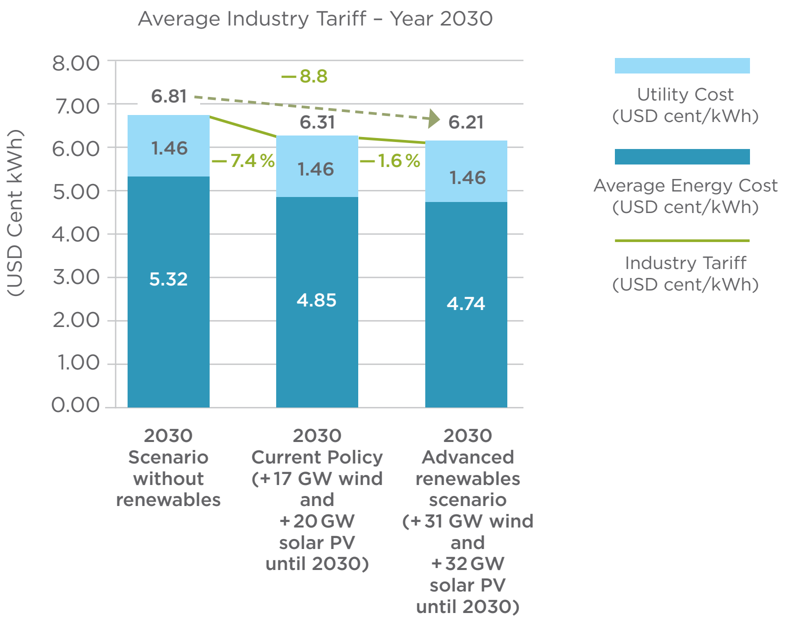


Figure 12: Average annual retail electricity prices for 2030 (Scenario without renewables, Current Policy, and Advanced Renewables Scenario) Source: own

Total electricity cost savings for the industrial sector

Industrial electricity consumers can benefit directly from the increased share of renewable energy sources in the power mix, as reflected in the estimated reduced electricity tariff for industry for the years 2020 to 2030.

Calculation of cost savings from 2020 to 2030

The cost savings (direct benefits) are calculated by utilising the differences between the industry retail tariff in the BAU Scenario and the Advanced RES Scenario with the hypothetical case that lacks renewables.

Based on the sectoral growth dynamics as outputs of the macro-economic model for the period 2018 to 2030, the projections for electricity demand (in terms of both payments in real 2018 TRY and physical units in GWh) is utilised. The direct benefits to industrial customers for the period 2020 to 2030 are thereby computed.

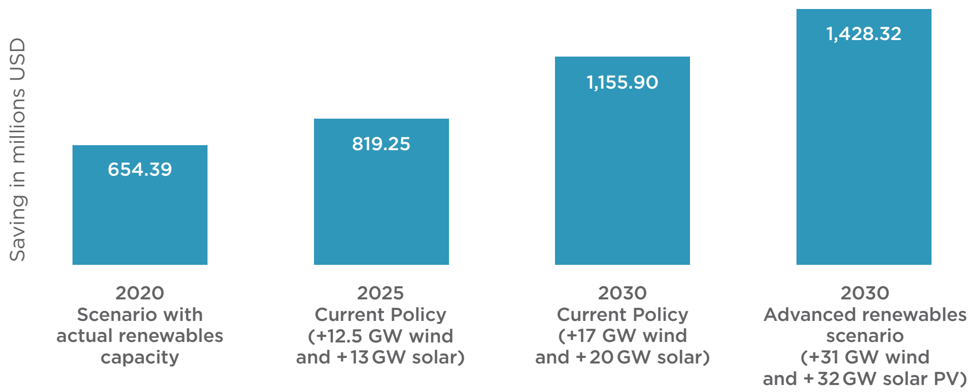


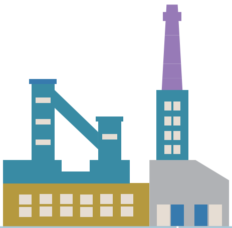
Figure 13: Electricity cost savings with renewables compared to a scenario without renewables (million USD) | Source: own

The direct benefits predicted for industrial sectors under the BAU scenario reach USD 820 million for 2025 and USD 1.15 billion for 2030.

If the Advanced Renewables Scenario is realised in the year 2030, the benefits can reach up to USD 1.43 billion for 2030 (See Figure 13). These values are calculated by comparing the actual renewables capacity scenario with the hypothetical scenario without renewables for Case A (stable fuel price, no carbon price).

In the BAU scenario, cumulative direct benefits (in terms of savings) from the increasing share of renewables in the Turkish energy market can amount to USD 9.52 billion from 2020 to 2030.

The Advanced Renewables Scenario in 2030 certainly adds to the estimated benefits. As can be seen from Table 3, by 2030 the Advanced Renewables Scenario provides cumulative direct benefits estimated at USD 10.23 billion when compared to the scenario without renewables.



Industry	Nace Rev. 4	Saving with respect to hypothetical without renewables scenario USD (millions)						
						Cumulative		
		2020 Scenario with actual renewables capacity	2025 Current Policy (+12.5 GW wind and +13 GW solar)	2030 Current Policy (+17 GW wind and +20 GW solar)	2030 Advanced renewables scenario (+31 GW wind and +32 GW solar)	2020-25 Current Policy	2020-30 Current Policy	2020-30 Advanced renewables
Paper & publishing	17-18	30,78	37,12	52,31	64,53	203,65	431,76	465,35
Non-metallic minerals	23	83,17	101,63	143,30	176,81	554,31	1.179,32	1.271,07
Metal industry	24	190,70	253,52	358,79	444,61	1.341,21	2.910,07	3.136,48
Other industry	16-31-32	26,90	32,49	45,64	56,36	178,30	377,79	407,19
Mining (excluding coal and gas)	07-08-09	13,87	17,12	23,99	29,65	93,06	198,20	213,62
Textiles & wearing apparel	13-14-15	103,03	125,36	175,58	216,67	684,69	1.453,02	1.566,06
Chemical, rubber, plastic products	20-21-22	77,38	93,93	132,62	163,67	513,45	1.092,11	1.177,08
Fabricated metal products	25	12,79	16,14	22,81	28,17	87,03	186,68	201,20
Transport equipment	29-30	5,73	8,48	12,49	15,41	42,89	96,79	104,32
Machinery, electric machinery & electronics	26-27-28	55,02	69,29	99,36	122,66	373,74	803,72	866,25
Food	10-11-12	55,04	64,18	89,02	109,79	357,78	748,76	807,01
TOTAL (USD)		**654,39**	**819,25**	**1.155,90**	**1.428,32**	**4.430,10**	**9.478,21**	**10.215,64**
TOTAL in TRY (millions)		**3.171,30**	**3.970,20**	**5.601,69**	**6.921,86**	**21.468,96**	**45.932,86**	**49.506,55**

Table 3: Electricity cost savings in 2020, 2025 and 2030; and cumulative benefits for 2020–25 and 2020–30 (Case A)

Source: own

3.3 Hedging against fuel price risk: Reducing the share of fossil fuels

The Turkish energy production system is heavily dependent on imported fossil gas (more than 98%) and hard coal (more than 97%). Here, fossil gas plays a significant role, as most gas-based power plants impose high short-run marginal costs compared to other conventional generation technologies such as coal or lignite. In most cases, gas-based power plants are marginal power plants for defining the market clearing price, also referred to as "price maker" power plants. Hence, the volume and average cost within the sector is also significantly affected by the fossil gas prices of these primary energy sources.

In order to understand the impact of gas price increases on electricity prices for industrial consumers in Turkey, a 31% fossil gas price increase was modelled in all three reference scenarios (for Case B and D). This price increase was based on the IEA's new policy forecasts (IEA, 2016) for the year 2030 and did not even take the most recent gas price increases in 2021 and 2022 into consideration. More details can be found in Annex 1.

A 31% fossil gas price increase results in a 16.1% surge in electricity retail tariff for industry in a hypothetical power market without any renewables (Scenario without renewables). Even in the Current Policy Scenario, industrial consumers would still face a retail price increase of 4.7%. In contrast, under the Advanced Renewables Scenario, the gas price increase would only result in 2.6% higher retail prices for industrial consumers, showing the potential for hedging against fossil fuel price risks via renewable energy deployment (see Figure 14).

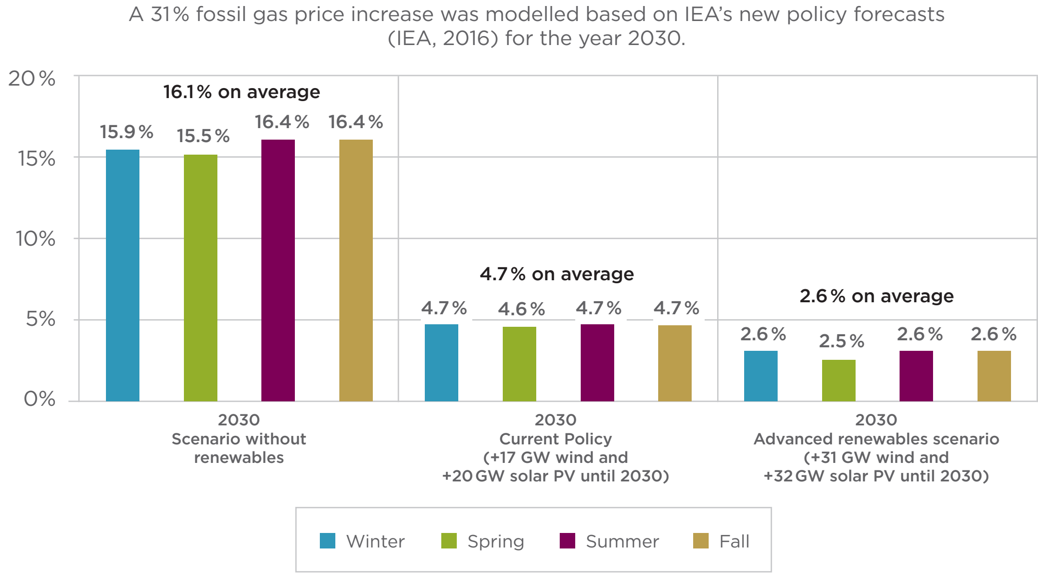


Figure 14: The effects of higher fossil gas prices on electricity retail tariffs for industry | Source: own

3.4 Hedging against carbon price risk: Reducing the carbon intensity of the power sector

In order to achieve the objectives of the Paris Agreement, the negative externalities associated with carbon emissions need to be "internalised", i.e., reflected and included in the prices of fossil fuels. Therefore, carbon pricing is becoming an increasingly important policy tool in the global energy transition.

As of 2021, carbon pricing was implemented in 65 countries and regions around the world.[6] The High-Level Commission on Carbon Prices concluded that carbon prices should be in the range of 40–80 USD/tCO_{2e} in 2020 and 50–100 USD/tCO_{2e} by 2030 (World Bank, 2020). In the European Union, the price for carbon in the emission trading system (ETS) has significantly increased in recent years. At the end of 2019, the ETS price stood at 28.2 USD/ton of CO_2, increasing to more than 35.3 USD/ton[7] at the end of 2020 and to more than 94.1 USD/ton at the end of 2021.[8]

The following two cases were used to evaluate how the introduction of a carbon price may affect future electricity prices for industrial consumers in Turkey: An electricity system without carbon pricing (Cases A and B); and an electricity system with a carbon price of 70.6 USD/ton of CO_2 (Cases C and D). More details on the assumptions employed in the CO_2 price are provided in Annex A1.3.

The implementation of a high carbon price will lead to higher prices for industrial consumers. However, the price increase can be dampened by increasing the share of zero-carbon renewable energy technologies. Under the Current Policy Scenario and a hypothetical carbon price of 70.6 USD/ton of CO_2, retail electricity prices for industrial consumers would increase by 20.6% on average in the year 2030. However, the price increase would be significantly lower in the Advanced Renewables Scenarios, at only 15.8% (See Figure 15).

In addition, a highly carbon-intensive industrial sector is likely to become a significant competitive disadvantage for Turkey's future global trade. Carbon 'border adjustments' are being actively considered at the EU level as part of its Green New Deal. In July 2021, the European Commission adopted a proposal for a new Carbon Border Adjustment Mechanism that will put a carbon price on imports of a targeted selection of products.[9] Other jurisdictions are currently discussing similar mechanisms. Therefore, reducing the carbon intensity of the Turkish electricity system can also be understood as a policy measure to safeguard Turkish exporting industries.

[6] Carbon Pricing Dashboard, World Bank https://carbonpricingdashboard.worldbank.org/

[7] Referring to metric tonnes (1 metric ton = 1,000 kg)

[8] Carbon Price Viewer, Sandbag https://sandbag.be/index.php/carbon-price-viewer/

[9] Carbon Border Adjustment Mechanism, EC. https://ec.europa.eu/taxation_customs/green-taxation-0/carbon-border-adjustment-mechanism_en

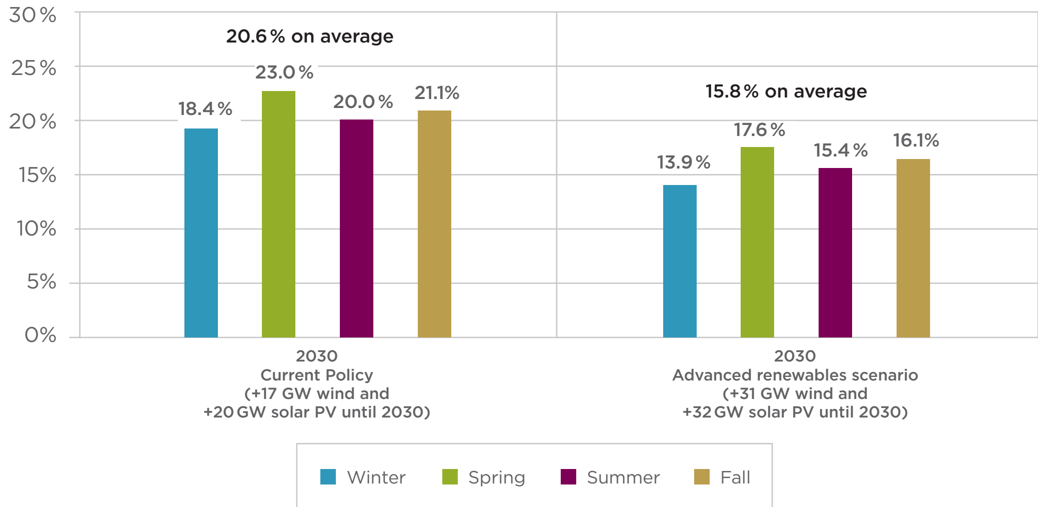


Figure 15: Increase in electricity prices for industrial consumers: high carbon price compared to zero carbon price | Source: own

Transforming the electricity system towards higher shares of renewables will require slightly higher grid investment and costs for increasing the flexibility of the grid; nevertheless, this be cheaper than sticking to a highly carbon-based system.

3.5 Macro-economic benefits: job creation (Labour demand) and exports

Lower electricity prices for industrial consumers will have positive **spillover effects** for the Turkish economy as a whole. The positive spillover effects from reduced industrial electricity tariffs are evaluated utilising the supply side of the model economy (see Section A2.2 and Section A2.7 in Annex 2). This includes the impacts **on job creation (labour demand)** and **exports**.

Figure 16 compares the relative **spillover effects** for CASE A regarding: a) labour demand, and b) total exports for 2030 in the Current Policy versus Advanced Renewables scenarios. Labour demand is estimated to be 18.75% higher and, similarly, total exports will be 22.30% greater in the Advanced Renewables Scenario compared to the Current Policy Scenario.

EU Carbon Border Adjustment Mechanism (CBAM)

In line with the long-term climate policy targets set in the EU Green Deal: In July 2021, the European Commission presented a CBAM legislative proposal to ensure that non-EU producers pay a price for their direct emissions incurred during the production (Scope 1 emissions) of imported goods; the CBAM price will be comparable to that paid by EU producers under the EU Emission Trading System (ETS).

The CBAM will initially apply to imports of **cement, fertilisers, iron and steel, aluminium, and electricity goods**. The CBAM proposal is still undergoing review. The full CBAM is expected to become operational in 2026. However, in a transitional phase starting in 2023, non-EU producers are expected to report the emissions embedded in their exported goods, but without paying a financial adjustment (no purchasing of CBAM certificates).

In addition, Figure 17 depicts the **spillover effects** with respect to the hypothetical scenario (without renewables) in case of increasing fossil fuel costs and implementation of carbon pricing. As can be seen, the benefits gained from the labour demand and export perspectives are higher in Case D compared to Case A. The main reason is that the electricity cost savings in Case D are considerably higher than that of Case A. In the year 2030, **labour demand** is predicted to increase from 16,000 people to 75,000 people (365% growth) in the Current Policy Scenario, and from 19,000 people to 77,000 people (305%) in the Advanced Renewables scenario. **Exports** are increased from USD 0.95 million to USD 4.47 million (369% growth) in the Current Policy Scenario, and from USD 1.165 billion to USD 4.7 billion (301%) in the Advanced Renewables Scenario.

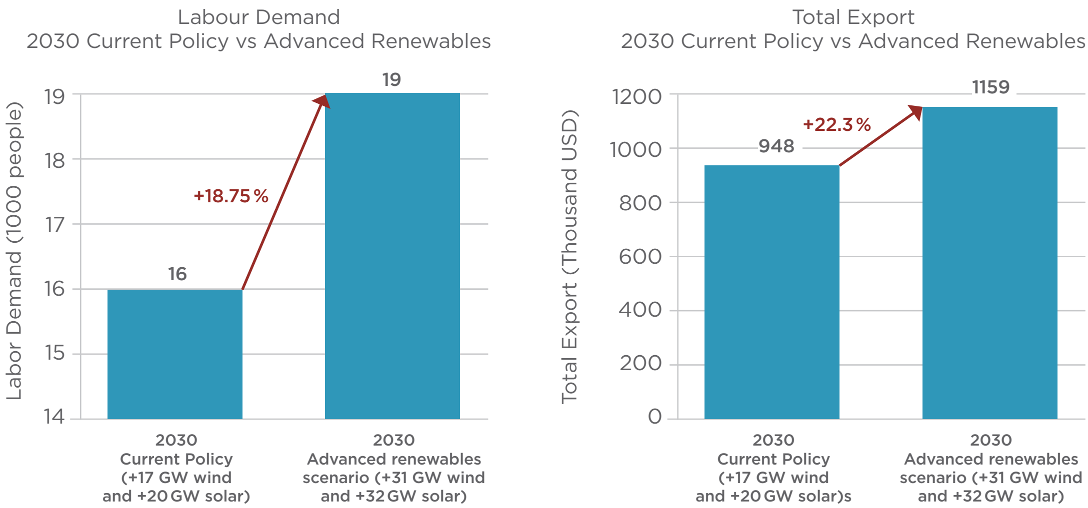


Figure 16: Relative spillover effects with respect to hypothetical scenario without renewables (2030 Current Policy vs Advanced Renewables): a) Labour demand, b) total exports – Case A | Source: own

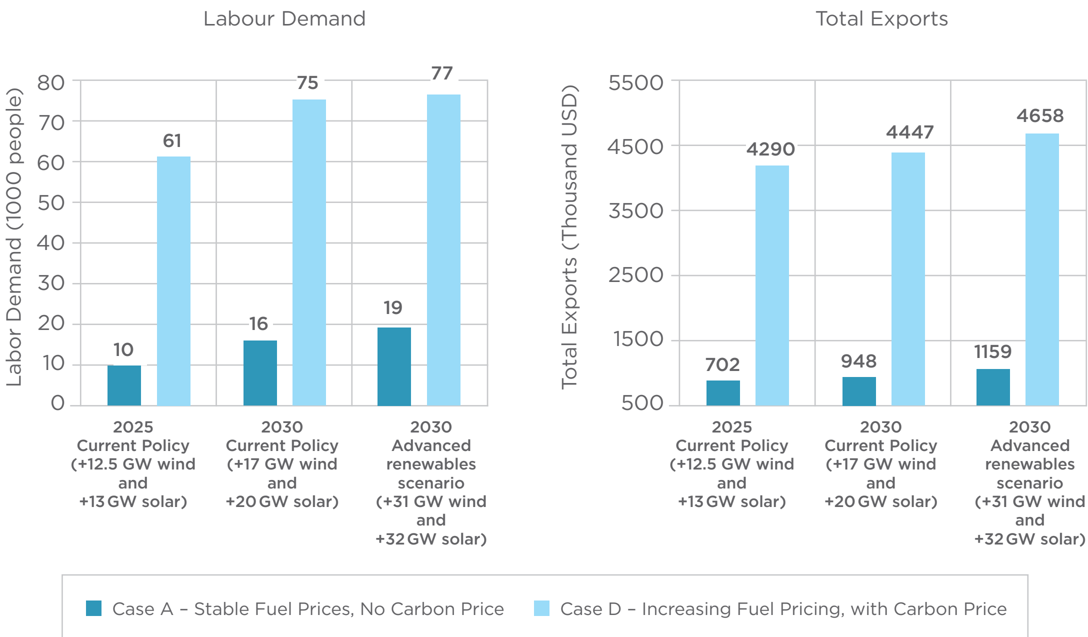


Figure 17: Spillover effects with respect to hypothetical scenario without renewables (Case A vs Case D): a) labour demand, b) total exports | Source: own

Illustrative case study at local level: The Demirtaş Organized Industrial Zone (DOSAB)

By focusing on a specific industrial zone, the impact of historical and potential future cost savings become more tangible.

The study applied the main findings at a pilot scale to one of the largest industrial zones of Turkey, the Demirtaş Organized Industrial Zone (Turkish abbreviation DOSAB) located in Bursa Province.*

Accordingly, the direct savings among the selected firms in 2019 was around USD 2 million for the BAU compared to the hypothetical scenario without renewables; and the **cumulative savings between 2015 and 2020 amounted to around USD 7.3 million**. The results indicate that cost savings were around 2.5% of the total electricity bill for these firms in 2019.

	2015	2016	2017	2018	2019	2015-19 Cumulative
Textiles & wearing apparel	375.653	343.748	387.882	476.518	537.848	**2.121.648**
Chemical, rubber, plastic products	45.603	106.783	101.001	123.391	139.280	**516.058**
Transport equipment	477.243	839.793	959.274	1.090.659	1.231.181	**4.598.150**
Food	5.805	6.706	8.139	9.820	11.085	**41.556**
Metal industry	2.286	3.095	5.300	5.644	6.369	**22.693**
TOTAL (USD)	**906.590**	**1.300.124**	**1.461.596**	**1.706.031**	**1.925.763**	**7.300.105**

Table 4: Total savings for the Current Policy Scenario compared to the hypothetical scenario without renewables for 2015-2019 (USD)

Source: own

Compared with the hypothetical scenario without renewables: Total savings under the Current Policy Scenario could be as high as USD 4.59 million in 2030 and **USD 35.73 million between 2020 and 2030;** and USD 5.52 million in 2030 and USD 38.52 million between 2020 and 2030 under the Advanced Renewables Scenario.

	2030	2020-25	2020-30
Textiles & wearing apparel	1.076.067	4.044.159	8.719.551
Chemical, rubber, plastic products	277.629	1.035.873	2.239.389
Transport equipment	3.201.769	10.611.389	24.496.006
Food	20.697	80.139	170.120
Metal industry	13.952	50.297	111.139
TOTAL (USD)	**4.590.113**	**15.821.858**	**35.736.205**

Table 5: Total savings for the BAU scenario compared to the hypothetical scenario without renewables for 2020-2030 (USD)

Source: own

* A selected sample of DOSAB firms that have available data for calculating past and future savings. The selected sample in 2019 comprised around 54% of the total electricity demand for DOSAB (1,140.3 GWh).

4. Creating an environment enabling the industrial sector to benefit from lower electricity costs

Impulses for furthering the debate

This COBENEFITS study shows that the Turkish industrial sector has and will benefit greatly from increasing the shares of renewable energy sources in the electricity mix. Higher shares of renewables reduce both the wholesale electricity price and the retail electricity price. The industrial sector can benefit from these cost reductions, which in turn will improve the sector's economic competitiveness.

In terms of reducing the **wholesale electricity price**, a scenario with a higher share of renewables can reduce wholesale electricity price by 2.4% on average by 2030 (compared with the currently planned deployment of renewables). This would amount to total savings of TRY 1.96 billion (USD 477 million) in 2030 alone. The **retail electricity price** for the industrial sector can be reduced by 1.65% in 2030 when comparing current renewable energy expansion plans with the more rapid expansion of wind and solar PV under the Advanced Renewables Scenario. This would amount to total electricity cost savings of TRY 1.32 billion (USD 274 million) for the industrial sector in 2030 alone. Renewable energy procurement can also reduce the risks associated with fossil fuel price volatility.

In addition, by reducing electricity prices and increasing the economic competitiveness of the industrial sector, **exports** are expected to increase by TRY 5.6 million (USD 1.16 million), amounting to a 0.13% increase in **GDP**. By making the Turkish industrial sector more competitive internationally, it can grow more rapidly, with the prospect of creating up to **19,000 new jobs**.

What can government agencies and political decision makers do to create a suitable enabling environment to further increase savings for the industrial sector in Turkey?

Building on the study results and the surrounding discussions with political partners and knowledge partners, we propose to direct the debate to the following areas where policy and regulations could be put in place or enforced in order to facilitate the industrial sector's access to lower electricity costs.

- Protecting the industrial sector in Turkey by anticipating EU Carbon Border Adjustment Mechanism (High-Impact Action 1)
- Promoting flexibility measures to facilitate the integration of renewables within Turkish power systems (High-Impact Action 2)
- Improve the regulatory regime for self-consumption of renewable energy by industry (High-Impact Action 3)
- Promoting green tariffs/a regime for a Guarantee of Origins System (Additional Impact Action)
- Establishing a network-driven mechanism to harvest maximum benefits of renewable energy (Additional Impact Action)

High-Impact Action 1: Protecting the industrial sector in Turkey by anticipating EU Carbon Border Adjustment Mechanism

To ensure the competitiveness of the industrial sector, the Turkish Government can take measures to prevent legal uncertainty and define a long-term financing programme for decarbonisation of the industrial sector while adopting its national carbon pricing system.

The adoption of the CBAM proposal has significantly intensified "low-carbon economy" discussions among Turkish industry. Considering that the EU region is Turkey's largest foreign trading partner,[10] the Turkish Government would be well advised to become more proactive and take bold measures in a timely manner for mitigating the potential risks and benefiting from the opportunities presented by the CBAM proposal. Moreover, as an EU candidate country, the Turkish Government needs to accelerate its efforts to comply with EU climate and energy acquis.

In order to respond to the potential implications of the EU Green Deal for the Turkish economy, the Ministry of Trade announced a National Green Deal Action Plan on July 16, 2021. The plan foresees a "national carbon pricing position" without establishing an ETS-like mechanism or carbon tax instrument in the short run.[11] However, the Turkish private sector requests a fully operational national emission trading system be put into operation as soon as possible, that works in harmony with the EU ETS. In so doing, the industrial sector will become prepared before the enactment of the CBAM reporting requirement planned for 2023 (Certain third countries that participate in the EU ETS or have an emission trading system linked to the EU ETS are expected to be excluded from the CBAM. This is the case for members of the European Economic Area and Switzerland).

This study also modelled potential savings in the case of enacting a national carbon price and increasing fossil gas prices for the industrial sector. Table 6 shows the estimated direct benefits, compared with the hypothetical scenario without renewables in the case of increasing fossil fuel prices and implementing carbon pricing. The relative direct savings can reach USD 7 billion in the year 2030 alone.

Institution to champion the Action	Collaborative bodies to successfully implement the Action	Timeframe of the Action
Ministry of Environment, Urbanisation and Climate Change (MoEUCC) **Ministry of Trade**	Ministry of Energy and Natural Resources (MoENR) Energy Market Regulatory Authority (EMRA) Energy Exchange Istanbul (EPİAŞ)	Short term

[10] Turkey's exports in five product groups anticipated to be subject to CBAM amounted to 4.8 billion USD, representing 32% of Turkey's total exports. The costs of CBAM for Turkish exports are calculated as EUR 1.1 to EUR 1.8 billion per year. See *"The New Climate Regime through the Lens of Economic Indicators"*, report prepared by the TUSİAD.

[11] The Turkish Government needs to reach a consensus with the European Commission for modernisation and upgrading of the Customs Union, which will be decisive for the establishment of a comparable explicit carbon pricing mechanism (via national emission trading system and/or carbon tax instrument) in Turkey.

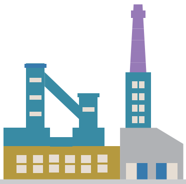


Table 6: Direct benefits for year 2030: Case A vs Case D compared to scenario without renewables

Source: own

Industry	Saving with respect to hypothetical without renewables scenario (million USD)					
	2025		2030			
	Case A	Case D	Case A	Case D	Case A	Case D
Paper & publishing	37,3	280,9	52,6	300,0	64,9	317,0
Non-metallic minerals	102,1	769,2	144,0	821,8	177,7	868,6
Metal industry	254,8	1.918,8	360,6	2.057,5	446,9	2.184,3
Other industry	32,7	245,9	45,9	261,7	56,6	276,9
Mining (excluding coal and gas)	17,2	129,5	24,1	137,6	29,8	145,7
Textiles & wearing apparel	126,0	948,8	176,5	1.006,9	217,8	1.064,4
Chemical, rubber, plastic products	94,4	710,9	133,3	760,5	164,5	804,1
Fabricated metal products	16,2	122,2	22,9	130,8	28,3	138,4
Transport equipment	8,5	64,2	12,6	71,6	15,5	75,7
Machinery, electric machinery & electronics	69,6	524,4	99,9	569,8	123,3	602,6
Food	64,5	485,8	89,5	510,5	110,4	539,4
TOTAL (million USD)	**823,4**	**6.200,6**	**1.161,8**	**6.628,8**	**1.435,6**	**7.016,9**
TOTAL (million TRY)	**3.970,2**	**29.895,5**	**5.601,7**	**31.960,5**	**6.921,9**	**33.831,7**

High-Impact Action 2: Promoting flexibility measures to facilitate integration of renewables into Turkish power systems

Building on the study results, the amount of integrated renewable energy and associated share in the generation mix has a direct bearing on the market clearing price and, consequently, on industry tariffs. The introduction of renewables displaces costlier generation units, shifting them down the merit order and resulting in a cheaper marginal power plant while clearing the market. However, the integration of renewables presents challenges for the flexibility of the power system.

For instance, in the case of high renewable generation and low demand, two options are available to maintain generation–consumption balance: 1) Shut down in-service conventional power plants, which is a difficult task due to hard constraints of some conventional power plants (e.g., nuclear power plants); 2) Curtail renewable-based energy generation, which reduces harvested benefits. To avoid such issues, flexibility options such as battery storage devices, pump-storage units, and interconnections with neighbouring countries can be used.

Flexibility countermeasures avoid renewable curtailment while satisfying the hard constraints of conventional power plants in the generation fleet. Grid studies of the Turkish power system illustrate that by having 600 MW battery storage and 1000 MW pump storage units, the Turkish power system can benefit from direct benefits and co-benefits of 63 GW renewable-based energy resources (31 GW wind and 32 GW solar). This amount can also be increased by increasing the net transfer capacities at the interconnection with the ENTSOE and Georgia, and using advanced market mechanisms such as market coupling and imbalance netting.

Institution to champion the Action	Collaborative bodies to successfully implement the Action	Timeframe of the Action
Ministry of Energy and Natural Resources (MoENR)	Energy Market Regulatory Authority (EMRA), TSO (TEIAS)	Short or mid term

High-Impact Action 3: Improve the regulatory regime for renewable energy self-consumption

The current regulatory regime for unlicensed production is not at the desired level, due to disincentives and an insufficient regulatory enabling environment for administrative processes and project financing.

To increase the uptake of self-consumption by the industrial sector, Turkish authorities need to improve the enabling regulatory environment and encourage companies by amending existing legal measures and defining new ones.

Measures to improve enabling regulatory environment and encourage self-consumption by companies

- Amendment of net metering rules (as an annual offset)
- Recognition of unlicensed solar generation players as market participants
- Formulation of long-term power purchase agreements (PPA) between energy companies and consumers
- Rewarding best-performing companies
- Mechanisms to incentivise the installation of energy storage devices
- Ensuring the distributed energy portfolio for incumbent retail companies

Enabling environment

Amendment of net metering rules

One of the challenges in providing an enabling environment involves amending current legislation on net metering rules[12] (payment modalities for excess electricity) for unlicensed power generation. Currently, the offsetting process is carried out monthly in supplying the extra generated electricity to the grid. A shift to annual offsetting will motivate more industrial players to invest in self-consumption.

[12] This refers to monthly calculation of the difference between consumption and generation that such actors sell to the grid.

Unlicensed solar generation players as market participants

As of 2021, unlicensed solar generation facilities account for substantial installed capacity in excess of 6000 MW. However, they are not considered as market participants. Consequently, they are not able to benefit from certain schemes, for example carbon certificates. Measures should be introduced to enable unlicensed solar generation facilities to participate in existing and new mechanisms.

Moreover, the market authority can involve these operators in the wholesale electricity markets after their feed-in tariff periods; such moves would avoid situations in which a substantial amount of available generation capacity is unused.

Formulation of long-term power purchase agreements (PPA) between energy companies and consumers

With the amendments to the Unlicensed Generation Regulation published in May 2021, consumers are now able to set up unlicensed ground-type solar power plants in the same distribution region without exceeding their contractual power. The industrial sector has welcomed this regulatory reform and requested an additional amendment that enables long-term PPAs to be signed between the energy company and the consumer.

Incentives

In order to benefit from self-consumption in the industrial sector, it is crucial to establish attractive incentives and improve the existing ones, to benefit consumers ranging from large-scale industrial players to SMEs.

The industrial sector (including SMEs) can accelerate their investment decisions for self-consumption with the help of incentives (i.e., reduced VAT rates applied to the solar equipment, real estate tax exemption/reduction) and via the availability of long-term and low-interest financing models for end-users. In addition, the electricity regulatory authorities can identify regulatory measures for the development of new business models (bilateral agreement, roof rental, etc.) that will support self-consumption installations.

Rewarding best-performing companies

Large energy consumers demand more state incentives for efficiency/self-consumption investments, which will directly affect competitive advantage, rather than subsidising energy prices.[13]

The new incentive mechanisms can reward best-performing companies (high environmental score, low carbon footprint-renewable leaders in the industrial sector) based on their performance levels. Levelised tariffs for the industrial sector could be suggested based on companies' energy performance (the quality of use of energy, investments for electricity storage systems, and renewables).

[13] The majority of large energy consumers also demand state incentives for efficiency/self-consumption investments, which will directly affect competitive advantage, rather than subsidising energy prices. TÜSİAD, 2021. Large Energy Consumers Survey.

Institution to champion the Action	Collaborative bodies to successfully implement the Action	Timeframe of the Action
Ministry of Energy and Natural Resources (MoENR)	Energy Market Regulatory Authority (EMRA)	Short term, over the next 1–2 years

Support for the installation of energy storage devices through incentive mechanisms and subsidies

The quality of electricity supply is sometimes problematic for continuous production in certain industrial sectors (e.g., chemical manufacturing). Therefore, the use of energy storage devices is required to increase flexibility and decrease intermittency at the installation level. However, these devices are expensive and would only be economically feasible for investors if supported by the government.

The government may also support industrialists who plan to invest in energy storage systems. New, targeted incentives (such as tax cuts, credits, or grants) can enable the switch from net metering to small-scale battery storage installations and contribute to the system's flexibility.

Ensure distributed energy portfolio for retail companies

Along with these measures, retail companies also need to be encouraged to make extra efforts to promote distributed energy. The electricity regulatory authorities can adopt a portfolio standard that will encourage/require electricity retail companies to obtain a certain percentage of energy from renewables.

Additional Impact Action 1: Promoting green tariffs/Guarantees of Origin System

Green tariffs and renewable energy resource guarantee certificate schemes are among the available tools that can benefit industrial companies in their climate and energy policy targets. These schemes are also expected to encourage consumers to use renewable energy in Turkey. The national Renewable Energy Resource Guarantee (YEK-G) system, where participation is provided on a voluntary basis, became operational on June 1, 2021.[14] YEK-G certificates are issued by EPİAŞ to monitor, prove, and disclose that the electricity supplied to consumers is generated from renewable energy resources, and to enable consumers to receive electricity generated from documented renewable resources. Turkish authorities must ensure that the YEK-G system is harmonised with the European Energy Certificate System (EECS).

Finally, in order to increase interest in the YEK-G system and create an additional incentive for investment in renewables, the inclusion of unlicensed solar power plants (6.258 MW at the end of 2020) is suggested.

[14] The Organized YEK-G Market is operated by EPİAŞ according to a continuous trade model, and is where YEK-G certificates are bought and sold among system users.

Institution to champion the Action	Collaborative bodies to successfully implement the Action	Timeframe of the Action
Ministry of Energy and Natural Resources (MoENR) **Ministry of Environment, Urbanisation and Climate Change (MoEUCC)**	EMRA, EPİAŞ	Short term or mid term

Additional Impact Action 2: Establishing network-driven mechanism to harvest maximum benefits of renewable energy

One of the main barriers to the proliferation of renewables is the lack of an appropriate transmission grid to host such intermittent resources. In the conventional power system with limited integration of renewables, expansion of the transmission system is planned based on the integration of bulk generation systems and the major load centres. However, the integration of renewables into conventional power systems changes this balance. To offer further details, integration of renewables is mostly based on a resource-driven approach in which installation schemes focus on locations with abundant renewable resources such as wind energy. However, such an approach might challenge the transmission system, which has capacity and congestion issues. In other words, a resource-driven approach has the potential to integrate additional renewable-based generation; however, various grid constrains might lead to high curtailment of renewable and mean that this potential is not realised. In Turkey, the main tension of the above-mentioned resource-driven approach is imposed on a 400 kV system that has the highest expansion cost. To reduce possible curtailment of renewables and relieve grid constraints, it is recommended that a network-driven approach be adopted for integration of renewables. In such an approach, renewable resources are mostly concentrated near major load centres and connected to the transmission system through a 154 kV grid. Such integration has two major advantages: 1) The renewable resources are very close to the load centre, which enables on-site generation/consumption concepts and reduces the need for grid investment; 2) Renewable curtailment due to grid constraints will be considerably reduced.

Institution to champion the Action	Collaborative bodies to successfully implement the Action	Timeframe of the Action
Ministry of Energy and Natural Resources	EMRA, EPİAŞ, TSO (TEIAS), DSOs	Short term, over the next 1–2 years

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COBENEFITS assessments in Turkey

In Turkey, the project is guided by the Istanbul Policy Center (IPC) and a council consisting of representatives of the Ministry of Energy and Natural Resources (MENR), Ministry of Environment and Urban Affairs (MoEU), Ministry of Treasury and Finance (MoTF, formerly Ministry of Economics MoE), Ministry of Foreign Affairs (MFA), and Ministry of Health (MoH).

COBENEFITS has assessed important social and economic co-benefits of increasing the shares of carbon-neutral renewable energy in Turkey's power systems. Building on these assessment results, the project consortium has worked with the government of Turkey to develop policy options to unlock these co-benefits for the country's citizens and businesses. The results of the co-benefits assessments have been published in the COBENEFITS Turkey Study series, which can be downloaded from **www.cobenefits.info**

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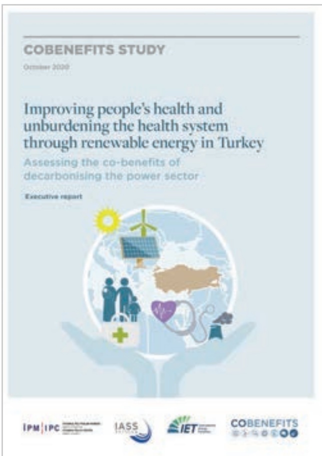

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Abbreviations

AGE	Applied general equilibrium
CBAM	Carbon Border Adjustment Mechanism
DAM	Day-ahead market
DOSAB	Demirtaş Organized Industrial Zone
EPDK	Energy Market Regulatory Authority
EPİAŞ	Turkish energy exchange operator
ETS	Emisyon Ticaret Sistemi (Emission Trading System)
GDP	Gross domestic product
GW	Gigawatt
IASS	Institute for Advanced Sustainability Studies, Potsdam
IEA	International Energy Agency
IPC	Istanbul Policy Center, Sabancı University
kWh	Kilowatt-hour
LCOE	Levelised cost of electricity
MCP	Market clearing price
MoENR	Ministry of Energy and Natural Resources
MoEUCC	Ministry of Environment, Urbanisation and Climate Change
MoTF	Ministry of Treasury and Finance
MFA	Ministry of Foreign Affairs
MoH	Ministry of Health
MWh	Megawatt-hour
PV	Photovoltaics
RE	Renewable energy
SHURA	SHURA Energy Transition Center

SRMC	Short-run marginal cost
TEİAŞ	Turkish Electricity Transmission Corporation
TWh	Terawatt-hours
YEKDEM	Renewable Energy Resources Support Mechanism
YEK-G	Renewable Energy Guarantees of Origin System

Technical Annex

Contents of the Annexes

List of Tables for Annexes

List of Figures for Annexes

Annex 1: Methodology, modelling inputs and assumptions

A note on currencies used in the annexes: Most calculations in the study were made in euros (EUR) and are therefore presented as such. For better international comparison, we have converted those currencies to U.S. dollars (USD) in the Executive Report.

A1.1 Key assumption for market simulation: generation fleet for Current Policy Scenario

The generation fleet for the years under study is reported in Table A.1. Here, the Business as Usual scenario is considered, where for the year 2030 two scenarios for renewables are depicted as in Table A.1.

The total demands for years 2015, 2020, and 2030 are represented in Figure A.1. For year 2015 and 2015, the hourly demand profile is available. To calculate the hourly demand profile for year 2030, the demand profile of year 2020 is considered as the reference. Events such as religious holidays, which are time varying, are considered while profiling each year from 2020 to 2030. The hourly demand profiles for years 2015, 2002, and 2030 are depicted in Figure A.2.

	2015 (GW)	2020 (GW)	2025 (GW)	2030 (GW)
Gas	25.1	25.6	25.8	25.8
Total Coal	15.3	19.9	21.5	23.2
Local Coal	0.4	0.8	0.9	0.9
Imported Coal	6.1	9	9.6	10.3
Lignite	8.8	10.1	11	12
Geothermal	0.6	1.5	2.2	2.9
Biomass	0.3	0.9	2.1	3.3
Total Hydro	25.9	29.8	31.7	31.7
Hydro	19.1	21.9	23.5	23.5
RoR	6.8	7.9	8.2	8.2
Total Renewables	4.8	14.4	25.5	36.5
Wind	4.5	8.1	12.4	16.7
PV	0.2	6.4	13.1	19.8
Nuclear	0	0	0	4.8
Other	1.2	1.1	1.1	1.1
Total Interconnection	1.2	1.2	1.2	1.2
ENTSO	0.5	0.5	0.5	0.5
Georgia	0.7	0.7	0.7	0.7
Total	**73.1**	**94.5**	**111.1**	**130.5**

Table A.1: The generation fleet in the Business as Usual (BAU) case

Source: own

[15] https://seffaflik.epias.com.tr/transparency/

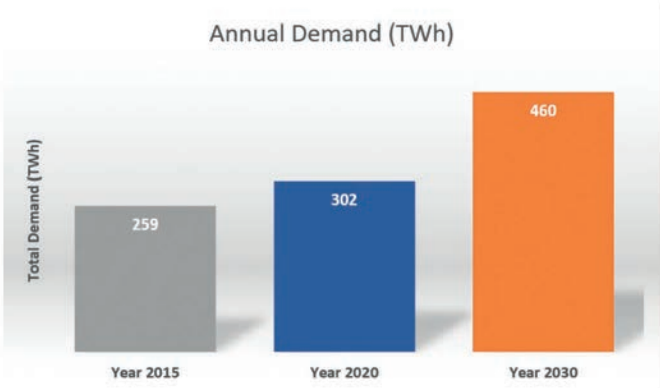


Figure A.1: Total demand for the years 2015, 2020, and 2030 | Source: own

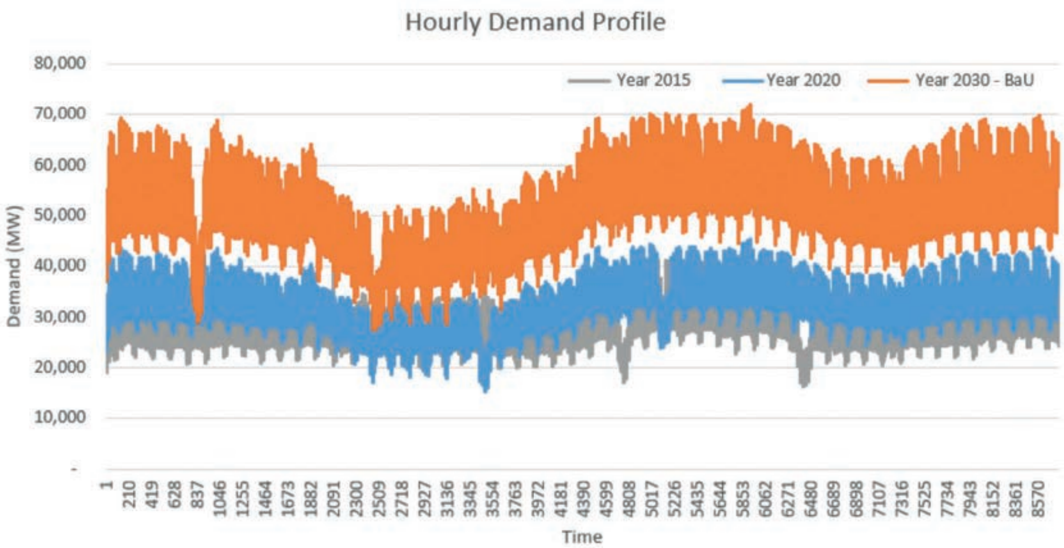


Figure A.2: Hourly demand for the years 2015, 2020, and 2030 | Source: own

The hourly generation profiles of individual wind and solar power plants are based on the methodology utilised in the SHURA report as part of the study "Increasing the Share of Renewables in Turkey's Power System: Options for Transmission Expansion and Flexibility" for the target year 2030. The hourly generation profiles of individual wind power plants are based on a national database[16] that uses satellite data from the European Centre for Medium-Range Weather Forecasts (ECMWF).[17] The installed capacities of renewable generation as well as associated weekly profiles for the year 2020 are depicted in Figure A.3 and Figure A.4, respectively.

[16] Hale Çetinay, "Determination of Wind Power Potential and Optimal Wind Power Plant Locations in Turkey," Master Thesis, Middle East Technical University, May 2014.

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

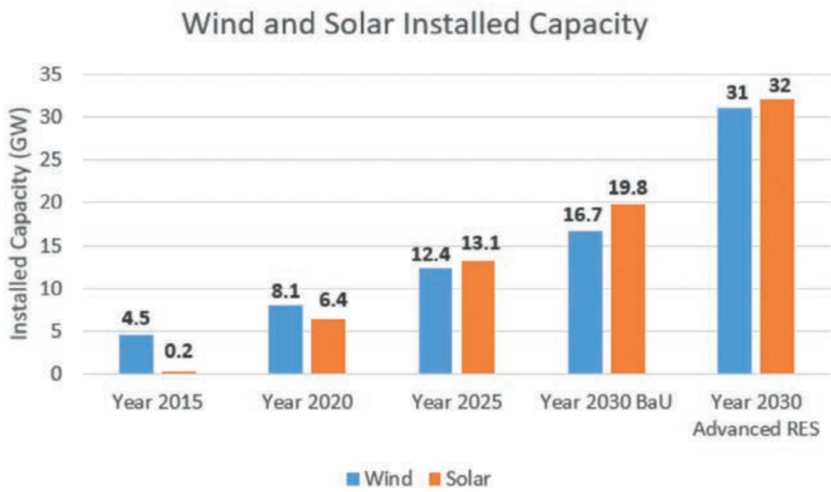


Figure A.3: Installed renewable generation capacities | Source: own

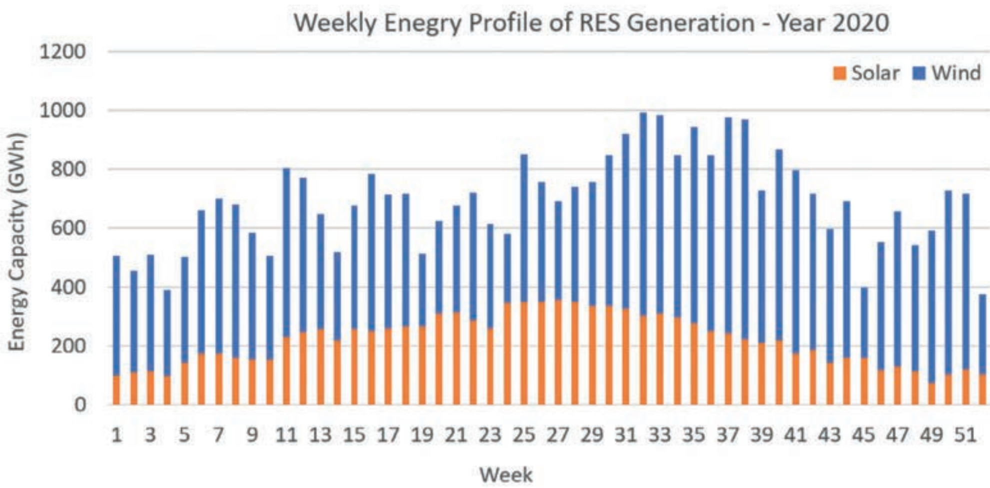


Figure A.4: Weekly profiles of renewable generation for the year 2020 | Source: own

A1.2 Market simulation tool to quantify historical savings

To quantify the electricity price savings for the industrial sector related to the deployment of renewable energies (the merit order effect), a price calculation tool was developed (see Figure A.5). The tool takes advantage of two main engines, which are depicted in blocks #1 and #2.

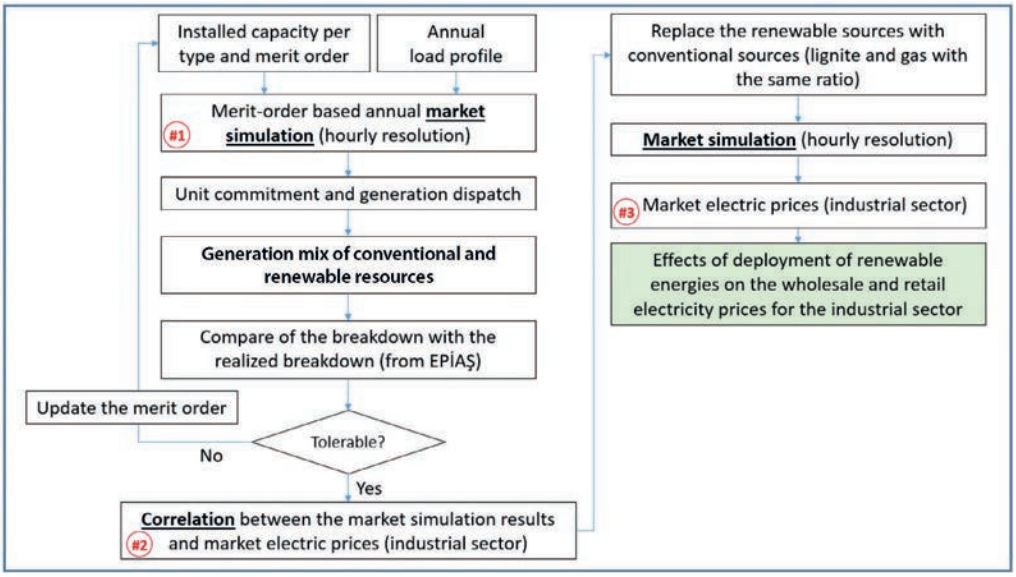


Figure A.5: Methodology for assessing historical costs savings | Source: own

In Figure A.5, Block #1 is the market simulation engine that simulates the day-ahead power exchange (PX) electricity market in Turkey. This acquires the generation fleet, merit order of different generation technologies, and annual profiles pertaining to the load and renewable-based generations. The merit order is a way of ranking available electricity generation technologies (see Figure A.6) based on ascending price (which may reflect the order of their short-run marginal costs of production) and sometimes pollution, together with the amount of energy that will be generated. In the market simulation, the ranking functions so that energy supplies with the lowest marginal costs are the first to be brought into service to meet demand, and plants with the highest marginal costs are the last to be used. Dispatching generation in this way, known as "economic dispatch", minimises the cost of producing electricity.

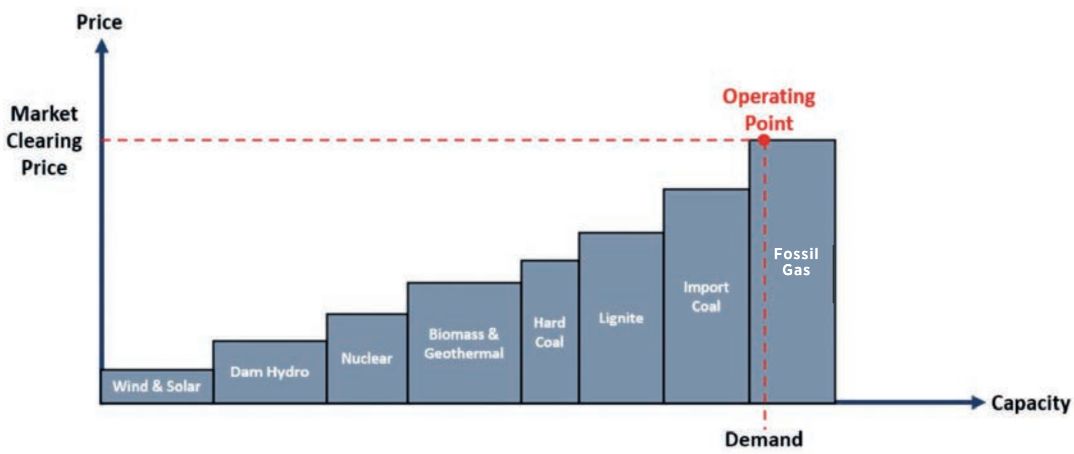
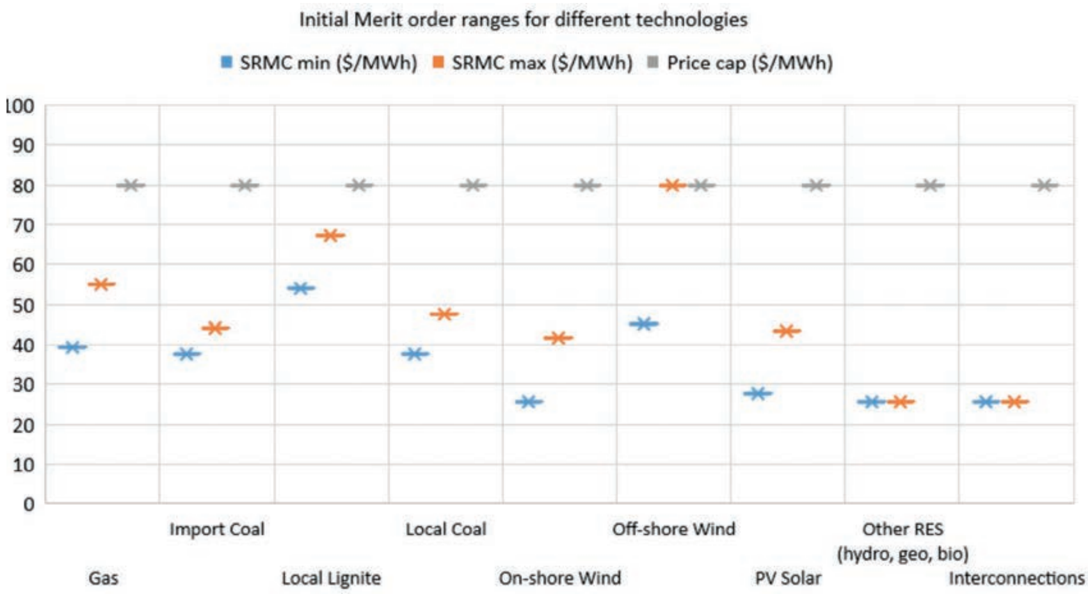


Figure A.6. Merit order concept in market simulation | Source: own

The market simulation engine inserts the aforementioned input data into an optimisation model where the objective is to minimise the total operation cost of the system subject to a suite of technical constraints. Here, the main constraints are the ramp-rate requirement of different power plants, minimum up- and downtimes of generators, permissible operation ranges of generators, maintenance requirements, weekly energy constraints of hydropower plants, etc. The outputs of the market simulation engine consist of hourly dispatch status and generated power of different generators, the marginal generation each hour, renewable curtailments, etc. The outputs of the market simulation tool are processed to derive annual generation breakdowns in terms of different technologies. The annual generation breakdown is used to verify the effectiveness of the adapted merit order for different technologies. In other words, the calculated annual generation corresponding to different generation technologies is compared with the realised generation, e.g., for the year 2020. Based on the difference between the calculated and realised generation values, the merit order input of the market simulation engine is revised, and the engine calculations may be repeated. Despite the hierarchical order of merits, there exist overlaps among the merit blocks due to the variations in age and efficiency of different power plants (see Figure A.7 - merit order ranges for different technologies). References and calculations for the merit order in Figure A.7 are presented in Table A.2 and Table A.3.



* SRMCs of other RES (hydro, geothermal, biomass) and interconnections are assumed to be constant and at the bottom of the merit order, along with on-shore wind power plants.

Figure A.7: Merit order ranges considered for the assessment (see block #1 in Figure A.5) | Source: own

	Gas	Imported Coal	Local Lignite	Local Coal	On-shore Wind	Off-shore Wind	PV Solar	Other RES (hydro, geo, bio)	Inter-connec-tions
SRMC min (USD/MWh)	39.30	37.63	53.83	37.63	25.63	45.05	27.58	25.63	25.63
SRMC max (USD/MWh)	55.15	43.98	67.30	47.33	41.58	80.00	43.27	25.63	25.63
Price cap (USD/MWh)	80.00								

Table A.2: Merit order assumptions in terms of SRMC

Source: own

Parameters & References	Gas	Imported Coal	Local Lignite	Local Coal	On-shore Wind	Off-shore Wind	PV Solar
Capacity factor %	27 %	78 %	48 %	51 %	34 %	49 %	20 %
Investment cost (USD/kW)	750	1300	1700	1300	950	3000	550
Lifetime (years)	20	30	30	30	20	20	20
SRMC (USD/MWh)	39.30	37.63	53.83	37.63	25.63	45.05	27.58
LCOE (USD/MWh) – calculation	55.15	43.98	67.30	47.33	41.58	80.00	43.27

Table A.3: SRMC and LCOE data

Source: own

Revising the merits in Figure A.7 involves revising the overlaps between the merits blocks in Figure A.6. Once the optimal merit configuration, which satisfies the tolerable error between the calculated and realised values, is achieved, the price calculation engine (block #2) calculates the market clearing price based on the outputs of the market simulation engine.

A flow chart of the proposed market clearing price engine is depicted in Figure A.8. Here, the outputs of the market simulation engine (i.e., the dispatch of different generators) provide the inputs for the market clearing price calculation engine. In addition, the market clearing price calculation engine acquires historical transparent data available from market operator platforms, such as EPİAŞ in Turkey.

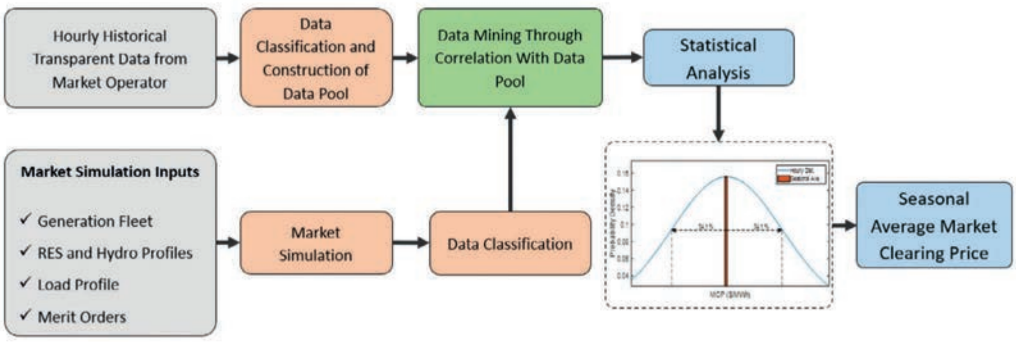


Figure A.8: Flow chart of market clearing price calculation | Source: own

The transparent market data at hand are used to construct a data pool. Figure A.9. depicts the historical hourly renewable energy resources (RES) generation versus market clearing price (MCP) from initial investigations for this study. The data pool provides the market clearing price versus the dispatch vector of conventional generators, which are often price makers, e.g., gas, imported coal, and lignite technologies. The inputs from the market simulation engine are compared with the data pool and the market clearing price is calculated by establishing optimum correlations between the dispatches acquired from the market simulation engine. Here, a seasonal classification is considered for price calculation, primarily because the load behaviour and availability of different generation technologies vary by season. Hence, a seasonal classification enables more accurate estimations from the price calculation engine.

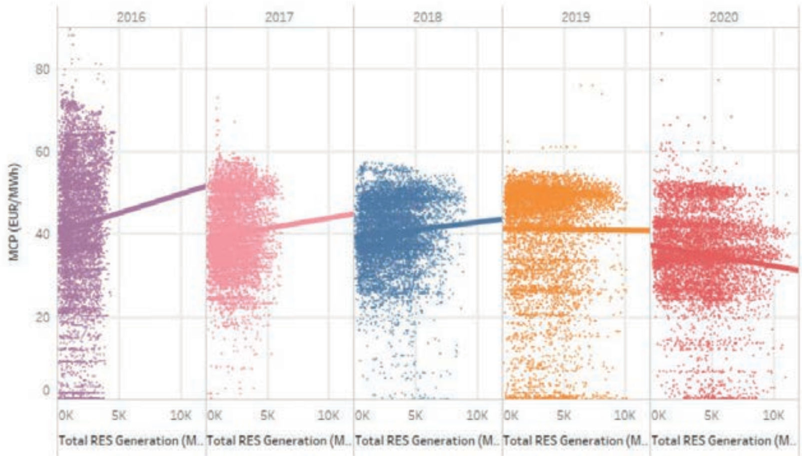


Figure A.9: Historical hourly RES generation vs market clearing price (MCP) | Source: own

In Figure A.10, for comparison with the 'no renewables' case, the renewable sources are replaced by an equivalent conventional generator, with a cost-effective merit order. Here, the substituted technologies can be gas or an imported coal-based power plant. The main reason is that these power plants are mainly marginal power plants that have a price-determining role. The price-making role changes from gas to imported coal according to the operating season. The market simulation and price calculation engines are executed to calculate the electricity wholesale and retail prices. The difference between the price calculated as the output of block #2 and the price calculated by block #3 is the effect of renewables development on wholesale prices.

Quantitative analysis employs the methodology presented in Figure A.10. Here, the wholesale electricity prices calculated in Figure A.8 are used to define retail electricity prices, particularly from an industrial standpoint. With the retail electricity prices in place, the associated effects on cost savings and benefits to the industrial sector are calculated.

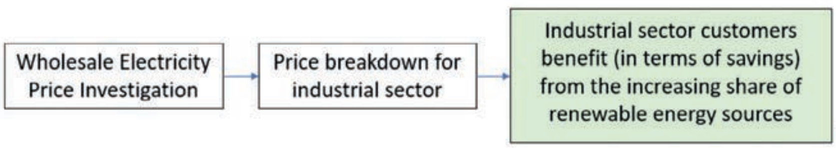


Figure A.10: Methodology for calculating historical industry benefits | Source: own

A1.3 Market simulation tool for quantifying future savings (until 2030)

Similarly to the quantification of historical savings, a cost-based merit order was developed for market simulations and the industry tariff calculation is as depicted in Figure A.11. The first step is scenario identification. A policy-directed scenario approach is considered here, with the scenario configuration represented in Figure A.12. For each scenario, generation fleet and demand projection are calculated and inserted into the market simulation engine. The market simulation engine was discussed in Section 2.2.2. The result of the market simulation is inserted into the price calculation engine. With the wholesale electricity price at hand, the retail price is calculated using the approach presented in Section 6.1.3. Here, four cases are considered as depicted in Figure A.11.

Case A deals with a condition where reference prices for IEA New Policies are considered for fossil gas prices and no carbon price is assigned. In cases B and C, increasing fossil gas prices[18] and high carbon price factors are taken into account, respectively. Case D considers the simultaneous effect of increasing fossil gas prices and high carbon prices.

[18] https://heatroadmap.eu/wp-content/uploads/2020/01/HRE4_D6.1-Future-fuel-price-review.pdf

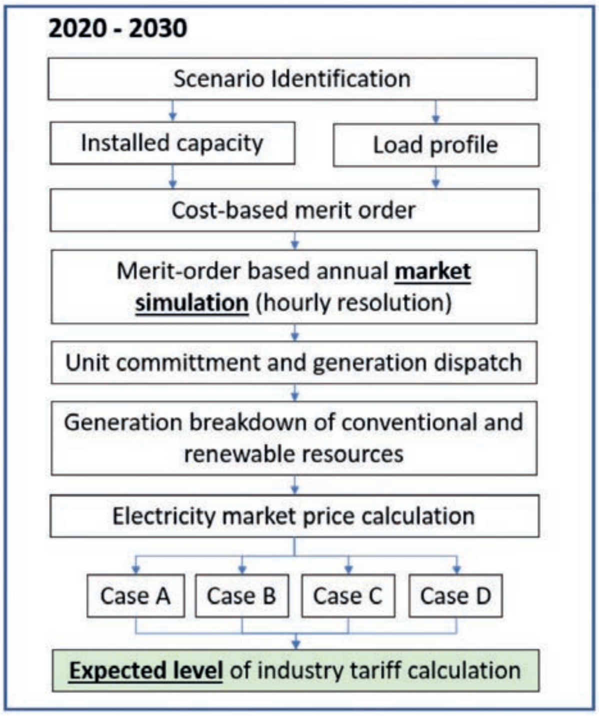


Figure A.11: Methodology for addressing future costs savings | Source: own

Figure A.12: Scenario configuration in the conducted study | Source: own

In Case B, the effect of increased fossil gas price on the industry retail tariff is considered as depicted in Figure A.13. In addition, the fossil gas prices for the reference and high price conditions are depicted in Figure A.14.

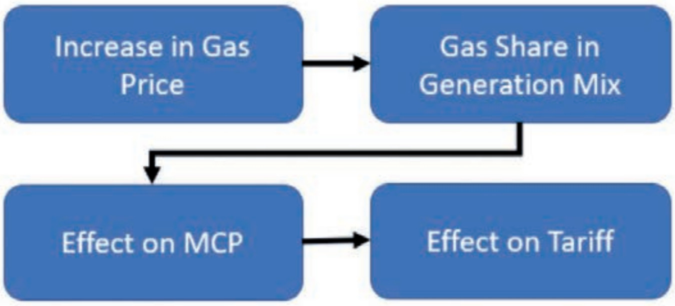


Figure A.13: Flow chart for calculating the effect of increased fossil gas price | Source: own

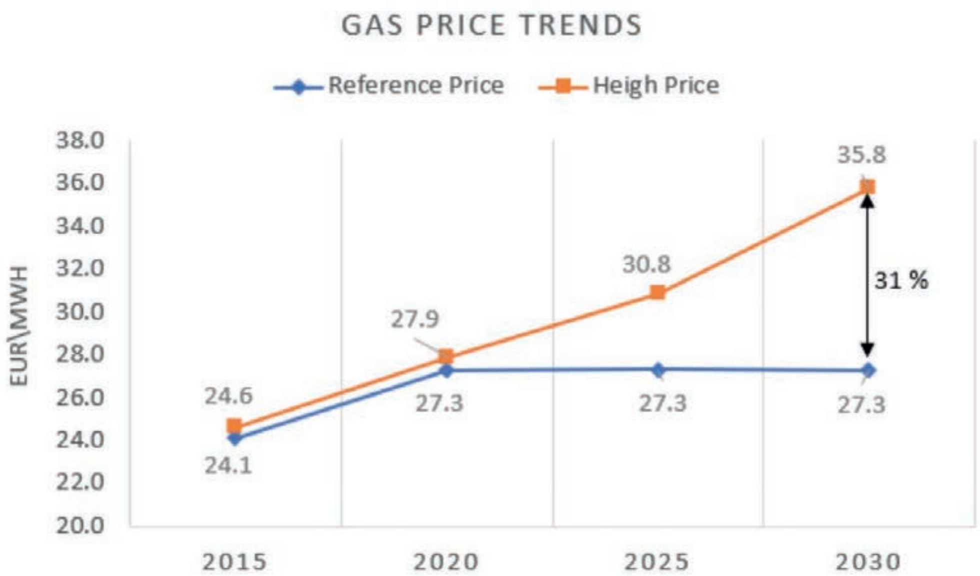


Figure A.14: Fossil gas price figures for reference and high price condition[19] | Source: own

In Figure A.14., the fossil gas price is considered fixed from year 2020 to year 2030, implying a long-term fuel purchase contract. The difference between the reference price and high price condition is used in Figure A.13. In Figure A.13, the increment in fossil gas price is multiplied by the share of fossil gas-based power plants in the generation mix and added to the MCP pertaining to the reference price condition. The resultant MCP is inserted into the industry tariff calculation approach (discussed in Section 6.1.3) to calculate the industry tariff.

Case C examines the implications of a high carbon price, as depicted in Figure A.15. In Figure A.15, emissions are calculated using the total thermal generation together with the emission coefficient reported in Table A.4. By multiplying the generation data for each thermal technology by the emission coefficients in Table A.4, the total cost of CO_2 is calculated considering a figure of 70.6 EUR\t$CO_2$. The CO_2 cost for each TWh generated is calculated by

[19] https://heatroadmap.eu/wp-content/uploads/2020/01/HRE4_D6.1-Future-fuel-price-review.pdf

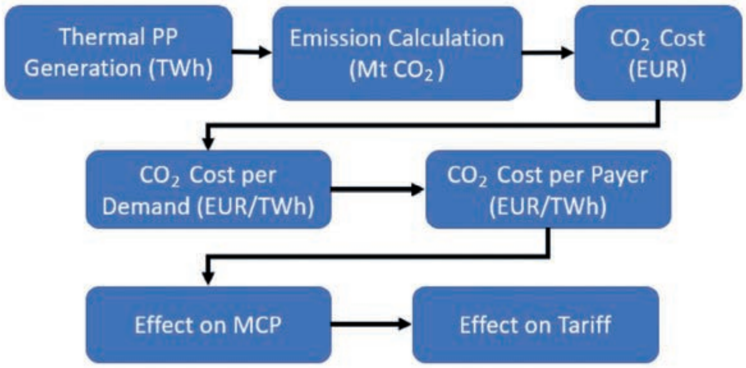


Figure A.15: Flow chart for calculating the effect of high carbon price | Source: own

	Other	Hard Coal	Imported Coal	Lignite	Gas
Emission ($Mt\ CO_2/TWh$)	0.5	1.03	0.96	1.19	0.4

Table A.4: Emissions for each generation technology

Source: own

A1.4 Quantification of industry retail electricity prices

Based on the historical data (see Figure A.16), the industry retail tariff comprises two main components, i.e., energy cost and utility cost.

To calculate the energy component of the industry tariff, market clearing price (MCP) is used, to which is added the amount of RES support as depicted in Figure A.17.

The Renewable Energy Resources Support Mechanism (YEKDEM) is a power purchase agreement programme that started in 2011 to support renewable energy investments in Turkey. The first phase of the mechanism operated until the end of 2020, and the second phase is still ongoing with modified rules.[20]

The prices to be applied to facilities during the first phase of YEKDEM were determined by the YEK Law: 7.3 USD cent/kWh for hydroelectric and wind energy-based

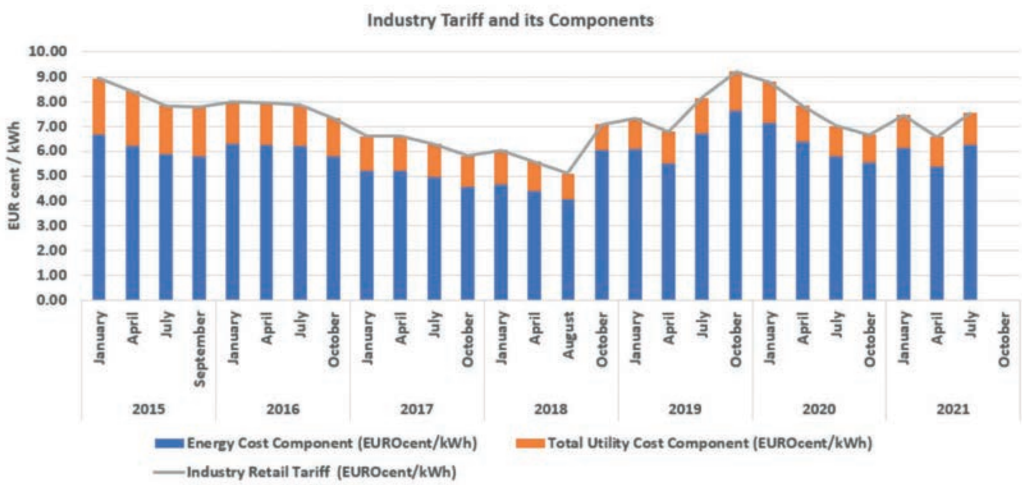


Figure A.16: Overview of historical industry retail tariff | Source: own

[20] The new YEKDEM mechanism will also apply for 10 years to energy facilities commissioned between 1 July 2021 and 31 December 2025. The new system switched the feed-in tariffs from USD to TRY which is subject to a quarterly basket-based adjustment (PPI, CPI, USD, and EUR with a balanced breakdown), subject to a cap in USD. In addition to the purchase guarantee, the new YEKDEM defines additional support up to a level of 8 kuruş/kWh provided for 5 years if domestic equipment is used.

Figure A.17: Energy components of industry retail tariff, 2015 to 2020 | Source: own

generation facilities, 10.5 USD cent/kWh for geothermal energy-based generation facilities, and 13.3 USD cent/kWh for biomass and solar energy-based generation facilities.

The duration of the support is 10 years, starting from the first day on which the generation facility goes online. The mechanism started with 201 MW in 2011 and reached a capacity of 24,567 MW at the end of the first phase in 2020.

Figure A.18 below shows the annual cumulative contracted RES capacity that received YEKDEM support in Turkey per year. The capacity declined after 2021 due to the end of the 10-year period for those started in the early years of the mechanism.
The YEKDEM mechanism has a direct impact on electricity tariffs. It is accounted in the energy component of the tariff as an additional cost on top of the market price of electricity. Therefore, it is important to forecast the possible impact of YEKDEM on the energy component in 2025 and 2030. A linear regression methodology is adopted by analysing the historical annual cost of the mechanism and the total contracted RES capacity.

After the end of the first YEKDEM phase in 2021, the total capacity in the mechanism declined due to the end of the early 10-year support period for integrated RES capacity. Therefore, the highest cost will be seen in 2021 as 8.1 EUR/MWh but will decrease to 3.5 EUR/MWh in 2025 and 0.4 EUR/MWh in 2030. The YEKDEM cost per MWh and the leftover contracted capacity are shown in Figure A.18.

To calculate the energy tariff components for the years 2020–2030, the nuclear support factor should be also added to the energy component calculation as depicted in Figure A.19.

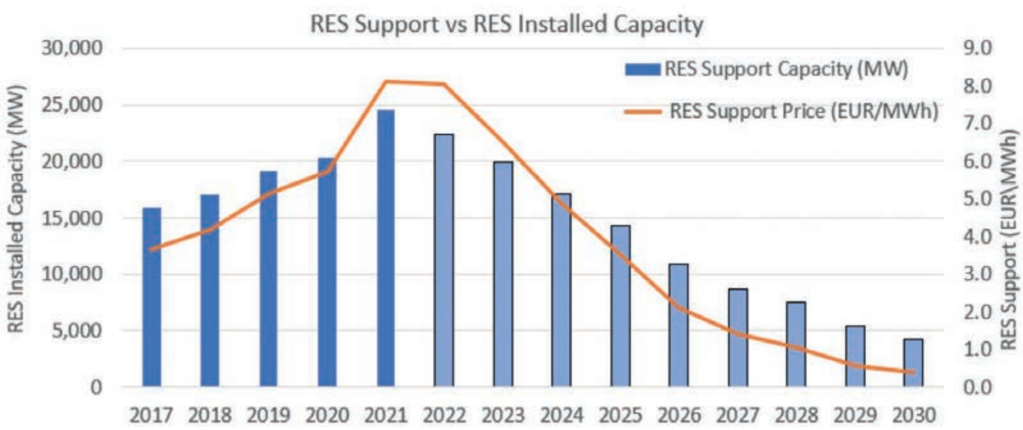


Figure A.18: Historical and estimated YEKDEM cost per MWh per year | Source: own

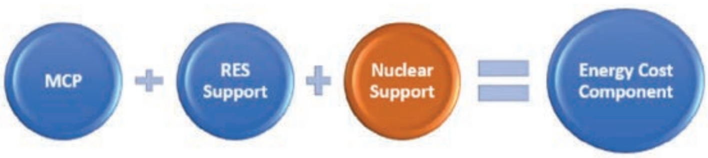


Figure A.19: Energy components of industry retail tariff, 2020 to 2030 | Source: own

The nuclear support mechanism is approved by the Ministry of Energy and Natural Resources. The mechanism is a power purchase agreement for the Akkuyu Nuclear Power Plant, covering 70% of the electricity generated from the first two reactors and 30% of the third and fourth reactors for 15 years. Based on an assumption that each reactor will go online after 2027, the contracted nuclear capacity is also shown in Figure A.20. The total contracted nuclear installed capacity reaches 2,400 MW in 2030.

Based on the assumption that the first reactor will be online in 2027, the only affected year in the study with the additional nuclear support mechanism is 2030. The total generation from the Akkuyu Nuclear Plant is calculated by the dispatch algorithm and then the total cost of the support is calculated based on the power purchase agreement of an average 123.5 USD/MWh (assumed to be 100 EUR/MWh). Both the YEKDEM and nuclear support mechanisms are accounted as an additional cost on top of the market price, and both are considered in the energy component of the tariff. The analysis shows that while the cost of the RES support mechanism is diminishing over time, the nuclear support mechanism is taking over the associated cost in 2030. The flow chart of nuclear support factor calculation is depicted in Figure A.20.

The levels of financial support for renewable and nuclear energy are given in Table A.5.

Figure A.20: Nuclear power purchase agreement | Source: own

	Renewable Support (EUR/MWh)				Nuclear Support (EUR/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
2015	1.90	1.90	1.90	1.90	0	0	0	0
2020	5.72	5.72	5.72	5.72	0	0	0	0
2025	3.52	3.52	3.52	3.52	0	0	0	0
2030	0.38	0.38	0.38	0.38	3.58	4.17	4.28	4.44

Table A.5: Renewable and nuclear support cost components

Source: own

Regarding the utility tariff component, historical data show a decreasing trend as depicted in Figure A.21. To calculate for the year 2030, one may propose extrapolating the same trend to derive a utility component for the year 2030. However, due to the integration of renewable resources and the need for network reinforcement, we can assume that the utility tariff will be fixed from the year 2020 to 2030. Note that fixed values in euros will inherently represent an increasing trend in terms of Turkish lira. The figures attained for the utility cost component of the industry tariff are depicted in Figure A.22.

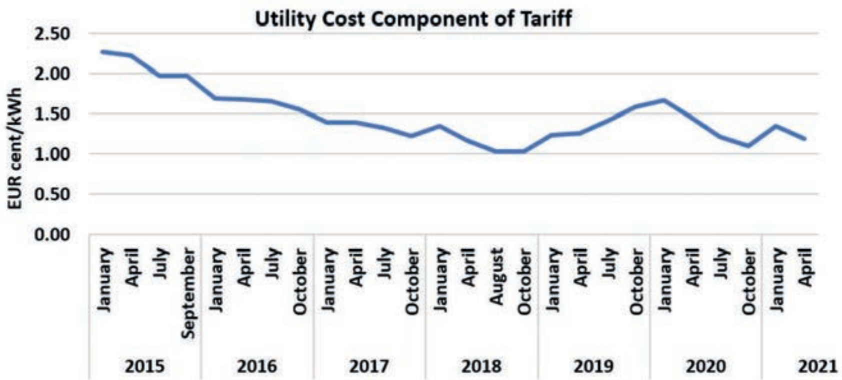


Figure A.21: Historical trend of utility cost component of industry tariff | Source: own

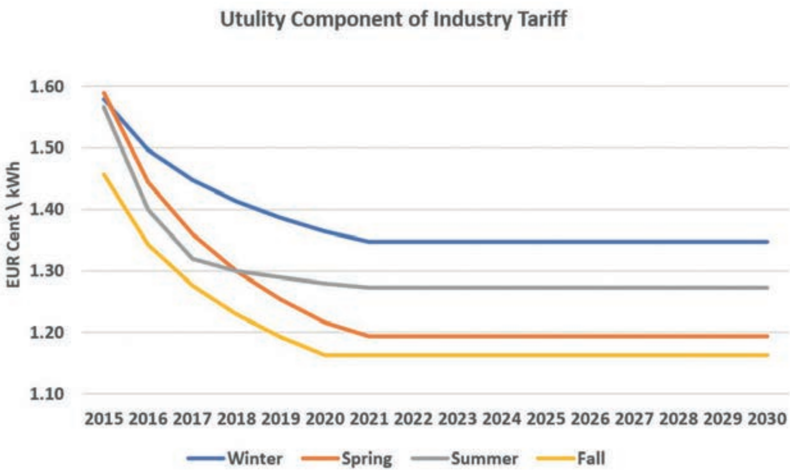


Figure A.22: Utility cost component of industry tariff, 2015 to 2030 | Source: own

To summarise, the MCP is the main input for calculating the industry tariff. The energy component is calculated using values for MCP, RES support, and nuclear support. The utility component is calculated based on Figure A.22. Hence, the industry tariff is calculated by summing the energy and utility components.

A1.5 AGE model descriptions to quantify total savings for the industrial sector and macro-economic impacts

The method for quantifying the **historical cost saving** effects of lower electricity prices for the 2015–20 (past) period utilises Energy Balance Tables from the Ministry of Energy and Natural Resources, which give composite energy consumption as well as consumption by each sector.

However, to assess the **future cost savings** for industry over the period 2020–30 and to evaluate the macro-economic impacts necessitates: i) projecting an economic growth path that is consistent with the total electricity demand projections utilised in this study, and ii) also reflecting this growth path within sectoral growth dynamics. A dynamic applied general equilibrium model (AGE) is utilised to quantify the direct effects of increasing share of renewables in Turkey's energy market for 2020–30.

The model disaggregates the total economy into 23 sectors, comprising agriculture, services, energy, and industrial sectors. Eleven of these sectors represent industry, where a decomposition is carried out to ensure thorough representation and consistency within different data sources (e.g., 2014 GTAP [Global Trade Analysis Project] data set, and Energy Balance Tables by from the Ministry of Energy and Natural Resources).

The AGE model provides the dynamics of sectoral input and energy-composite demands; hence one can evaluate the significance of the impact of changes in electricity prices for each sectors energy and total input costs. Here, the proposed method can simulate the (percentage) change in electricity prices and calculate the direct cost-savings at the sectoral level.

The AGE model is used to quantify the larger macro-economic effects of renewable energy deployment on the Turkish economy. A dynamic applied general equilibrium model (AGE) was utilised. Building on the augmented data structure (decomposing the overall economic activity into 23 sectors), the model represents total supply absorption at the national level as the sum of the additional value produced in the economy.

The proposed method deconstructs the industrial sectors into electricity-intensive and export-oriented sectors such as "Food", "Textiles", "Chemicals" and "Metal industry", as well as the electricity-intensive and domestic market-oriented sectors. Sectors such as "Transport equipment" are categorised as export-oriented with comparatively low electricity demand per unit of production. Table A.6 provides a list of industrial sectors that is consistent with the GTAP dataset, the national accounts, and energy balance statistics.

Table A.6 depicts the sectors considered in the macro-economic analysis, along with the sectoral aggregation used to perform this analysis.

Table A.6: Sectors considered in macro-economic analysis

Source: own

Index #	Aggregated Sector	Definition	GTAP 2014 Sector No.	NACE Rev. 2
1	agri	Agriculture	1–14	
2	food	Food industry	19–26	10–12
3	coal	Coal	15	
4	oil	Crude oil	16	
5	gas	Gas	17	
6	ppp	Paper & paper products	31	17–18
7	roil	Refined oil	32	
8	nmm	Non-metallic minerals: cement, plaster, lime, gravel, concrete	34	23
9	nfm & irst	Non-ferrous metals; Iron and steel	35	24
10	text	Textiles and apparel	27–28	13–15
11	chem	Chemicals; Rubber/plastic products	33	20–22
12	elect & mach	Electronic equipment and machinery	40–41	26–28
13	auto	Transport equipment	38–39	29–30
14	otmn	Mining of metal ores...	18	07–09
15	trnRW	Transportation: road, rail, pipelines, auxiliary transport activities, etc.	59–60	
16	trnA	Air transport	61	
17	othr	Other industry	29–30, 3–42	16, 31–32
18	meta	Fabricated metal products	36–37	25
19	serv	Services	56,61–68	
20	RnwE	Renewable power	47, 50, 52, 54	
21	NucE	Nuclear power	44	
22	FosE	Fossil power		
23	TnD	Transmission and distribution	43	

The projected sectoral growth paths (See Table A.7 below) also generate the sectoral electricity demand, in terms of both physical quantities (GWh) and monetary values (in base year 2018 prices).

Table A.7: Set of economic variables along with the baseline

Source: own

	Real GDP growth (%)	Real GDP (billion TRY, 2018 prices)	Electricty Demand (TWh)	Electricity Demand Growth (%)	Energy Efficiency Growth (%)
2018		3776,06	300,00		
2019	0,99	3813,52	300,64	0,21	0,51
2020	1,58	3873,85	304,42	1,26	0,30
2021	4,36	4042,76	317,68	4,36	
2022	3,43	4181,51	328,55	3,42	0,03
2023	3,26	4317,65	338,99	3,18	0,04
2024	3,20	4455,98	349,04	2,96	0,20
2025	3,16	4596,69	359,48	2,99	0,21
2026	3,18	4742,88	370,07	2,94	0,22
2027	3,16	4892,60	380,84	2,91	0,20
2028	3,13	5045,63	391,51	2,80	0,20
2029	3,01	5197,61	401,64	2,59	0,26
2030	3,11	5359,42	412,40	2,68	0,28

The model is calibrated to the 2018 macro-economic/sectoral equilibrium of the Turkish economy. The main reference point in constructing the macro-economic/sectoral model for the 2018–30 BAU scenario is the BAU scenario of the power sector (in terms of BAU electricity market price for the industrial sector and electricity demand projections). The macro-economic model then produces a consistent baseline macro-economic path and the paths of sectoral production.

The BAU GDP growth that is approximately consistent with the projected electricity demand of the power-sector model incorporates a modest average rate of energy efficiency gain (annual growth rate 0.2% for 2020–30). The real GDP growth rate along the baseline is 3.3% on average for 2020–30.

The AGE modelling methodology provides an analytical framework to capture the impact of and the policy trade-offs implied by different paths of energy/electricity prices on sectoral production activities and the overall macro economy within the discipline of Walrasian general equilibrium theory. It is Walrasian in the sense that it brings behavioural assumptions, production technologies, and market institutions together, optimising in response to price signals, all within the resource constraints of general equilibrium. Along with this equilibrium, production processes introduce production factors (capital, labour, intermediate inputs, and also energy as a composite input) within a dynamically adjusting technological pathway.

For details of the modelling framework utilised in this study, refer to Acar, Voyvoda, and Yeldan (2018) and Kat, Paltsev, and Yuan (2018). Several country-level analyses of the dynamic impacts of electricity-supply mix on prices and end-users include both pure top-down energy–economy models of AGE tradition and more comprehensive (hybrid) models that bring together bottom-up (electricity) and top-down (economy) approaches within a single framework. The main references include: Li et al. (2014), Song and Cui (2016), Wing (2006), Proença and Aubyn (2013), O'Ryan, Nasirov, and Álvarez-Espinosa (2020), Rodrigues and Linares (2015), and Böhringer, Landis, and Reanos (2017).

In order to evaluate the direct impact (through industrial customer savings) of the dynamic changes in electricity input price, we assume a fixed real output supply for each time period t along the business-as-usual (BAU) scenario and calculate the changes in electricity input cost for each sector.

The most important feature of the current model is the representation of the production structure of a typical industrial sector. The model represents the production of sectoral output **XS_i**, via multi-layer nested structures, which can identify electricity/energy demand during the production of each sector's output as well as substitution possibilities among the factors/inputs.

Here, one way to model the production (of industrial sectors) is to assume that material input (intermediates) are to be used in fixed proportion (Leontief specification) to the energy-value-added composite, KLE. The KLE composite then combines composite energy and value-added (VA) through a Constant-Elasticity of Substitution (CES) function.

Here, the substitution elasticity between value added (VA) and the energy bundle sigma ("kle") is given parametrically and assumed to remain constant across sectors. The energy bundle further assumes a second round of substitution between electricity and non-electric energy, with a (constant) substitution elasticity of sigma ("ele_ne").

Non-electricity primary energy inputs (coal, oil, gas) are combined through a CES function, assuming a substitution elasticity of sigma ("ne"). XS_i produced then is either exported or consumed domestically (see Figure A.23). Figure A.23 is also instrumental in illustrating the major supply-side variables representing the co-benefits, namely: sectoral employment, energy/output prices, real output, and exports.

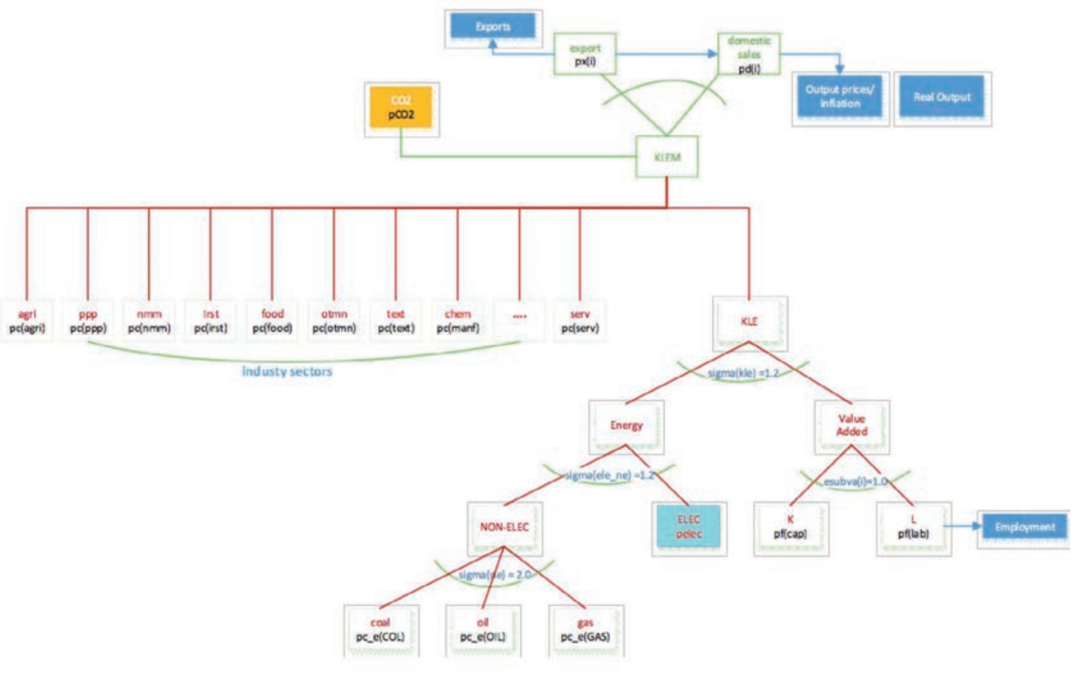


Figure A.23: Methodology for assessing macro-economic benefits | Source: own

In order to evaluate the macro-economic effects (indirect effects of the increased share of renewables in the power sector), the model uses the production structure displayed in A.23.

Utilising for each sector the production technology via the multi-level nested structure of CES composites, it is possible to calculate the impact of reduced electricity prices (pelec) on the unit cost structure (also taking into account the substitution possibilities among the production inputs) of sectoral production. Together with the quantitative impacts (increased production due to cost changes), it will then be possible to evaluate the co-benefits for each sector as well as the overall industrial sector.

Annex 2: Details of Key Findings

A2.1 Reduction of the wholesale electricity market price for years 2015 to 2020

This section summarizes the details of the calculation wholesale electricity market price for years 2015 to 2020.

The market simulation is depicted in Figure A.24, showing the annual generation mix across all power generation technologies, i.e., gas, coal, lignite, renewables, etc.

To validate the performance of the market simulation engine, the generation breakdown is compared with the actual values for the years 2015 and 2020 (see Table A.8).

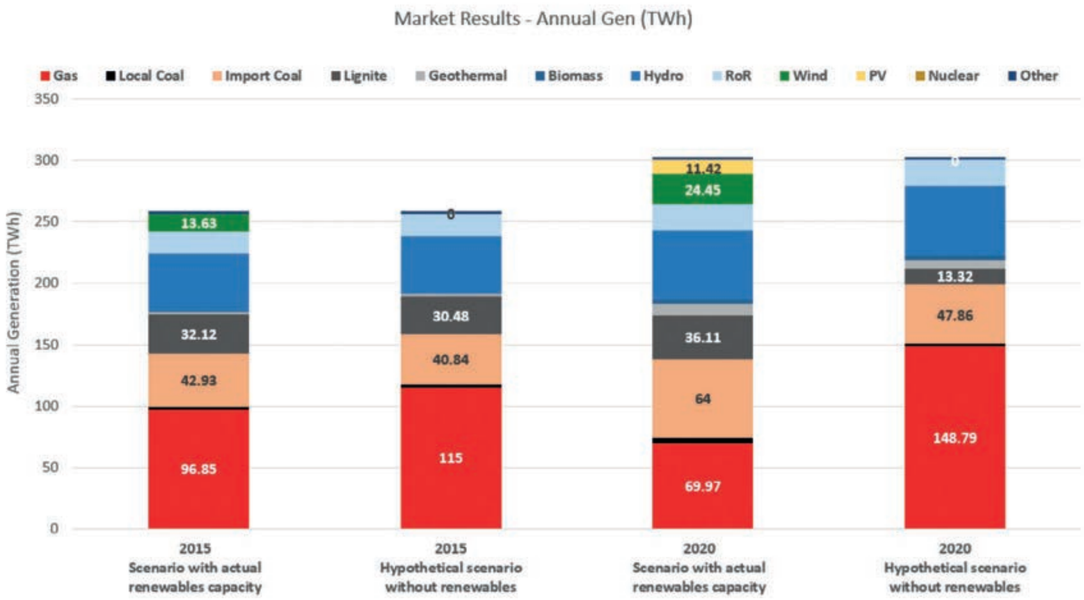


Figure A.24: Market simulation results for the electricity mix | Source: own

As can be seen from Table A.8, the market simulation engine accurately represents the Turkish electricity market with marginal error (maximum 1% error). Note that the generation mix in Figure A.24 and Table A.8 are derived from the iterative process discussed in the Methodology Section 2.2.

Figure A.24. also depicts the effect of theoretically excluding renewables from the generation fleet. In that case, the share of fossil gas would have been 19% higher in the year 2015 and 113% higher in 2020.

	Technology				Year 2015			
Technology	Market Simulation (TWh)	Realised by EPİAŞ (TWh)	Installed Capacity (MW)	Error	Market Simulation (TWh)	Realised by EPİAŞ (TWh)	Installed Capacity (MW)	Error
	69.97	68.07	25,632	1%	96.85	98.55	25,145	1%
Total Coal	103.96	104.02	19,875	0%	77.7	74.52	15,260	1%
Gas	3.85	3.78	811	0%	2.65	3.35	350	0%
Imported Coal	64	62.46	8,967	1%	42.93	40.05	6,070	1%
Lignite	36.11	37.78	10,097	1%	32.12	31.12	8,840	0%
Geothermal	8.62	9.31	1,515	0%	2.1	3.06	624	0%
Biomass	3.46	4.065	869	0%	0.22	1.16	272	0%
Total Hydro	77.94	77.83	29,790	0%	65.04	66.41	25,868	—

Table A.8: Simulated vs actual power generation mix

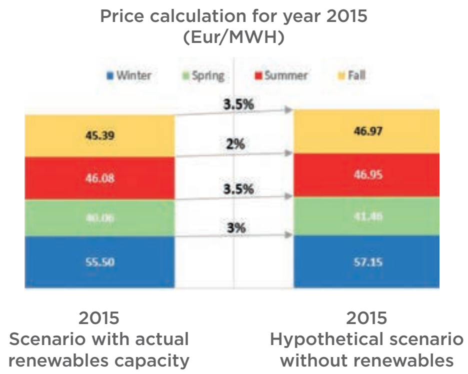
Source: own

Table A.8: Simulated vs actual power generation mix

Source: own

	Technology				Year 2015			
Technology	Market Simulation (TWh)	Realised by EPİAŞ (TWh)	Installed Capacity (MW)	Error	Market Simulation (TWh)	Realised by EPİAŞ (TWh)	Installed Capacity (MW)	Error
Hydro	56.93	57.32	21,877	0%	47	47.53	19,077	0%
RoR	21.01	20.51	7,913	0%	18.04	18.88	6,791	0%
Total Renewables	35.87	35.88	14,438	0%	14.08	11.66	4,752	1%
Wind	24.45	24.46	8,077	0%	13.63	11.66	4,503	1%
PV	11.42	11.42	6,361	0%	0.45	0	249	0%
Other	2.5	2.5	1,088	0%	2.5	3.12	1,226	0%
Total	302	302	93,207	–	258.5	258.5	73,147	–

Based on the simulated power generation mix, the seasonal wholesale market clearing price (MCP) was calculated for the years 2015 and 2020 (see Figure A.25). In 2015, wholesale MCP would have been up to 3.5% higher in a scenario without renewables, namely in the fall and spring seasons. In 2020, the MCP was as much as 12% lower during the fall season for the actual power generation mix in 2020, when compared with a hypothetical scenario involving no renewables.



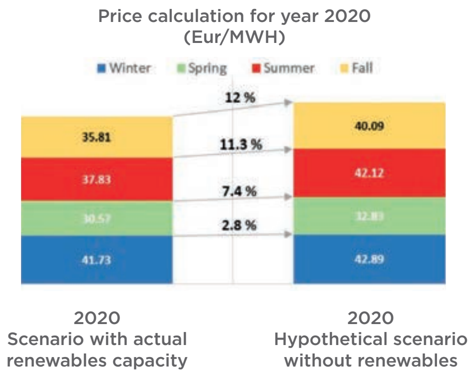


Figure A.25: Comparison of seasonal wholesale market clearing prices in 2015 and 2020 (actual power generation mix with renewables vs scenario without renewables)
Source: own

A2.2 Reduction of the retail electricity market price for years 2015 to 2020

This section summarises calculation of retail electricity market prices for the years 2015 to 2020.

The industry retail tariff and associated components for the years 2015 and 2020 are depicted in Table A.9. Here, seasonal tariffs are shown, as prices for the industrial sector vary seasonally in Turkey. A more detailed discussion of the various components of the retail electricity price is included in Annex 1 under Section A1.2.

Year	Scenario	Average Energy Cost (EUR cent/kWh)				Utility Cost (EUR cent/kWh)				Industry Tariff (EUR cent/kWh)			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
2015	Actual power generation mix with renewables	5.74	4.20	4.80	4.73	1.58	1.59	1.57	1.46	7.32	5.78	6.36	6.19
	Hypothetical scenario with-out renewables	5.90	4.34	4.89	4.89	1.58	1.59	1.57	1.46	7.48	5.92	6.45	6.34
2020	Actual power generation mix with renewables	4.75	3.63	4.36	4.15	1.36	1.22	1.13	1.16	6.11	4.84	5.48	5.32
	Hypothetical scenario with-out renewables	4.86	3.85	4.78	4.58	1.36	1.22	1.13	1.16	6.23	5.07	5.91	5.74

Table A.9: Industry retail tariff and associated components for the years 2015 and 2020

Source: own

A2.3 Total electricity costs savings for the industry sector for years 2015 to 2020

This section summarises the details of the calculation for the total electricity costs savings years 2015 to 2020. To calculate the direct impact (in terms of industry customer savings) from the increased share of renewable energy sources, the Energy General Equilibrium Tables 2015 to 2019 by the Ministry of Energy and Natural Resources were utilised.

Table A.10 provides the electricity demand (in GWh) compiled for each sector, for 2015 to 2019. Keeping the demand fixed, it is possible to directly calculate the annual and the cumulative amount of direct savings for the industry, utilising the differences between the industry retail tariff BAU Scenario and the hypothetical scenario without renewables.

Here, the assumption is that the price changes follow a linear trend between 2015 and 2020. The industrial sectors in Turkey benefitted from savings amounting to more than EUR 1 billion in the period 2015 to 2019, when comparing the actual costs with a power market scenario without any renewables.

			Electricity Demand (GWh)					2015-19: Additional Electricity Bill - Without RES	
	Code	Nace Rev. 2							
Industry			2015	2016	2017	2018	2019	2015	2015-2019 Cum.
Paper & publishing	ppp	17-18	4,018	4,139	3,506	3,439	3,418	5.6252	37.17
Non-metalic minerals	nmm	23	18,228	19,099	12,955	12,931	12,853	25.5192	149.76
Metal Industry	nfm+irst	24	19,462	24,375	29,262	29,092	28,918	27.2468	275.02
Other Industry	othr	16-31-32	5,885	6,388	18,928	18,552	18,441	8.239	151.04
Mining (Exc. Coal and Gas)	otmn	07-08-09	10,229	2,271	1,402	1,593	1,584	14.3206	29.09
Textiles & apparel	text	13-14-15	24,022	17,892	17,022	18,077	17,967	33.6308	189.94
Chemical, rubber, plastic products	chem	20-21-22	8,190	15,610	12,449	13,146	13,067	11.466	129.75
Fabricated Metal Products	meta	25	1,494	1,646	2,377	2,188	2,174	2.0916	20.76
Transport Equip.	auto	29-30	1,910	2,736	2,635	2,589	2,574	2.674	25.76
Machinery, Electric Mach. & Electronics	elect+mach	26-27-28	1,607	2,219	2,889	2,756	2,739	2.2498	25.80
Food	food	10-11-12	7,777	7,313	7,483	7,805	7,758	10.8878	77.94
TOTAL			102,822	103,687	110,907	112,167	111,493		
TOTAL in EUR (millions)								143.95	1,112.06

Table A.10: Electricity cost savings by sector, due to deployment of renewables (2015–19)

Source: own

A2.4 Reduction of the wholesale electricity market price for years 2020 to 2030

This section details the calculation of wholesale electricity market prices for the years 2020 to 2030. The power generation mix attained from the market simulation is depicted in Figure A.26.

As can be seen from Figure A.26, an electricity system without renewables would include substantially higher volumes of fossil gas. A power system without solar and wind-based renewable energy sources would result in 178% more gas-based generation in 2015, 237% more gas-based generation in year 2030 for the BAU with limited RES scenario, and 499% more gas-based electricity generation in year 2030 for the Advanced RES scenario.

Calculation of wholesale market price

The market simulations for the years 2025 and 2030 are performed based on the merit order adjustment made for the year 2020.

Depending on the different power mixes and the shares of renewables in 2025 and 2030, the wholesale market clearing price (MCP) was calculated on a seasonal basis. For the year 2025, a decrease of the wholesale market price of up to 13.9% was calculated for the summer period when comparing the Current Policy Scenario (BAU) with the hypothetical case of scenario without renewables (see Figure A.27).

A similar picture emerges when comparing the three reference scenarios for the year 2030 (see Figure A.28). Comparing the Current Policy Scenario (BAU) with the Advanced Renewables Scenario reveals that wholesale market prices can be reduced by up to 2.3% (fall season). The Advanced Renewables Scenario (summer season) can reduce wholesale prices by as much as 3.4% compared with the hypothetical case of a power system without renewables.

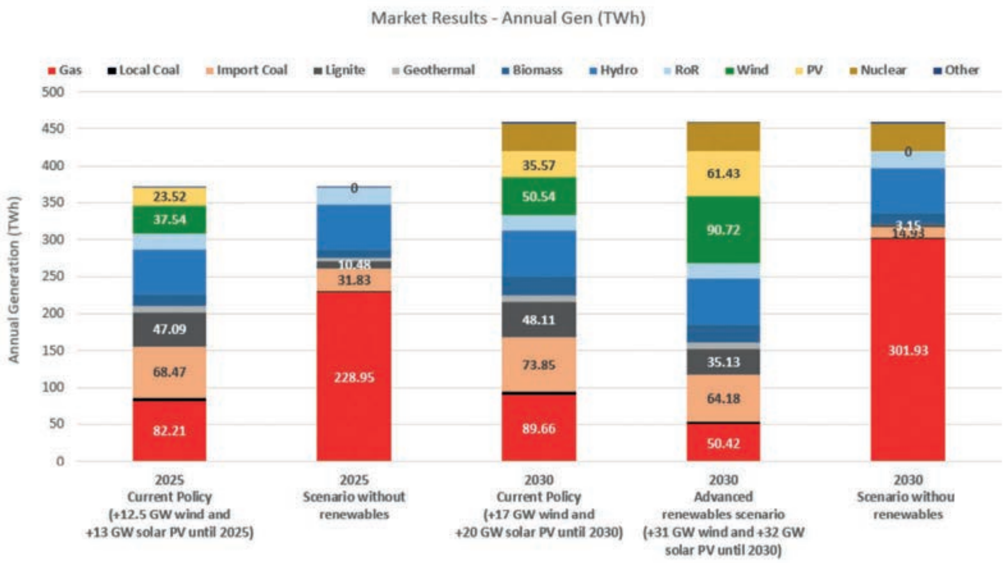


Figure A.26: Market simulation results: Future power generation mix | Source: own

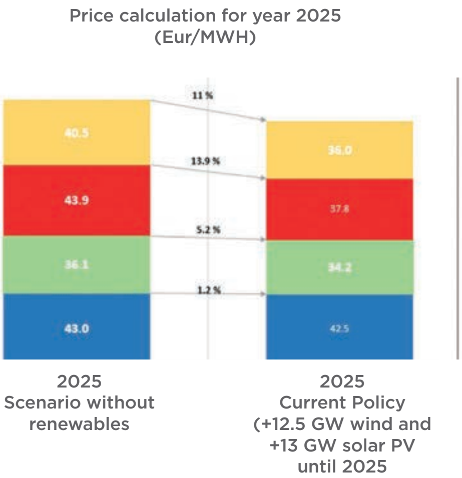


Figure A.27:
Modelled seasonal wholesale market clearing prices for the year 2025
Source: own

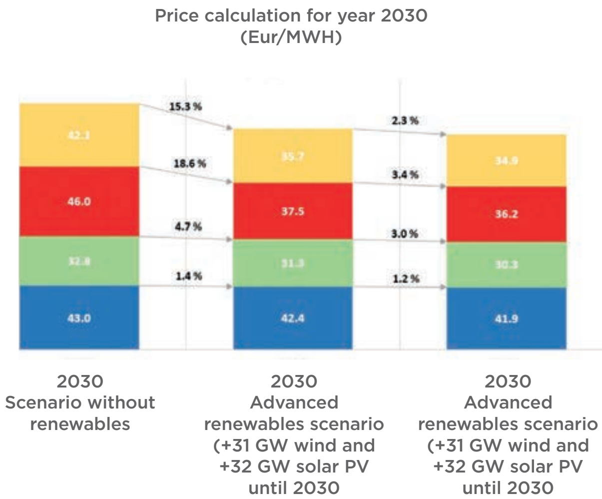


Figure A.28:
Modelled seasonal wholesale market clearing prices for the year 2030
Source: own

A2.5 Reduction of the retail electricity market price for years 2020 to 2030

This section summarises the calculation of retail electricity market prices for the years 2020 to 2030. The industry tariff and the utility costs for the years 2025 and 2030 (including seasonal variations) are reported in Table A.11.

A2.6 Total electricity costs savings for the industry sector for years 2020 to 2030

This section summarises the calculation of total electricity cost savings for the years 2020 to 2030.

Based on the sectoral growth dynamics as outputs of the macro-economic model for the period 2018 to 2030, the projections for electricity demand (both in terms of payments in real 2018 TRY and in physical GWh) are utilised. This enables calculation of the direct benefits to industrial customers for the period 2020 to 2030.

Note that the business-as-usual path considers the dynamics of the industrial tariff for electricity under the Current Policy Scenario. At the same time, any sectoral heterogeneity in the unit cost of electricity as implied by the intermediate flows of the 2018 Input–Output Table is taken into account. In this section, the direct savings are calculated with respect to the hypothetical scenario without renewables.

Industrial electricity consumers can benefit directly from the increased share of renewable energy sources in the power mix, as reflected in the electricity tariff for industry for 2020 (Table A.12).

As the table indicates, the cost of electricity as a fraction of total energy costs differs widely across the various sectors, ranging between 27.3 % (Transport Equip.) to 81.4 % (Textiles & Apparel), with an average of 59.0 %. In terms of electricity costs as a share of total inputs costs (including intermediate inputs, wages, rents, etc.), the minimum and maximum are defined by Transport Equip. (0.3 %) and the Metal Industry (7.8 %), which is also indicative of differences in energy intensity in production processes. Electricity cost as a proportion of value-added is also highest for the Metal Industry (18.0 %), which indicates the substantial implications of potential changes in electricity tariffs for industrial production/value-added. As a whole, the industry value-added in 2020 (in 2018 prices) is around TRY 962 billion, which corresponds to around EUR 170 billion and approximately 26.6 % of 2020 GDP.

The direct benefit to the industrial sectors during 2020 amounts to around EUR 560 (TRY 3.2 billion in 2018). This is calculated by considering 5.44 EUR cent/kWh for the 2020 actual renewables capacity scenario and comparing it with 5.44 EUR cent/kWh as the retail electricity tariff for 2020 in the hypothetical scenario without renewables.

Year	Scenario	Average Energy Cost (EUR cent/kWh)				Utility Cost (EUR cent/kWh)				Industry Tariff (EUR cent/kWh)			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
2025	Without RES	4.86	3.85	4.78	4.58	1.36	1.22	1.13	1.16	6.23	5.07	5.91	5.74
	With RES	4.60	3.77	4.13	3.96	1.35	1.19	1.27	1.16	5.95	4.96	5.40	5.12
	Without RES	4.70	3.74	5.07	4.70	1.35	1.19	1.27	1.16	6.04	4.93	6.34	5.86
2030	BAU with limited RES (Current Policy)	4.64	3.58	4.21	4.05	1.35	1.19	1.27	1.16	5.98	4.78	5.49	5.21
	Advanced Renewables Scenario	4.58	3.49	4.09	3.97	1.35	1.19	1.27	1.16	5.93	4.68	5.36	5.13

Table A.11: Industry tariff and associated components for years 2025 and 2030

Source: own

2020			Electricity Demand (GWh)	Electricity Payment (cst. 2018 prices -million TRY)	Electricity Share in Total Input Costs (%)	Electricity Share in Total Engy. Cost (%)	Electricity Cost /Value Added (%)
Industry	Code	Nace Rev. 4					
Paper & publishing	ppp	17-18	3,467.86	2,659.81	3.01	68.03	6.01
Non-metalic minerals	nmm	23	13,065.04	7,187.57	7.48	51.77	14.56
Metal Industry	nfm+irst	24	29,373.16	16,480.43	7.77	56.76	18.00
Other Industry	othr	16-31-32	18,590.65	2,324.33	2.27	72.19	7.95
Mining (Exc. Coal and Gas)	otmn	07-08-09	1,604.55	1,198.53	3.94	58.71	3.22
Textiles & Wearing App.	text	13-14-15	18,298.01	8,903.65	2.04	81.44	6.85
Textiles & apparel products	chem	20-21-22	13,296.80	6,686.96	2.59	28.29	6.74
Fabricated Metal Products	meta	25	2,215.51	1,105.55	1.18	75.69	2.61
Transport Equip.	auto	29-30	2,764.54	495.20	0.28	27.32	0.34
Machinery, Electric Mach. & Electronics	elect+mach	26-27-28	2,808.13	4,755.25	1.80	78.28	2.29
Food	food	10-11-12	7,808.66	4,756.34	1.12	50.26	5.48
TOTAL			**113,292.89**	**56,553.62**			**5.88**
TOTAL in EUR (millions)				**9,974.18**			

	Code	Nace Rev. 4	VA (cst. 2018 million TRY)	VA Share (%)	Additional Electricity Bill - Without RES (cst 2018 million TRY)	Additional Electricity Bill - Share of VA (%)
Paper & publishing	ppp	17-18	44,220.14	1.22	149.15	0.34
Non-metalic minerals	nmm	23	49,355.70	1.36	403.05	0.82
Metal Industry	nfm+irst	24	91,581.54	2.53	924.16	1.01
Other Industry	othr	16-31-32	29,236.85	0.81	130.34	0.45
Mining (Exc. Coal and Gas)	otmn	07-08-09	37,213.71	1.03	67.21	0.18
Textiles & Wearing App.	text	13-14-15	129,935.39	3.59	499.28	0.38
Textiles & apparel products	chem	20-21-22	99,158.97	2.74	374.98	0.38
Fabricated Metal Products	meta	25	42,397.69	1.17	61.99	0.15
Transport Equip.	auto	29-30	143,755.57	3.97	27.77	0.02
Machinery, Electric Mach. & Electronics	elect+mach	26-27-28	208,091.14	5.74	266.66	0.13
Food	food	10-11-12	86,771.37	2.39	266.72	0.31
TOTAL			**961,718.07**	**26.54**	**3,171.30**	**0.33**
TOTAL in EUR (millions)			**169,615.18**		**559.31**	

Table A.12: Summary: Calculation of direct benefits to the industrial sector in 2020

Source: own

Moreover, as Tables A.13 and A.14 indicate, the direct benefit ranges between EUR 700 million for 2025 and EUR 988 million for 2030 under the Current Policy Scenario. These values are calculated by comparing the actual renewables capacity scenario with the hypothetical scenario without renewables.

Table A.13 depicts the sectoral value-added (VA), electricity demand, both in physical units (GWh) and in monetary terms (in 2018 TRY), as well as additional indicators of electricity share in total energy bill and electricity share of total input costs for 2025, as projected by the base-run of the applied general equilibrium model. The last two columns of the table present the magnitude of direct benefits (in 2018 TRY) from the increased share of renewable energy sources, reflected in the electricity tariff for industry for 2025 (under the BAU Renewables Scenario, Case A). Table A.14 summarises the same indicators for 2030.

Table A.13: Sectoral value-added (VA) and indicators of electricity share in total energy bill (2025)

Source: own

2025		Electricity Demand (GWh)	Electricity Payment (cst. In 2018 prices - TRY)	Electricity Share in Total Input Costs (%)	Electricity Share in Total Engy. Cost (%)	Electricity Cost /Value Added (%)
Industry	Nace Rev. 4					
Paper & publishing	17-18	3,848.74	2,914.94	2.89	68.21	5.49
Non-metalic minerals	23	14,692.16	7,981.37	7.25	52.12	13.15
Metal Industry	24	35,936.81	19,910.31	7.53	57.00	14.89
Other Industry	16-31-32	20,664.96	2,551.28	2.22	72.42	7.26
Mining (Exc. Coal and Gas)	07-08-09	1,822.49	1,344.26	3.79	59.06	2.88
Textiles & apparel	13-14-15	20,490.62	9,845.55	1.93	81.43	6.18
Chemical, rubber, plastic products	20-21-22	14,854.47	7,376.65	2.51	28.63	6.13
Fabricated Metal Products	25	2,572.50	1,267.60	1.16	76.27	2.28
Transport Equip.	29-30	3,766.85	666.27	0.27	27.49	0.26
Machinery, Electric Mach. & Electronics	26-27-28	3,254.13	5,441.42	1.75	78.38	2.00
Food	10-11-12	8,380.13	5,040.44	1.04	50.38	5.17
TOTAL		130,283.84	64,340.07			5.78
TOTAL in EUR (millions)			11,347.45			

	Nace Rev. 4	VA (cst. 2018 billion TRY)	VA Share (%)	Additional Electricity Bill - Without RES (cst 2018 million TRY)	Additional Electricity Bill - Share of VA (%)
Paper & publishing	17-18	48,460.07	1.12	179.87	0.37
Non-metalic minerals	23	54,651.97	1.27	492.50	0.90
Metal Industry	24	110,698.85	2.57	1228.60	1.11
Other Industry	16-31-32	32,003.62	0.74	157.43	0.49
Mining (Exc. Coal and Gas)	07-08-09	41,659.19	0.97	82.95	0.20
Textiles & apparel	13-14-15	144,044.38	3.34	607.53	0.42
Chemical, rubber, plastic products	20-21-22	109,068.12	2.53	455.19	0.42
Fabricated Metal Products	25	48,560.50	1.13	78.22	0.16
Transport Equip.	29-30	193,381.20	4.48	41.11	0.02
Machinery, Electric Mach. & Electronics	26-27-28	237,917.48	5.51	335.77	0.14
Food	10-11-12	91,997.74	2.13	311.03	0.34
TOTAL		1,112,443.11	25.78	3,970.20	0.36
TOTAL in EUR (millions)		196,198.08		700.21	

Table A.14: Sectoral value added (VA), and indicators of electricity share in total energy bill (2030)

Source: own

2030			Electricity Demand (GWh)	Electricity Payment (cst. In 2018 prices - TRY)	Electricity Share in Total Input Costs (%)	Electricity Share in Total Engy. Cost (%)	Electricity Cost /Value Added (%)
Industry	Code	Nace Rev. 4					
Paper & publishing	ppp	17-18	4,216.82	3,146.67	2.77	68.57	5.99
Non-metalic minerals	nmm	23	16,105.04	8,620.05	7.00	52.57	14.58
Metal Industry	nfm+irst	24	39,537.36	21,582.52	7.36	57.66	17.95
Other Industry	othr	16-31-32	22,568.31	2,745.22	2.14	72.67	7.94
Mining (Exc. Coal and Gas)	otmn	07-08-09	1,986.04	1,443.32	3.64	59.58	3.22
Textiles & apparel	text	13-14-15	22,309.76	10,561.75	1.84	81.51	6.79
Chemical, rubber, plastic products	chem	20-21-22	16,304.92	7,977.68	2.42	29.09	6.77
Fabricated Metal Products	meta	25	2,825.98	1,371.99	1.12	76.85	2.59
Transport Equip.	auto	29-30	4,311.80	751.43	0.26	28.04	0.35
Machinery, Electric Mach. & Electronics	elect+mach	26-27-28	3,627.92	5,977.10	1.70	78.62	2.28
Food	food	10-11-12	9,036.19	5,354.99	0.97	50.62	5.46
TOTAL			142,830.13	69,532.73			5.72
TOTAL in EUR (millions)				12,263.27			

	Code	Nace Rev. 4	VA (cst. 2018 billion TRY)	VA Share (%)	Additional Electricity Bill - Without RES (cst 2018 million TRY)	Additional Electricity Bill - Share of VA (%)
Paper & publishing	ppp	17-18	52,492.06	1.04	253.50	0.48
Non-metalic minerals	nmm	23	59,128.44	1.17	694.45	1.17
Metal Industry	nfm+irst	24	120,228.60	2.38	1,738.73	1.45
Other Industry	othr	16-31-32	34,553.02	0.68	221.16	0.64
Mining (Exc. Coal and Gas)	otmn	07-08-09	44,799.66	0.89	116.28	0.26
Textiles & apparel	text	13-14-15	155,528.27	3.08	850.87	0.55
Chemical, rubber, plastic products	chem	20-21-22	117,895.63	2.34	642.70	0.55
Fabricated Metal Products	meta	25	52,878.93	1.05	110.53	0.21
Transport Equip.	auto	29-30	217,800.90	4.32	60.54	0.03
Machinery, Electric Mach. & Electronics	elect+mach	26-27-28	261,777.61	5.19	481.53	0.18
Food	food	10-11-12	98,140.54	1.94	431.41	0.44
TOTAL			1,215,223.66	24.08	5,601.69	0.46
TOTAL in EUR (millions)			214,325.16		987.95	

Under the current BAU policy, the increased share of renewable energy sources in Turkey's power market can provide direct benefit of EUR 8.1 billion (cumulative savings) over the period 2020–30.

Looking forward to 2030, the Advanced Renewables Scenario certainly adds to the predicted benefits. As can be seen from Table A.15, the direct benefits gained under the Advanced Renewables Scenario in 2030 compared to the scenario without renewables amount to EUR 1.22 billion. Table A.15 provides results for individual years as well as the cumulative 2020–25 and 2020–30 effects. The industrial sector stands to gain direct benefits of around EUR 560 million in 2020 alone from using renewable energy sources.

Overall benefits can amount to around EUR 3.78 billion for 2020–25 and to around EUR 8.1 billion for 2020–30 (in 2018 prices), under the current policy and if fossil gas prices increase and Turkey sets a price for carbon. If the Advanced Renewables Scenario is realised in year 2030, the cumulative benefits can reach up to EUR 8.73 billion for 2020–30.

Table A.15: Direct benefits for individual years and cumulative effects for 2020–25/2020–30

Source: own

		Saving with respect to hypothetical without renewables scenario						
Industry	Nace Rev. 4	2020 Scenario with actual renewables capacity	2025 Current Policy (+12.5 GW wind and +13 GW solar)	2030 Current Policy (+17 GW wind and +20 GW solar)	2030 Advanced renewables scenario (+31 GW wind and +32 GW solar PV)	2020-25 Cumulative	2020-30 BAU Cumulative	2020-30 ADV. RES. Cumulative
Paper & publishing	17-18	149.15	179.87	253.50	312.72	986.94	2,092.35	2,255.14
Non-metalic minerals	23	403.05	492.50	694.45	856.83	2,686.30	5,715.17	6,159.82
Metal Industry	24	924.16	1,228.60	1,738.73	2,154.67	6,499.71	14,102.65	15,199.87
Other Industry	16-31-32	130.34	157.43	221.16	273.12	864.05	1,830.85	1,973.30
Mining (Exc. Coal and Gas)	07-08-09	67.21	82.95	116.28	143.69	450.98	960.52	1,035.26
Textiles & apparel	13-14-15	499.28	607.53	850.87	1,050.01	3,318.09	7,041.54	7,589.39
Chemical, rubber, plastic products	20-21-22	374.98	455.19	642.70	793.16	2,488.27	5,292.53	5,704.30
Fabricated Metal Products	25	61.99	78.22	110.53	136.52	421.75	904.68	975.07
Transport Equip.	29-30	27.77	41.11	60.54	74.68	207.86	469.05	505.54
Machinery, Electric Mach. & Electr	26-27-28	266.66	335.77	481.53	594.41	1,811.19	3,894.94	4,197.97
Food	10-11-12	266.72	311.03	431.41	532.06	1,733.83	3,628.59	3,910.90
TOTAL		**3,171.30**	**3,970.20**	**5,601.69**	**6,921.86**	**21,468.96**	**45,932.86**	**49,506.55**
TOTAL in EUR (millions)		**559.31**	**700.21**	**987.95**	**1,220.79**	**3,786.41**	**8,101.03**	**8,731.31**

In order to further compare the macro-economic impacts under alternative scenarios, Table A.16 provides further results for selected variables for 2030, under both the BAU Renewables and Advanced Renewables Scenarios (Cases A & D).

Table A.16: Indirect savings for year 2030 under BAU and Advanced Renewables Scenarios

Source: own

	Unit Price of Energy Composite (% change)		Real Output (2018 million TRY)		Output Price (% change)		Labor Demand (1000 people)		Exports (thousand EUR)	
2030	**Case A**	**Case D**	**Case A**	**Case D**	**Case A**	**Case D**	**Case A**	**Case D**	**Case A**	**Case D**
Paper & publishing	6.34	34.77	-0.82	-3.86	0.22	1.21	-0.31	-1.47	-11.59	-54.65
Non-metalic minerals	5.31	28.46	-1.93	-9.02	0.55	2.95	-0.51	-2.39	-44.34	-207.20
Metal Industry	6.06	32.99	-5.39	-25.11	0.58	3.17	-4.41	-20.52	-308.05	-1,434.30
Other Industry	6.36	34.89	-1.03	-4.87	0.17	0.93	-0.18	-0.84	-52.22	-245.70
Mining (Exc. Coal and Gas)	5.89	31.96	-0.23	-1.10	0.29	1.56	-0.08	-0.38	-8.22	-38.89
Textiles & apparel	6.83	37.91	-4.09	-19.27	0.15	0.81	-6.33	-29.81	-168.18	-792.39
Chemical, rubber, plastic products	3.89	20.17	-2.34	-11.05	0.19	0.98	-0.14	-0.66	-91.77	-432.59
Fabricated Metal Products	7.88	44.76	-0.40	-1.89	0.09	0.51	-0.06	-0.30	-20.79	-98.47
Transport Equip.	3.91	20.26	-0.16	-0.75	0.02	0.10	-0.01	-0.03	-15.12	-71.80
Machinery, Electric Mach. & Electronics	6.67	36.87	-1.22	-5.77	0.14	0.75	-1.70	-8.04	-52.56	-249.11
Food	5.04	26.85	-2.76	-13.01	0.08	0.40	-2.22	-10.50	-37.24	-175.78
AVERAGE	**5.83**	**31.81**			**0.22**	**1.22**				
TOTAL			**-20.37**	**-95.70**			**-15.95**	**-74.94**	**-810.08**	**-3,800.88**

	Unit Price of Energy Composite (% change)		Real Output (2018 million TRY)		Output Price (% change)		Labor Demand (1000 people)		Exports (thousand EUR)	
2030 - ADV	**Case A**	**Case D**	**Case A**	**Case D**	**Case A**	**Case D**	**Case A**	**Case D**	**Case A**	**Case D**
Paper & publishing	7.79	36.60	-1.00	-4.04	0.27	1.28	-0.36	-1.47	-14.15	-57.15
Non-metalic minerals	6.52	29.92	-2.36	-9.43	0.68	3.11	-0.59	-2.36	-54.25	-217.11
Metal Industry	7.44	34.72	-6.61	-26.37	0.72	3.36	-5.38	-21.44	-377.70	-1,505.94
Other Industry	7.82	36.73	-1.26	-5.09	0.21	0.99	-0.24	-0.98	-63.84	-257.23
Mining (Exc. Coal and Gas)	7.23	33.63	-0.28	-1.15	0.36	1.65	-0.06	-0.23	-10.02	-40.62
Textiles & apparel	8.40	39.92	-5.00	-20.16	0.18	0.86	-7.55	-30.46	-205.34	-828.44
Chemical, rubber, plastic products	4.77	21.18	-2.86	-11.56	0.23	1.03	-0.18	-0.74	-112.06	-452.34
Fabricated Metal Products	9.70	47.20	-0.49	-1.98	0.11	0.54	-0.04	-0.16	-25.41	-103.09
Transport Equip.	4.79	21.27	-0.19	-0.78	0.02	0.11	-0.01	-0.03	-18.45	-75.05
Machinery, Electric Mach. & Electronics	8.20	38.83	-1.49	-6.04	0.17	0.79	-1.99	-8.08	-64.20	-260.55
Food	6.19	28.22	-3.36	-13.60	0.09	0.43	-2.65	-10.72	-45.39	-183.45
AVERAGE	**7.17**	**33.48**			**0.28**	**1.29**				
TOTAL			**-24.91**	**-100.20**			**-19.06**	**-76.67**	**-990.83**	**-3,980.97**

In addition, Table A.17 illustrates the cumulative results for 2020–30 under both scenarios Cases A&D.

A2.7 Macro-economic benefits: job creation (labour demand) and exports

In order to disaggregate the impact of electricity price as a crucial production input for industrial sectors, the analysis focuses on partial equilibrium effects. It is assumed that all other input prices (other energy inputs such as coal, gas; labour unit costs, capital rental cost and unit costs of other intermediate inputs) remain constant, in order to isolate any further general equilibrium impacts. Thus, this approach focuses on the contribution of changes in electricity prices only.

Table A.18 expresses the spillover effects on selected variables with respect to the hypothetical scenario without renewables. In Table A.18, "Real Output" represents the value of sectoral output/production in constant 2018 prices; "Output Price" is the market price of the sector's output/production; and "Export" represents the sector's exports to the Rest of the World (in thousands of euros).

Indirect Effects of Change in Industrial Tariffs 2020-2030 Cumulative, Selected Variables, ADV. RES.

		Real Output (2018 million TRY)		Labor Demand (1000 people)		Exports (thousand EUR)	
2020-2030		Case A	Case D	Case A	Case D	Case A	Case D
Cumulative	Paper & publishing	-6.77	-31.08	-0.31	-1.47	-100.99	-461.16
	Non-metalic minerals	-15.98	-72.72	-0.51	-2.39	-374.95	-1,700.75
	Metal Industry	-44.20	-202.18	-4.41	-20.52	-2,530.74	-11,639.68
	Other Industry	-8.61	-39.37	-0.18	-0.84	-464.58	-2,104.36
	Mining (Exc. Coal and Gas)	-1.93	-8.90	-0.08	-0.38	-70.90	-325.67
	Textiles & apparel	-33.56	-154.20	-6.33	-29.81	-1,444.82	-6,609.98
	Chemical, rubber, plastic products	-19.39	-88.94	-0.14	-0.66	-788.17	-3,593.38
	Fabricated Metal Products	-3.27	-15.13	-0.06	-0.30	-173.96	-803.12
	Transport Equip.	-1.24	-5.83	-0.01	-0.03	-117.72	-558.84
	Machinery, Electric Mach. & Electronics	-9.99	-46.18	-1.70	-8.04	-451.46	-2,085.88
	Food	-22.91	-104.94	-2.22	-10.50	-390.83	-1,723.61
	TOTAL	**-167.84**	**-769.46**	**-15.95**	**-74.94**	**-6,909.13**	**-31,606.42**
	TOTAL (milion EUR)	**-29.60**	**-135.71**				
		Real Output (2018 million TRY)		**Labor Demand (1000 people)**		**Exports (thousand EUR)**	
2020-2030 ADV		Case A	Case D	Case A	Case D	Case A	Case D
Cumulative	Paper & publishing	-7.31	-31.59	-0.36	-1.47	-108.72	-468.66
	Non-metalic minerals	-17.23	-73.89	-0.59	-2.36	-404.54	-1,730.34
	Metal Industry	-47.72	-205.44	-5.38	-21.44	-2,740.04	-11,855.39
	Other Industry	-9.28	-40.01	-0.24	-0.98	-499.78	-2,139.25
	Mining (Exc. Coal and Gas)	-2.08	-9.05	-0.06	-0.23	-76.35	-330.86
	Textiles & apparel	-36.22	-156.74	-7.55	-30.46	-1,556.59	-6,718.15
	Chemical, rubber, plastic products	-20.92	-90.39	-0.18	-0.74	-849.03	-3,652.42
	Fabricated Metal Products	-3.53	-15.38	-0.04	-0.16	-187.81	-816.91
	Transport Equip.	-1.34	-5.93	-0.01	-0.03	-127.72	-568.54
	Machinery, Electric Mach. & Electronics	-10.78	-46.95	-1.99	-8.08	-486.67	-2,120.37
	Food	-24.70	-106.65	-2.65	-10.72	-416.47	-1,747.64
	TOTAL	**-181.11**	**-782.01**	**-19.06**	**-76.67**	**-7,453.74**	**-32,148.53**
	TOTAL (milion EUR)	**-31.94**	**-137.92**				

Table A.17: Cumulative savings for year 2030 under BAU and Advanced Renewables Scenarios

Source: own

Index #	Average Change of Energy Composite Unit Price (%)	Total Real Output (2018 million EUR)	Average Change of Output Price (%)	Labour Demand (1000 people)	Total Exports (thousand EUR)
2020 Scenario with actual renewables capacity	4.10	-11.40	0.17	-16.46	-474.64
2025 Current BAU Policy (+12.5 GW wind; +13 GW solar)	4.50	-14.43	0.18	-10.02	-600.11
2030 Current BAU Policy (+17 GW wind; +20 GW solar)	5.83	-20.37	0.22	-15.95	-810.08
2030 Advanced Renewables Scenario (+31 GW wind; +32 GW solar PV)	7.17	-24.91	0.28	-19.06	-990.83
2020–2030 Cumulative Current Policy	–	-29.6	–	-15.95	-6909
2020–2030 Cumulative Advanced Renewables	–	-31.94	–	-19.06	-7453

Table A.18: Calculated spillover effects on selected variables in the hypothetical scenario without renewables

Source: own

Annex 3: Illustrative local case study: The Demirtaş Organized Industrial Zone (DOSAB)

The Demirtaş Organized Industrial Zone (abbreviated as DOSAB in Turkish) was established in 1990 in Bursa City. DOSAB registered as an organised industrial zone in 2001 within the scope of the Organized Industrial Zones Law No. 4562, which entered into force on April 15, 2000.

As of 2020, the DOSAB site covers 485 hectares (Figure 47), comprising 384 hectares of industrial parcels, 11 hectares for a wastewater treatment plant, 6 hectares of technical infrastructure, and green areas of 84 hectares. DOSAB is divided into 381 parcels, comprising 342 industrial parcels (316 of which are currently occupied), and 39 occupied by administrative/social facilities and infrastructure areas.

Figure A.29: DOSAB industrial zone | Source: www.dosab.org.tr

Data from 2019 indicate a total of 547 active companies[21] employing 42,000 people.

In 2019, 43 DOSAB companies entered Bursa's list of Top-250 Companies. Of these, 23 were involved in Textiles and Apparel, 13 were in Automotive and Sub-industries (Transport Equip.), and 7 were representatives of Machinery, Metal, and other sectors. These 43 companies generated TRY 29.9 billion, which is 18.2% of the total turnover of the top 250 companies. Of this, TRY 23.6 billion, which corresponds to 20% of the net sales of the 250 companies, was generated by 43 companies located at DOSAB.

As of 2020, the sectoral breakdown of DOSAB (by number of companies) was:[22]

[21] https://www.dosab.org.tr/Detay/1008/43-DOSAB-Firmasindan-2,9-Milyar-Dolar-Ihracat,-19-bin-687-Istihdam

[22] https://webdosya.csb.gov.tr/db/cygm/icerikler//2018-organize-sanayi-bolgeleri-envanteri-20181112091121.xls

- Textiles and Apparel: 68%
- Transportation Equip.: 22%
- Food, Plastic, Chemistry, and others: 10%

In 2019 companies located at DOSAB consumed around 1.14 TWh of electricity. The installed capacity of distribution transformers was 569 MVA at the end of 2019.[23]

By focusing on a specific industrial zone, the impacts of historical and potential future cost savings become more tangible. Data on electricity demand are available for the top-250 firms located at DOSAB:

- How much did DOSAB Top-250 firms benefit from the increasing share of renewable energy sources (wind and solar) in the Turkish power market from 2015 to 2020?
- How much will DOSAB-Top 250 firms benefit from a further increase in renewables (wind and solar) between 2020 and 2030?

Table A.19 presents a summary of selected variables for 28 of the 43 DOSAB firms that provided data on their total revenues, exports, and employment in 2019. These 28 firms represent 92% of the total revenues of the 43 DOSAB firms in the Top 250 in 2019. Electricity demand among this selected sample in 2019 accounted for around 54% of the total electricity demand throughout DOSAB (1,140.3 GWh).

		Revenue (milion TRYs) (net of VAT)	Exports (million USD)	Avg. Employment	Sales from Prod. (million TRYs)	Electricty Demand 2019 (GWh) *
Textiles & apparel	text	5,275.8	393.5	8,833.0	3,648.1	171.5
Chemical, rubber, plastic products	chem	1,203.7	13.9	699.0	1,008.9	44.4
Transport Equip.	auto	20,503.5	2,383.4	8,590.0	17,367.7	392.6
Food	food	142.6	0.0	45.0	0.0	3.5
Metal Industry	nfm+irst	436.2	39.4	359.0	431.6	2.0
TOTAL		**27,561.7**	**2,830.1**	**18,526.0**	**22,456.2**	**614.2**
Top 250 Firms		164,858.2	11,521.8	151,741.0	118,445.0	
Share of DOSAB Top Firms in Top 250 (%)		16.7	24.6	12.2	19.0	

*/ Approximated via the AGE model results.

Table A.19: Descriptive statistics for sample DOSAB firms in Top 250 in 2019

Source: own

To approximate the 2015–2019 savings by DOSAB Top-250 firms, we assume that the electricity demand growth dynamics for these firms closely followed the growth dynamics of the industry average, which is available via Energy General Equilibrium Tables. This enables estimates of the total direct savings by these firms for the period 2015–19. As shown in Table A.20, the direct saving by these selected firms in 2019 was around EUR 1.7 million in the scenario with actual renewables capacity mix compared to the hypothetical scenario without renewables; and the cumulative saving between 2015 and 2020 amounted to around EUR 6.2 million. These savings on electricity costs represent around 2.5% of the total electricity bill of these firms in 2019.

		2015	2016	2017	2018	2019	2015-19 Cum.
Textiles & apparel	text	321,070.65	293,801.43	331,522.88	407,280.27	459,699.23	**1,813,374.46**
Chemical, rubber, plastic products	chem	38,976.69	91,267.19	86,326.03	105,462.01	119,042.96	**441,074.89**
Transport Equip.	auto	407,900.29	717,771.74	819,892.36	932,187.22	1,052,291.22	**3,930,042.83**
Food	food	4,961.55	5,731.93	6,956.23	8,393.33	9,474.62	**35,517.65**
Metal Industry	nfm+irst	1,954.18	2,645.01	4,529.56	4,823.58	5,443.52	**19,395.85**
TOTAL		**774,863.36**	**1,111,217.30**	**1,249,227.06**	**1,458,146.41**	**1,645,951.55**	**6,239,405.68**

Table A.20: Total savings for actual renewables capacity mix comparing to hypothetical scenario without renewables for DOSAB Top-250 Firms, 2015–19 (EUR)

Source: own

[23] https://www.dosab.org.tr/dosyalar/dokumanlar/18012021214012Q7MQL9.pdf

A projection for 2020–2030 is obtained by a similar method: utilising the AGE, we first estimate the growth rate of each industry and the corresponding path of electricity demand. Two crucial assumptions are that: 1) The technological coefficients representing electricity input and the resulting outputs (for DOSAB firms in each sector during 2020–30) can be approximated by industry averages; and 2) that DOSAB-Top-250 firms will follow similar pathways of growth, energy efficiency, and electricity demand as the industry averages. Given those assumptions: Compared with the hypothetical scenario without renewables (see Table A.21), the Current Policy Scenario can provide direct savings for DOSAB Top-250 firms of up to EUR 3.9 million in 2030 alone, and EUR 30.4 million between 2020 and 2030; these potential savings increase to EUR 4.7 million in 2030 and EUR 32.75 million during 2020–30 in the Advanced Renewable Scenario.

		2030	2020-25	2020-30
Textiles & apparel	text	915,022.77	3,438,911.03	7,414,584.26
Chemical, rubber, plastic products	chem	236,078.76	880,844.30	1,904,242.12
Transport Equip.	auto	2,722,592.30	9,023,290.23	20,829,937.26
Food	food	17,599.77	68,145.22	144,659.63
Metal Industry	nfm+irst	11,863.61	42,769.93	94,505.98
TOTAL		**3,903,157.21**	**13,453,960.71**	**30,387,929.26**

Table A.21: Total savings from increased share of renewables for DOSAB Top-250 firms, 2020–30 (EUR)

Source: own

Annex 4: The electricity market in Turkey

The Electricity Market Law No. 6446 defines the rules for generation, transmission, distribution, wholesale, retail, and other electricity services. The Ministry of Energy and Natural Resources (MENR) determines national energy policies and the Energy Market Regulatory Authority (EMRA) serves as an energy market regulator.

The Energy Exchange Istanbul (EXIST), or Enerji Piyasaları İşletme A.Ş. (EPİAŞ) by its Turkish name, is responsible for managing and operating energy markets, including power and gas commodities. The EPİAŞ operates **spot electricity markets**, power futures market, the Renewable Energy Guarantees of Origin System and Organized Renewable Energy Resource Guarantee (YEK-G) market.

The spot electricity markets include the **day-ahead Market (DAM)**[24] and the Intraday Market (IDM), which have been operated by EPİAŞ since 2015. However, not all electricity demand is traded in the spot electricity markets. The DAM had a total electricity trading share of 41.5% in 2016, which has subsequently shown an increasing trend, peaking at a record high of 62.3% in 2020. Annual demand and DAM volume share of annual demand are expressed in Figure 30.

The annual energy demand of Turkey's industrial sector and associated share of total national demand are presented in Figure 31. On average, the industrial sector accounted around 38% of total Turkish energy demand between 2015 and 2020.

Figure A.30: Annual demand and corresponding DAM share
Source: own

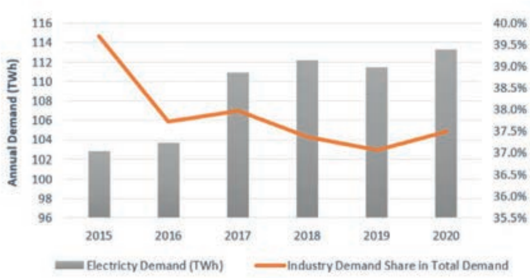


Figure A.31: Annual demand of Turkish industrial sector and corresponding share of total national demand
Source: own

[24] The day-ahead market (DAM) is an organised market used for electricity trading and balancing activities one day before the electricity delivery day, and is operated by EPİAŞ. EPİAŞ announces the hourly market clearing prices (MCPs-wholesale market price) for DAM based on bids from market participants.

Annex 5: Research limitations and options for further research

The study is based on transparent data acquired from the EPİAŞ platform, which provides the big picture of the Turkish electricity market; however, much commercially sensitive data are not available. This lack of data, particularly concerning bi-lateral contracts and the maintenance periods of power plants, are compensated by adjusting the merit order as described in Section 2.2. In addition, the business-as-usual scenario is based on 2019 data, and so excludes the effects of the COVID-19 pandemic. The renewables generation profiles are devised based on publicly available data and can be updated based on the exact location of renewable sources. For hydro power plants, wet year profiles are considered while modelling the energy constraints.

The AGE model utilised in this study is based on the 2018 macro-economic/sectoral equilibrium of the Turkish economy, which was built on 2014 GTAP Input–Output (I–O) Tables.[25] The most recent I–O Tables published by the Turkish Statistical Institute (TURKSTAT) also date back to 2012. Hence, it has not been possible to utilise updated versions of the I–O tables to potentially reflect more accurate sectoral electricity demands. The necessity to match the sectoral disaggregation of the I–O tables with that of the Energy Balance Tables also affected the level of sectoral disaggregation. For instance, the Nace Rev. 2 sectors 26–27–28 were aggregated under "Machinery, Electric Mach. & Electronics".

In order not to exploit any substitution possibilities, especially between electricity and other energy inputs as well as the energy composite and other production factors (K, L), the AGE modelling study employed does not make any assumptions regarding electricity-saving technical changes or the further electrification of production processes. Rather, the research design has kept the substitution possibilities among the production inputs as low as possible. Further sensitivity analyses, as well as analyses at the sectoral level, on the possibilities for electrification and/or energy-saving technical changes, could facilitate more refined results.

Further research can also be carried out on future retail electricity price development including:

- Analysis of the future wholesale electricity price can be modelled very accurately.
- Analysis of the future wholesale electricity price can be modelled very accurately if more data (such as cost-curves or short-run marginal costs of power plants) were available.
- For the development of the retail electricity price, many price components will influence the future price evolutions, such as the evolution of renewable support mechanisms. Further research is needed into the development of renewable energy support costs and how the costs of supporting nuclear power affect retail electricity prices.
- The wholesale day-ahead market price estimation for the future is based on historical prices and their correlation with the commitment status of different power plants at seasonal resolution. For more precise analysis at higher resolution, more sophisticated tools such as machine-learning techniques can be used.

To analyse fuel price risks, the fossil gas price in 2030 is considered identical to that of the year 2020 as the reference price. The reference price is acquired based on the IEA New Policies scenario. Further research on the subject of fuel prices and associated impacts on Turkish retail electricity prices for the industrial sector can be carried out, especially in light of the recent fossil fuel price increases in 2021 and 2022.

[25] 2014 GTAP Input-Output (I-O) Tables, https://www.gtap.agecon.purdue.edu/databases/v10/index.aspx).

Annex 6: Energy General Equilibrium model

The production structure in A.23, defines a “non-electricity energy composite” (of coal, gas, and oil) as the non-electricity sources of energy input for each sector and assumes imperfect substitutability between electricity and a “non-electricity energy composite” via a CES function to form an “energy composite” input for each sector i:

$$ENG_i = A\_\bar{E}NG_i[\delta_i NonEL_i{}^{-\rho_i} + (1-\delta_{ij})EL_i{}^{-\rho_i}]^{-1/\rho_i}$$

ENG_i in the equation above represents total energy demand of sector i in terms of the energy composite. NonEL is the level of “non-electricity energy composite” and EL is the electricity input in each sector i. The parameter $\delta = \dfrac{1}{1-\rho}$ is a constant representing the elasticity of substitution between these two inputs. The optimal energy demand strategy is derived by minimising the costs $P\_NonEL_i nonEL_i + pelec_i EL_i$, based on the relative prices. Hence, a change in electricity price, $pelec_i$. for each sector will have a direct impact on the price of the energy composite P_ENG_i.

A cost-minimisation strategy then leads to a relative demand of for -electricity energy composite, NonEL and electricity, EL as a function of the relative prices, the share of electricity payments in composite energy cost $(1-\delta_{ij})$, as well as the possibility of substitution between the carriers of energy, represented by $\sigma_i = \dfrac{1}{1-\rho_i}$.

$$\frac{NonEL_i}{EL_i} = \left[\frac{pelec_i}{P\_NonEL_i}\,\frac{\delta_i}{(1-\delta_{ij})}\right]^{\frac{1}{\rho_i+1}}$$

As illustrated in Figure A.23, the energy composite ENG_i for each sector then forms an input to final output production XS_i, along with the value-added VA_i, generated by labour (L_i) and capital (K_i) inputs:

$$XS_i = A\_\bar{X}S_i[\beta_i ENG_i{}^{-\rho X_i} + (1-\beta_{ij})VA_i{}^{-\rho X_i}]^{-1/\rho X_i}$$

Here, the unit price of energy composite P_ENG_i, as well as the unit price for value-added (of wage rate and capital rental rates) will affect the price of output, P_XS_i. Hence, the necessary condition for cost-minimisation becomes:

$$\frac{ENG_i}{VA_i} = \left[\frac{P\_VA_i}{P\_ENG_i}\,\frac{\beta_i}{(1-\beta_{ij})}\right]^{\frac{1}{\rho X_i+1}}$$

Thus, in a partial equilibrium setting, a change in the unit cost of electricity, $pelec_i$for each sector will affect the unit cost of energy composite, $P_ENG_i$and the unit price of output, P_XS_i. Keeping the unit prices of all other inputs (wage rate, price of capital, etc.) constant, a relative price change in energy composite will influence final production volumes via changes in demand for energy and electricity.

Annex 7: Price effect of renewable resources: Literature review

A7.1 Analysis of the effects of wind and solar

The impact of renewable energy generation on energy market prices is examined in the literature from different perspectives; however, the questions that are answered are not similar or identical to those of interest to the COBENEFITS project. For studies that aim to quantify the impacts of renewable generation on retail prices, the literature provides no consensus on whether retail prices are increasing or decreasing. Here, the considered scenarios play a significant role, which differs from the scenarios we have at hand for the COBENEFITS study. The expected outcome might be a decrease in the market prices with an increase in RES generation; thus, withdrawal from the market of production units with high production costs. However, the RES mark-up may increase through RES integration, which may further cause an increase or decrease in retail prices (Bode 2006).

The literature includes studies focusing on the impact of RES on markets and retail prices in Italy (Bigerna and Bollino 2016), Portugal (Gouveia et al. 2014), and China (Zhao et al. 2016). Some studies have shown that increased RES production reduces electricity market prices (Paraschiv, Erni, and Pietsch 2014,Hirth 2012, Dillig, Jung, and Karl 2016). However, other studies predict that, in the longer term, the use of variable energy sources will increase market prices (Osorio and Van Ackere 2016).

In order to analyse the impacts of increased RES on Turkish electricity market prices, hourly RES generation and MCP data were obtained from the EPİAŞ transparency platform. Figure A.32 illustrates historical hourly RES generation versus the day-ahead MCP (2016–20). It can be seen that generation by RES has increased significantly over the period shown, with linear trendlines overlaid to examine how this affects MCP. The slopes of the trendlines indicate declining prices over the period shown.

Figure A.32: Historical hourly RES generation vs MCP | Source: own

A7.2 Price Volatility

Due to present technical limitations on effectively storing electricity, a continuous clearing process operates in the electricity market (Božić et al. 2020). Fluctuations in this market-clearing price are termed volatility, which is an important element in forecasting processes in areas such as portfolio optimisation (Ignatieva 2014). Many methods can be used to calculate volatility, one of which is formulated as daily velocity based on daily average power price (DVDA) (Zareipour, Bhattacharya, and Canizares 2007), as shown in the following equation.

$$DVDA_i = \frac{1}{M}\left\{\frac{\left[\left(\sum_{j=1}^{M-1}|p_{i,j+1}-p_{i,j}|\right)+|p_{i-1,M}-p_{i,1}|\right]}{p_{i,.}}\right\} X\ 100\ , \quad i = 1,2,\ldots,\ N.$$

Here, N is the number of days, represented by the index i. M is the number of days within the period under study, indicated by index j; for the day-ahead market $M = 24$. $p_{i,j}$ refers to the market-clearing price on the ith day in the jth period. $p_{i,.}$ is the average daily price on the ith day, as in the following equation:

$$p_{i,.} = \frac{1}{M}\sum_{j=1}^{M} p_{i,j}\ , \quad i = 1,2,\ldots,\ N.$$

The main reason for using this approach is that this type of price volatility is mostly used to describe price behaviour within the electricity market. Hence, this index is used to facilitate comparisons between the behaviour of Turkish electricity markets and other markets around the world.

A7.3 DAM price volatility

Figure A.33 depicts the DVDA volatility metric for the day-ahead market. Day-ahead DVDA statistics, such as maximum, minimum, and weighted average by year, are illustrated in Figure A.34. As can be seen, the DVDA in DAM price shows a decreasing trend, implying that the Turkish electricity DAM is stabilising over a timeframe measured in years.

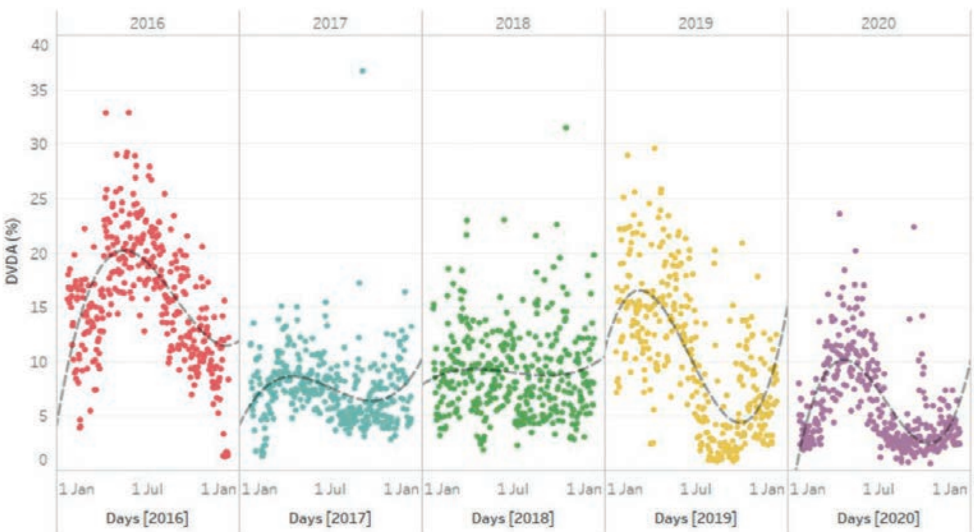


Figure A.33: Daily price volatility based on DVDA | Source: own

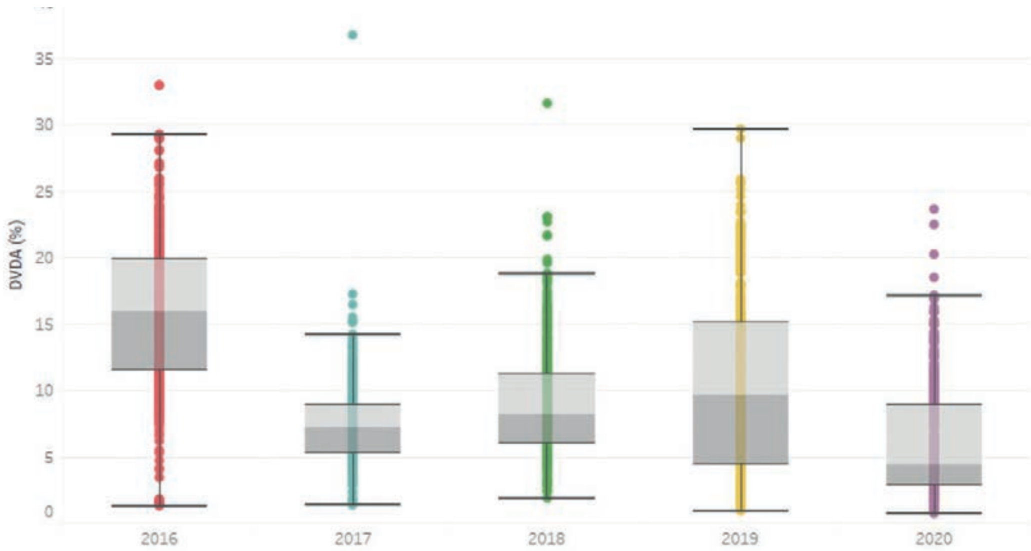


Figure A.34: DVDA statistics | Source: own

DVDA and daily RES generation data are plotted in Figure A.33. Daily total RES production is expressed in MWh/day on the horizontal axis and DVDA on the vertical axis. As can be seen, the trend is for DAM prices to show higher DVDA with increasing daily RES generation, which might be due to the intermittent character of the renewable resource.

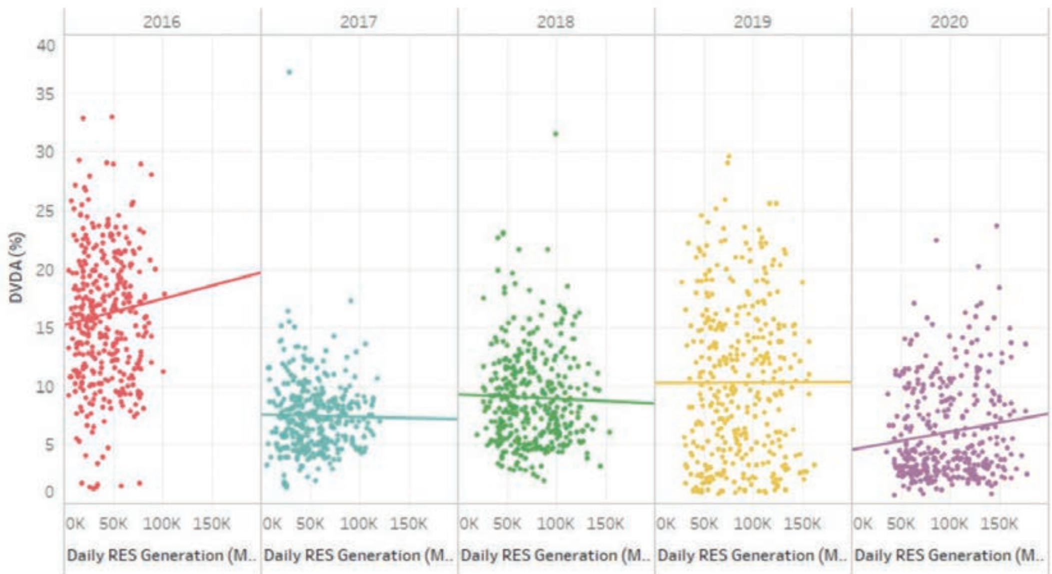


Figure A.35: DVDA vs Daily RES Generation | Source: own

A7.4 Volatility in European Power Markets

Power exchanges in Europe have been operating since the 1990s, while in the region of Southeast Europe (SEE) they are only a few years old. Volatility is one of the indicators that define the level of market development. Božić et al. (2020) studied volatilities for Bulgarian, Greek, Romanian, and Swiss power markets for the period 2016 to 2020. The daily velocity based on the daily average price (DVDA) metric is used for volatility measurement as given in Eq. (1). To compare the volatility findings of the Turkish DAM with other European power markets, the DVDA comparisons are presented visually in Figure A.35.

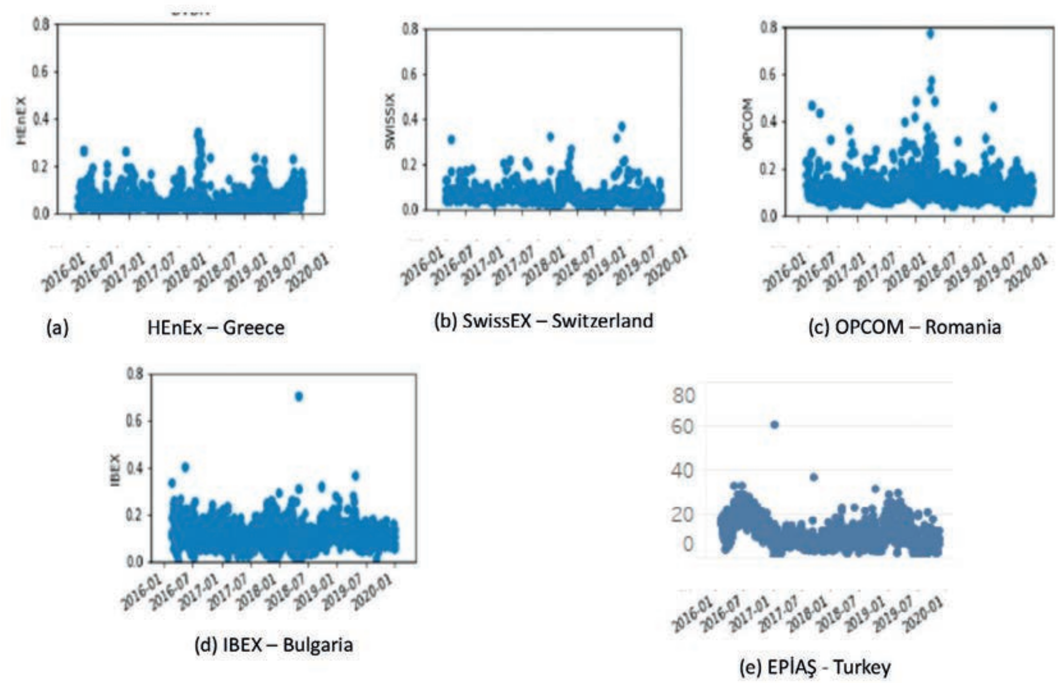


Figure A.36: DVDA of (a) Greece, (b) Switzerland, (c) Romania, (d) Bulgaria, (e) Turkey | Source: own

Statistics for several European markets between 2016 and 2020 are given in Table A.22. Note that the price volatility investigation is made here to provide a qualitative indication regarding the effect of renewable energy resource integration on day-ahead wholesale electricity prices. More detailed analysis and quantitative results will be made in response to a key question (see Methodology section).

Power Markets	Std. Dev.	Mean	Coefficient of Variation	Min.	Max.
HUPX	0.05	0.0963	0.47	0.03	0.68
BSP	0.08	0.1031	0.80	– 1.34	1.27
CROPEX	0.11	0.1010	1.10	– 3.40	1.22
PHELIX	0.76	0.0896	8.51	– 23.59	13.67
EXAA	0.50	0.0657	7.54	– 17.68	2.68
GME North	0.02	0.0676	0.35	0.02	0.21
GME South	0.04	0.0756	0.49	0.01	0.39
HEnEx	0.04	0.0509	0.83	0.00	0.34
SEEPEX	0.04	0.0816	0.50	0.03	0.91
OTE	0.36	0.1034	3.48	– 3.65	10.04
IBEX	0.05	0.1153	0.44	0.00	0.71
OPCOM	0.06	0.1140	0.51	0.04	0.78
OKTE	0.36	0.1113	3.22	– 3.65	10.04
SWISSIX	0.20	0.0574	3.47	– 6.77	2.10
FRANCE	0.09	0.0926	0.94	0.03	2.28
EXIST - TURKEY*	0.07	0.1069	0.62	0.01	1.14

Table A.22: DVDA statistics for various European countries

Source: own

Creating an enabling environment to seize the benefits of the energy transition for Turkey's industry. © Centre for Alternative Technology (CC BY 2.0)

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