On the way to efficiently supplying more than half of Turkey's electricity from renewables:

Balancing the location of wind and solar PV investments

SHURA Energy Transition Center

About SHURA Energy Transition Center

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

Authors

Değer Saygın (SHURA Energy Transition Center), Philipp Godron (Agora Energiewende), Erkut Cebeci and Osman Bülent Tör (EPRA Electric Energy)

Acknowledgements

Valuable review and feedback was provided by the SHURA Energy Transition Center Steering Committee, Ceren Ayas (ECF), Selahattin Hakman and Ümit Şahin (IPC). Megan Gisclon edited the paper.

SHURA Energy Transition Center is grateful for the generous funding provided by the ECF.

This report is available for download from www.shura.org.tr

For further information or to provide feedback, please contact the SHURA team at info@shura.org.tr.

Design

Tasarımhane Tanıtım Ltd. Şti.

Print

Printworld Matbaa San. Tic. A.Ş.

ISBN 978-605-2095-34-8

On the way to efficiently supplying more than half of Turkey's electricity from renewables:

Balancing the location of wind and solar PV investments

CONTENTS

LIST OF FIGURES

ABBREVIATIONS

EUR	Euro
GW	gigawatt
km	kilometre
kW	kilowatt
LCOE	levelised cost of electricity generation
MW	megawatt
TEİAŞ	Türkiye Elektrik İletim Anonim Şirketi
US$	United States dollar

HIGHLIGHTS

- By installing a total of 40 gigawatts (GW) of wind and solar capacity —up from 10 GW today—Turkey can supply 20% of its total electricity demand from these two renewable energy sources in the near future, according to SHURA's recently released study. This can be achieved without challenging the power system operation. No additional transmission grid investments are needed outside of those currently planned.
- Endowed with significant wind and solar resources, Turkey's power system can integrate even more renewables. The same study shows Turkey can integrate 60 GW of wind and solar power, which would supply 30% of the country's total electricity output. Including hydro, geothermal, and other renewables, this would increase the share of renewables in total electricity output to more than 50%. Increasing power system flexibility and allocating wind and solar capacity by taking into account their impact on the system will facilitate this.
- Achieving the integration of 60 GW of wind and solar power would require ramping up investments significantly. Annually, 2.6 GW of wind and 3 GW of solar photovoltaic (PV) capacity would be added to the system from 2018 until 2026, requiring average investments between EUR 4.7 and EUR 6.3 billion per year.
- One-quarter of the total installed wind and solar capacity would be relocated to areas with stronger grids and where demand for electricity is high, as compared to the case that favours investments at locations where resources are best. This shift predominantly impacts solar capacity (10 GW) since wind resources and demand are largely proportionate (both are highest in the northwest regions). Solar investment is partly redistributed from Central Anatolia and the West Mediterranean to the rest of Turkey. Approximately 5 GW of wind capacity is reallocated across the northern and eastern regions.
- Reallocation to less resource-intensive areas has a negligible impact on the overall output of solar and wind power, which would go down by between 3% and 5%. From the perspective of an investor, the loss in output is higher: the generation of those investments that are relocated could go down by up to 10% for solar PV. This increases the levelised cost of electricity generation of these solar plants by 12% on average; for wind the cost increase is lower, about 4%. Nevertheless, investors would adapt their investments if appropriate incentives are put in place.
- The benefits of the system-driven strategy may well outweigh its costs. The need for additional investments in transmission grids and sub-station capacity can be reduced by 6% compared to cases in which power plants are placed only in areas with the best solar and wind resources.
- Implementing a system-driven strategy—thereby also balancing generation variability to some degree—would nearly annul solar and wind curtailment and cut down one-quarter of total redispatch, which would otherwise be needed to guarantee secure and reliable grid operation. To further reduce the need for operational interference, the system-driven strategy should be complemented by system flexibility measures. These may include battery storage, pumped hydro, demand response, and more flexible thermal generators.

- To attain higher shares of renewable energy, making use of Turkey's resource potential and materialising the social and economic benefits for improving the welfare of Turkish citizens, the following suggestions are made for policy makers' consideration:
    - o Develop a regulatory framework that creates a balanced renewable energy market without limiting investments to resource-rich areas
    - o Reward investors that invest in system-friendly areas by considering the impact on the economics of the projects in a technology- and location-specific manner
    - o Integrate new regulatory frameworks with existing policies, e.g., for rooftop solar PV, that indirectly support a system-friendly allocation of solar and wind capacity
    - o Plan for renewable energy investments in each region by taking into account land availability, site selection constraints, economic activity, local value creation, and existing grid infrastructure
    - o Complement a system-driven strategy with a portfolio of technologies that can maximise output even from less resource-rich areas and options to increase system flexibility, thereby improving secure integration of wind and solar power and reducing operational challenges that wpuld otherwise increase curtailment and redispatch

1. Introduction

In 2017, Turkey entered a new phase of transforming its energy system. By the end of the year, total installed electricity generation capacity reached 85 gigawatts (GW), up from 78.5 GW in 2016. Renewables represented two-thirds of the total capacity additions in 2017, mostly small-scale solar photovoltaic (PV) installations. As a result, total installed solar and wind capacity stood at 10 GW by the end of 2017 (Enerji ve Tabii Kaynaklar Bakanlığı, 2018a,b).

SHURA's recently released analysis, "Increasing the share of renewables in Turkey's power system", shows that according to planning of the system operator Türkiye Elektrik İletim A.Ş. (TEİAŞ), solar and wind capacity would not exceed 20 GW by 2026 (Base Case Scenario). This projection is far below the country's current targets of 25 GW by 2023, its resource potential, and the market developments seen in recent years (Godron et al., 2018). In the same study, the impacts of two alternative pathways that favour higher shares of renewables on the transmission system and system operation have been assessed. The pathway that assesses the impact of doubling solar and wind capacity to 40 GW by the same year (Doubling Scenario) can be realized without additional investments compared to what is already planned by TEİAŞ today and without negative impact on operations. Without any prior planning for system adaptation, if Turkey invested in a total of 60 GW of solar and wind capacity by 2026 (Tripling Scenario), grid investments would increase by 40% compared to the Base Case and Doubling Scenarios. In addition, up to 3% of all solar and wind power would need to be curtailed, and the share of redispatched energy would double compared to 2016 levels.

Alleviating these challenges for a system with more than 50% renewables share in total electricity output requires planning early on. The flexibility of the power system needs to be improved, and there should be a more balanced approach in allocating wind and solar capacity—e.g., selecting areas that are not only resource-rich but also display local demand and adequate grid feed-in capacity (system-driven strategy)[1] (see Figure 1).

This paper at hand is part of the series of reports SHURA is preparing about "On the way to efficiently supplying more than half of Turkey's electricity from renewables". It provides details on the benefits of allocating wind and solar capacity in a system-friendly way and assesses the consequences in terms of benefits, investments, system costs, and implementation challenges. The paper ends with brief suggestions for policy makers, the energy industry, and civil society.

[1] Throughout this paper, two terminologies to define strategies for wind and solar capacity allocation are consistently used, namely: "resource-driven" which is the allocation of wind and solar capacity by resource quality and "system-driven" which is the allocation of wind and solar capacity by balancing resource quality and local demand.

Figure 1: *Comparison of annual transmission grid investments and the shares of curtailment and redispatch for all scenarios, 2016-2026*

A more flexible power system complemented with system-friendly location of solar and wind capacity brings multiple benefits: It will save EUR 100 million per year in additional transmission grid investments and reduce curtailment and redispatch volumes.

2. Benefits of a system-driven strategy to realise higher shares of renewables

Changes in capacity and output from solar and wind power by region

In the analysis conducted, 15 GW of wind and solar generation capacity was located in areas with higher electricity demand and stronger grid capacity.[2] This represents one-quarter of the total installed capacity of 60 GW in 2026 according to the Tripling Scenario (Figure 2).[3]

Figure 3 provides the overview of changes by each region of Turkey. Central Anatolia and the West Mediterranean regions are most affected with a decrease in their total capacity, whereas in Northwest Anatolia and the Central Black Sea regions, wind and solar capacity increase. What is not visible on the regional scale but needs to be borne in mind is the considerable redistribution of wind and solar capacities within the regions. The reason that this part of the redistribution cannot be seen on the map is due to the fact that it occurred on a substation level, especially in the 154 kV grid system.

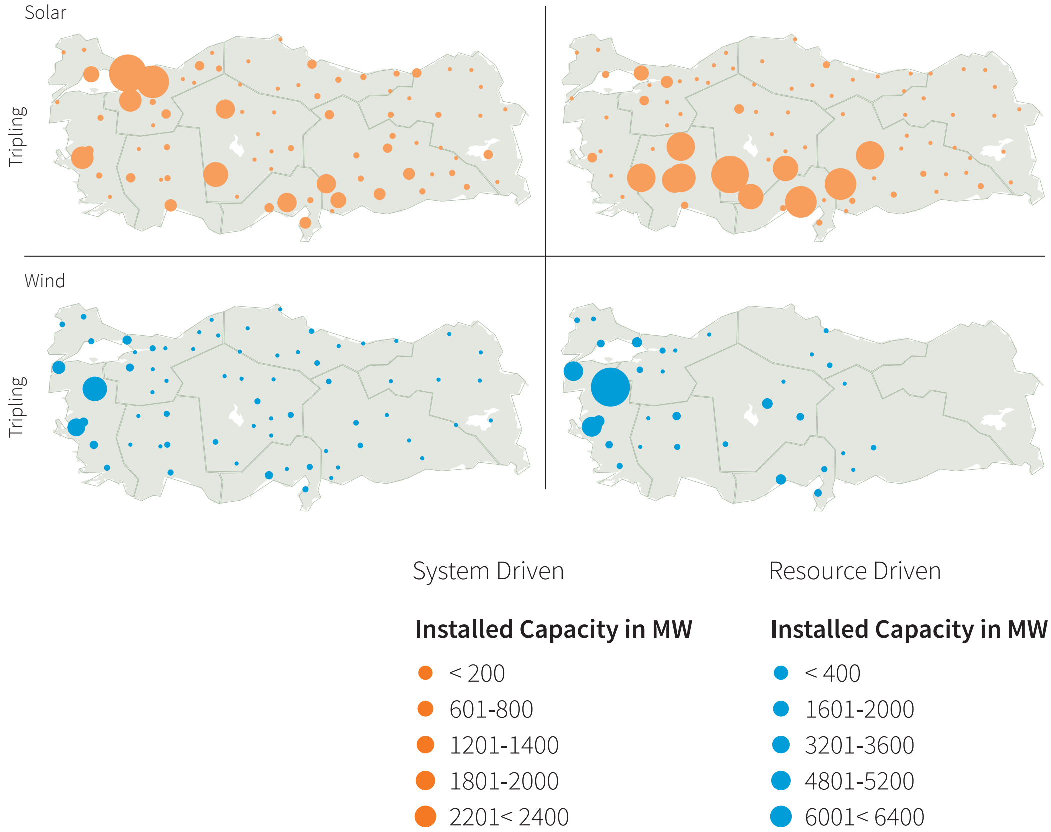
The best wind resources are already close to where demand for electricity is high and where transmission grids are strong. Therefore, the capacity share that is shifted in a system-driven strategy is rather low. Only about 5.1 GW out of a total of 30 GW of wind power plant capacity is relocated, mostly from the western parts of Turkey (3.5 GW in Western Anatolia and 1 GW in Thrace). This capacity is shifted to the central and eastern regions where there is wind power demand and grids capable of integrating additional wind power.

The change in solar is more pronounced. In total, 10 GW capacity is relocated. The southern regions of Turkey are characterised by excellent solar resources that offer the highest output for solar power plant investments. Most of the West Mediterranean region and parts of Central Anatolia have high demand for generated electricity; however, such a level of demand is not the case in many southern regions of Turkey. The population density and industrial activity in parts of Turkey's southern and eastern regions are relatively low; consequently, the transmission grid is rather weak in these areas. Under a system-friendly strategy, nearly 10 GW—or one-third of Turkey's solar power capacity—is relocated to Northwest Anatolia (3.4 GW), Thrace (1.6 GW), West Anatolia (1.6 GW), Central Black Sea (1.6 GW), and East Anatolia (1.5 GW) in Turkey. Because of reallocation, the capacity in Central Anatolia and the West Mediterranean decreases in roughly equal volumes.

[2] Approximately 15 GW, which is split into 9.9 GW solar and 5 GW, represents the interregional shift. This excludes the 1 GW additional shift for solar PV that takes place within each region.
[3] After excluding physically infeasible locations (already occupied space, populated areas, rugged terrain, etc.), the target generation capacity is distributed to the network via two distinct methodologies: (i) considering only the capacity factors that concentrate the installed capacity in high resource areas (resource-driven) and (ii) considering system load together with renewable energy capacity, which shifts some of the installed capacity to locations with less capacity but with high demand (system-driven). It should be noted that the system-driven approach is applied in practice by the transmission system operator via connection capacity limitations for specific regions.

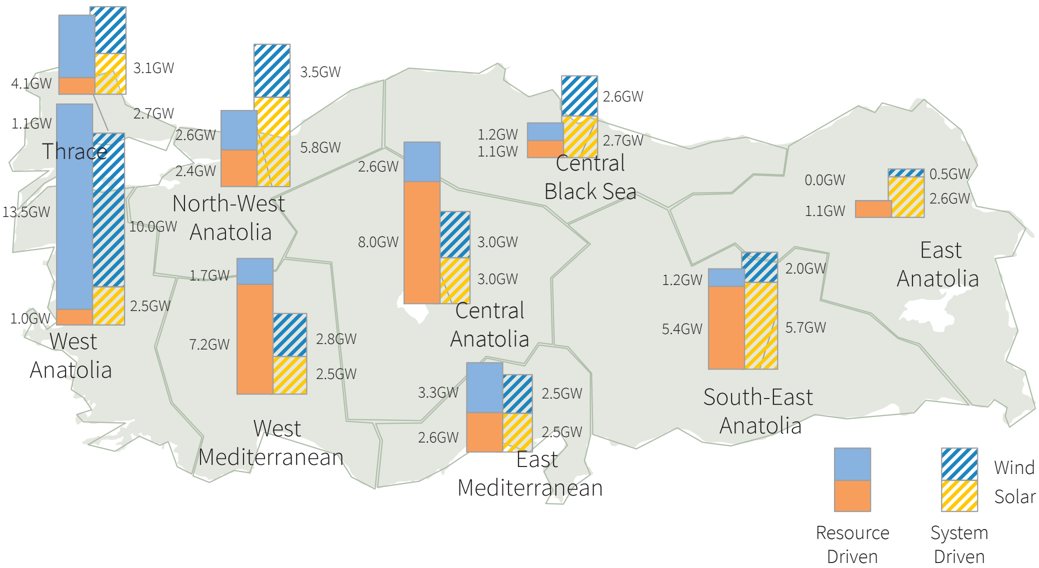
Based on a system-driven strategy, around 15 GW of total solar and wind capacity is relocated to regions of Turkey where electricity demand is high and transmission grids are strong.

Figure 2: *Changes in the location of installed solar and wind capacity in the Tripling Scenario, 2026*



Combined wind and solar capacity decreases in Central Anatolia and the West Mediterranean, whereas there is an increase in Northwest Anatolia and the Central Black Sea regions.

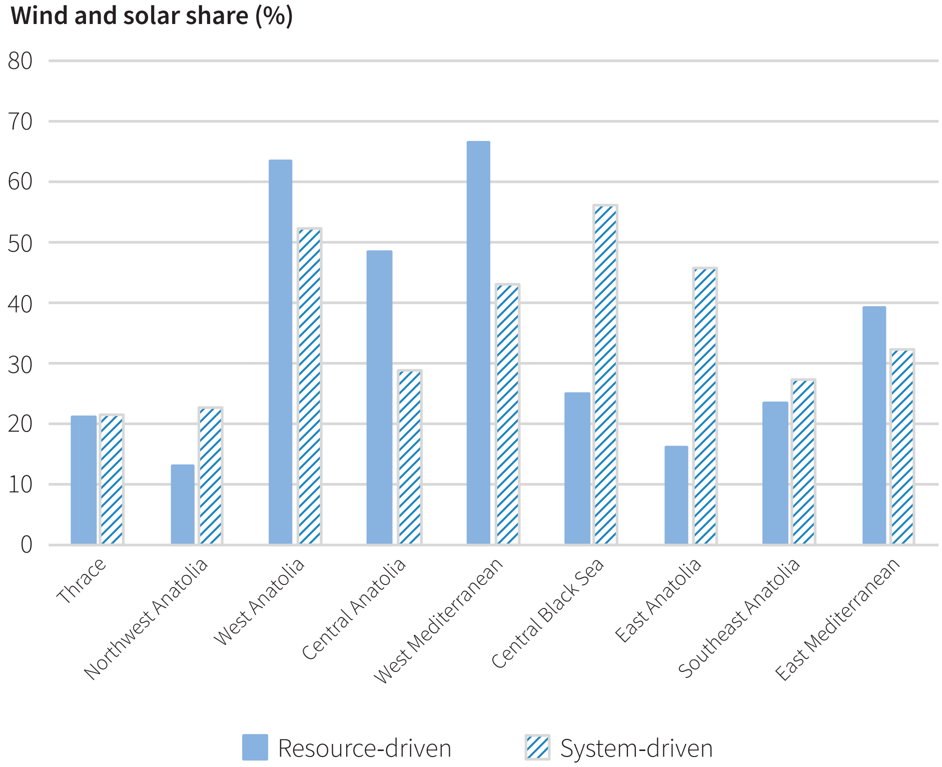
Figure 3: *Allocation of wind and solar capacities in the resource-driven and system-driven strategies according to the Tripling Scenario, 2026*



In the resource-driven strategy, solar and wind output covers more than half of the electricity demand of West Anatolia, Central Anatolia, and the West Mediterranean regions (see Figure 4). In the remaining regions, the total share of wind and solar power across Turkey averages 24%, ranging from as low as 13% in Northwest Anatolia to as high as 38% in the East Mediterranean. The system-driven strategy distributes wind and solar output across regions more in line with their demand levels. Differences in the shares of wind and solar power between regions are less pronounced in the system-driven approach, which also leads to more balanced output. Notably, the share of wind and solar power increases significantly in East Anatolia and the Central Black Sea regions. This covers more than half of the overall regional demand and is driven by an increase in both solar and wind output.

Under the system-driven strategy, wind and solar output is more evenly spread across Turkey's regions to cover between 20% and 57% of regional electricity demand.

Figure 4: *Wind and solar output relative to total demand by region in the Tripling Scenario, 2026*



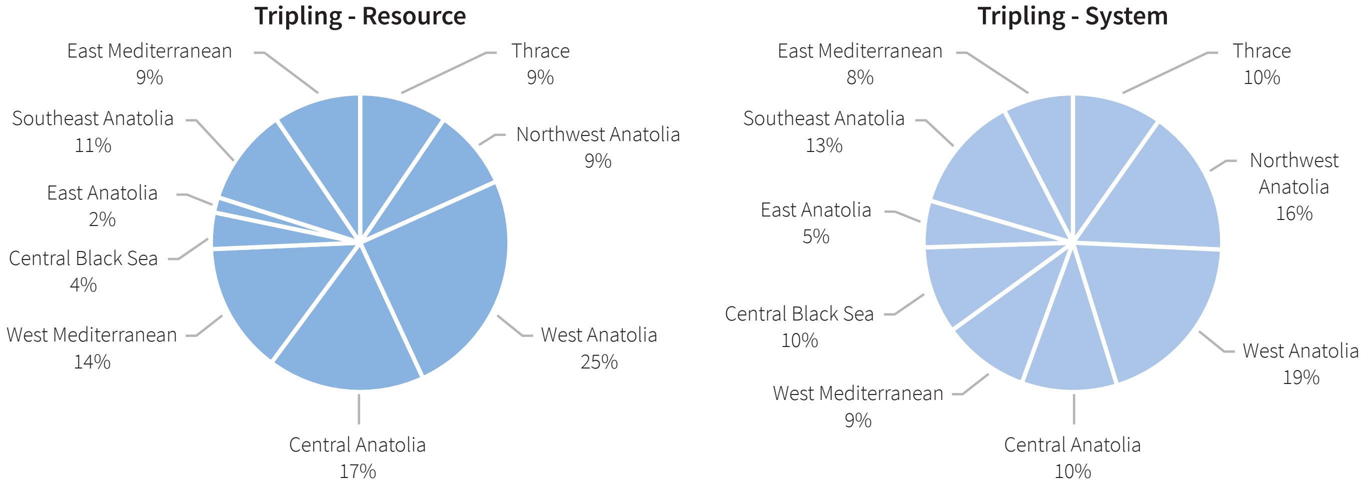
Investment needs for solar and wind and the change in generation costs

Average annual investment needs in wind and solar generation capacity is estimated at EUR 2.4-3.0 billion per year for wind and at EUR 2.3-3.3 billion per year for solar if Turkey invests 60 GW capacity by 2026. This is a six-fold increase compared to the level in 2017. The range depends on how the capital costs of wind and solar will evolve. Here it is assumed that capital costs of solar power plants will reach EUR 600-780 per kilowatt (kW) by 2026 because of a 40-48% decline from the 2016 levels at EUR 1,000-1,500/kW. The range for wind is estimated as EUR 865-1,100/kW by 2026, declining by 12-14% from 2016 levels of EUR 1,000-1,250/kW. The large range between the current capital costs of power plants is assumed in order to reflect the variations across different projects. The future estimates are based on the projections of the International Renewable Energy Agency for 2015-2025 (IRENA, 2016) and consider the global developments in capital costs of wind and solar between 2015 and 2016, which are adjusted for the Turkish case.

The projected average annual investment of EUR 4.7-6.3 billion/year in the period between 2018 and 2026 is at least 40% higher than total investments in wind and solar in 2017, which were around EUR 3.4 billion.[4]

Under the Tripling Scenario and when a resource-driven strategy is favoured, Northwest Anatolia, West Anatolia, and Central Anatolia represent half of all solar and wind capacity investments. The regions with the lowest investment numbers are East Anatolia and the Central Black Sea, representing only 2% and 4% of the total, respectively. With the system-driven strategy, this breakdown changes. As more solar and wind capacity is installed in the Central Black Sea, East Anatolia, and Southeast Anatolia regions, the share of solar and wind power in overall investments in Turkey increases from 17% to 28% (see Figure 5).

Figure 5: *Breakdown of investments in solar and wind capacity in the Tripling Scenario, resource-driven versus system-driven, 2026*



Northwest, Central, and West Anatolia regions receive around half of all investments in solar and wind capacity in Turkey. With the system-driven strategy, the Central Black Sea and East Anatolia regions' shares in these investments increase.

Since under the system-driven strategy, more capacity is installed in regions with somewhat lower resource availability, utilisation rates (i.e., full load hours over the period of one year) of the wind and solar installation that is relocated decreases compared to the resource-driven strategy. The impact on the overall capacity utilisation rate of wind and solar investments is found to be negligible (decreasing from 21.1% to 20.1% for solar and from 28.3% to 27.6% for wind). Indeed, the impact on wind and solar output is, thanks to Turkey's significant solar and wind capacity across its entire geography, much lower than in other countries. However, for the capacity that is relocated, capacity utilisation rates decline to 26.8% (for a total of 5.1 GW of wind capacity) and 18.7% (for a total of 9.9 GW of solar PV capacity).

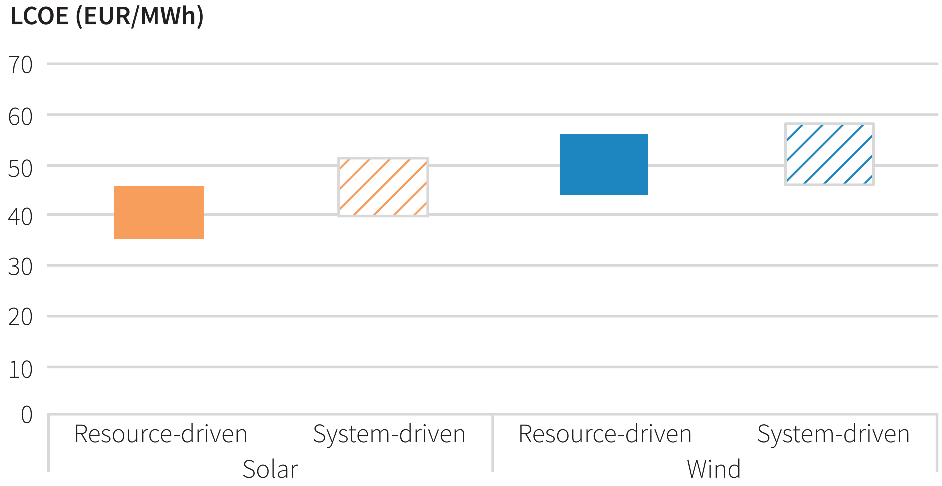
Therefore, a system-driven strategy impacts the levelised cost of electricity generation (LCOE) of solar and wind power. In the resource-driven strategy, power plants are located close to areas with the best available resources. This follows the logic of both the current auction design, as well as the feed-in tariff, which does not differentiate between resource quality. According to the resource-driven strategy, estimated LCOE for solar power ranges between EUR 35.3-45.8 per megawatt-hour (MWh) in 2026 depending on the assumed capital costs of power plants for 2026. For wind it is

[4] In 2017, a total of 5.84 GW licensed capacity was installed. Investments related to this capacity amounted to a total of US$ 6.2 billion. Of this total, US$ 900 million was related to total wind capacity additions totalling 746.3 MW (Erkul Kaya, 2018). Assuming an average currency exchange rate of 1.13 US$/EUR, this is equivalent to EUR 800 million. In 2017, a total of 2,587.5 MW solar PV capacity was installed (YEGM, 2018). Assuming an average capital cost of EUR 1,250/kW, total related investments amount to EUR 2.6 billion.

somewhat higher at EUR 44.0-56.0/MWh. The estimated reduction in capacity factors according to the system-driven strategy is 4% for wind and 11% for solar. This means an increase in the LCOE of solar by 12%, to EUR 39.6-51.5/MWh. The impact on wind is lower, a 4% increase in LCOE, to EUR 45.9-58.3/MWh (see Figure 6).[5] This increase in LCOE would have to be somewhat reflected in the incentive regime such as providing differentiated purchase prices to motivate investors to invest in these locations.

The impact of the reduction in electricity generated on the levelised cost of solar is equivalent to an increase of 12%, whereas for wind it is estimated at 4%.

Figure 6: *The impact of the system-driven strategy over the costs of electricity generation, 2026*

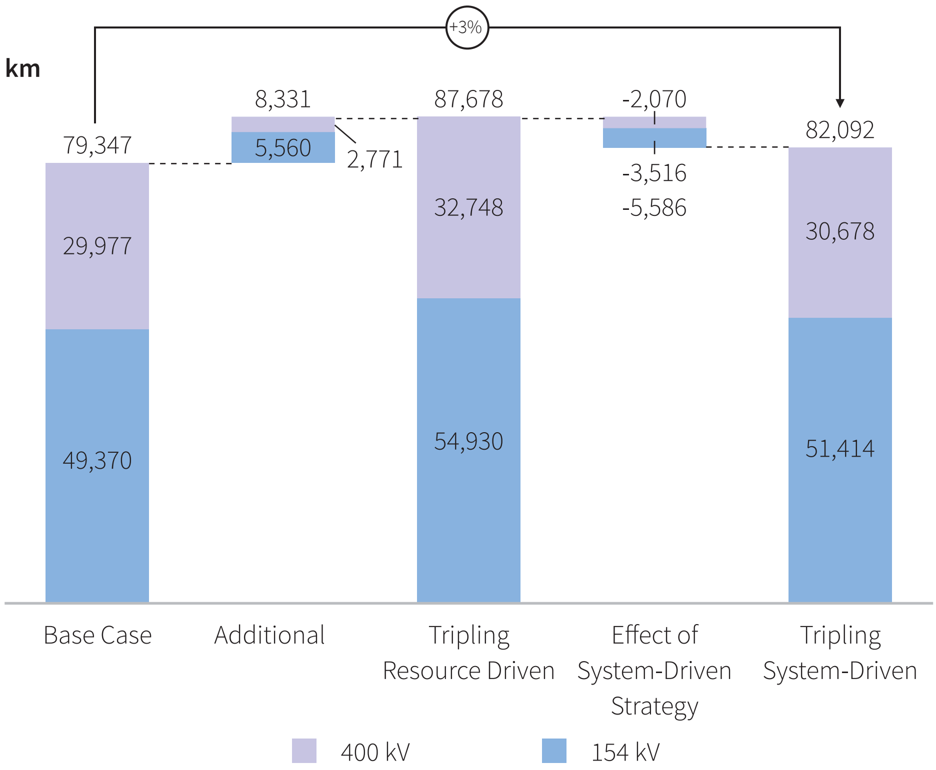


Benefits of the system-driven strategy

The system-driven strategy has important benefits for the Turkish power system such as integrating higher shares of renewables. Total investments in the transmission grid capacity would lead to an additional 87,678 kilometre (km) of grid capacity or a 10% increase compared to the Base Case scenario of 79,347 km in the resource-driven strategy. The system-driven strategy could reduce this by around 6%, limiting the additional need for 82,092 km of grid capacity (see Figure 7).

[5] *Capital costs of solar and wind power plants in 2026 are assumed as EUR 600-780/kW and EUR 865-1,280/kW, respectively. In the estimations, operation and maintenance costs of solar and wind are assumed as 1% and 4% per year of the total capital costs, respectively. A lifetime of 20 years for solar and 30 years for wind has been assumed. The discount rate is assumed as 7.5%.*

Figure 7: *Impact of the system-driven strategy on transmission grid investments, 2026*



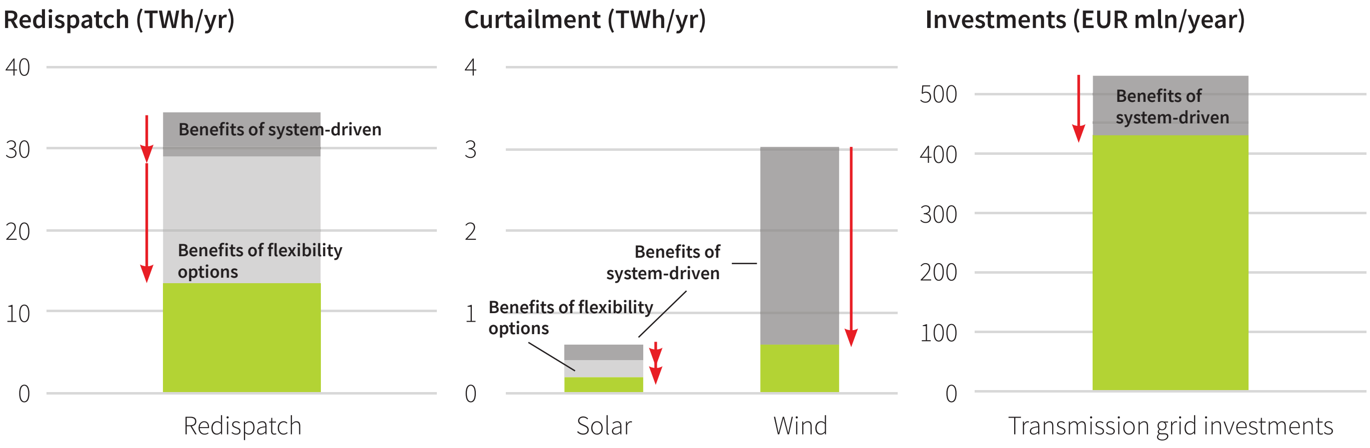
The system-driven strategy would reduce the need for additional investments in transmission grid capacity by around 6%, equivalent to a total of 5,586 km.

The underlying reason for a reduced need of additional grid capacity is that solar and wind generation is absorbed by demand closer to generation. This reduces congestions in the transmission system, which would have to be resolved by building new transmission lines or redispatching thermal generation, substituting lower cost generation with higher cost generation located in areas closer to demand, and reducing power flows in congested areas. Since demand is higher locally, it can also absorb additional solar and wind output, thereby also reducing the need for curtailment. As can be observed in Figure 8, relocation of wind and solar power brings about notable benefits by reducing the need for redispatch and curtailment. However, this strategy alone will be insufficient to ensure reliability and security of the grid when the share of solar and wind power exceed 30%. For further reducing redispatch, options to increase the flexibility of the power system should be explored.

The system-driven allocation of wind and solar has a balancing effect as well, with ramping rates going down, and the maximum hourly share of wind and solar in overall demand declining from 131.5% to 126.2%. The reduction in the maximum hourly ramp rate falls by about 100 MW, from 14.3 GW to 14.2 GW (-0.7%). Additional strategies and technologies have been developed in recent years that help smooth the output of wind and solar generation, decrease ramp rates, and therefore, increase the system value of the power generated. These include improved turbine design of wind power plants, increasing the turbine output in particular at lower resource areas, and for solar PV, changing the panel orientation, tracking the sun throughout the day, and adjusting the ratio between the generation capacity of solar panels and the maximum inverter output, as well as smartly mixing technologies (IEA, 2016).

In terms of investments, a transition to a system-driven strategy can save up to EUR 100 million per year in additional transmission grid investments related to tripling the total capacity of wind and solar to 60 GW by 2026.

Figure 8: *Benefits of a system-driven strategy to reduce redispatch, curtailment, and transmission grid investments versus the benefits of flexibility options for the Tripling Scenario, 2026*



The system-driven strategy creates significant benefits: it reduces redispatch and curtailment of renewable power and provides savings of EUR 100 million per year in additional transmission grid investment. However, only by increasing system flexibility current levels of grid planning and operational intervention can be sustained.

3. Challenges related to implementing the system-driven strategy

As this analysis shows, a system-driven strategy will provide clear benefits to integrating renewables to the grid. However, implementing this strategy could be constrained by several policy and technology challenges.

Without a regulatory framework to orient investors to designated areas and a policy environment that encourages a mix of larger -and smaller- scale renewable energy generation facilities, the investment climate will continue to favour resource-rich areas. Conversely, the current policy environment drawn in 2017 by the renewable energy capacity auctions in Turkey favours resource-rich areas only. The system benefits need to be (partially) directed towards investors as they, by nature, prioritise their profits to increase the rate of return on investments. In a system-driven strategy, the rate of return will be lower unless there is a clear incentive. This is exactly where the current design of auctions could potentially impede the implementation of a more balanced approach in locating new wind and solar plants. Two 1 GW-scale auctions in 2017 yielded world-record prices, but they focused capacity installations in areas where the sun shines strongest and where wind blows the fastest.

The Turkish government made the choice to create a renewables market, develop local value chains, and revive the solar market, which for years did not receive the attention it deserved against the country's resource potential. This policy choice is not too different than in other countries, but it is important to note that policies should develop as markets and technologies evolve. At the same time, actual solar investments in 2017 were exclusively in small-scale (mainly 1 MW) projects, based on the current feed-in tariff regime. During the first half of 2018, however, Turkey's renewable market has practically stalled. Notably, the solar sector was impacted. Policy uncertainty, Turkey's challenging economic conditions and overcapacity were the main reasons for investors' reservations.

With new policies and regulatory frameworks, policy makers can play a major role in turning this scenario around by providing a remedy to policy uncertainty. The focus should be on opening a window of opportunity for smaller-scale investors to develop businesses in regions with slightly lower wind speed and solar irradiation but where electricity can be fed to the grid without disruptions and sold without any major infrastructure investments. This must partly occur through investor initiatives. The new regulatory framework for rooftop solar PV is a good starting point for accelerating the deployment of more distributed capacity that can generate electricity where it will be consumed, thereby reducing stress on grid infrastructure and system operation.

A recent report by the World Bank report has shown that the most conservative estimates of rooftop solar PV potential in Turkey add up to 4 GW, around 10% of its theoretical potential of more than 40 GW, with much of that potential resting with commercial and industrial roofs (the World Bank, 2018). These locations where high potential for rooftop solar PV exists are exactly the areas where grids are strong, and demand is high—as suggested in this analysis. Hence, the government should build on the promising initiative for a regulatory framework for solar PV rooftops and expand such system-friendly approach to the broader set of wind and solar policies. There are several ways to do this: be it through top-ups on power purchase agreements, attractive investment loans, or others. As such financial support schemes are already available, adapting these would not create additional implementation hurdles or bureaucratic challenges.

Costs will not be the major challenge to the system. The impact of such a system-friendly policy on the overall system cost would be marginal, and surely less than if the generated electricity would have been curtailed. SHURA's forthcoming study will evaluate this in more detail, along with the costs and benefits of various flexibility options to supply more than half of all electricity output from renewables (Saygin et al., forthcoming). Indeed, the impacts on a single investor can be considerable; however, it will be individuals that will benefit from this, both economically and socially. This is why the existing regulatory framework should be enhanced to provide incentives for investors to invest in a system-friendly strategy.

On top of questions regarding regulation and associated costs, technical and social issues may arise. Regions with large demand and strong grids are those already densely populated and packed with large industrial and agricultural activity, like the western and northwestern parts of Turkey. These regions also attract much of Turkey's tourism, which brings another angle of debate to (renewable) energy investments. Planners will need to consider these issues as well as available land and garner public support in areas designated for more industrial activity. As mentioned above, rooftop solar PV policy would partly resolve this issue by utilising rooftops of empty buildings. This will free up land for other activities (e.g., recreational, agriculture, forestry, etc), but achieving this requires an integrated policy approach to account for benefits and limitations in other policies to ensure that regulatory frameworks for system-friendly wind and solar power locations are effective.

Finally, the shift in installed solar and wind capacities will have a positive impact on local value creation like jobs and new economic activity. As in any other country, the socio-economic benefits of renewables are high on Turkey's policy agenda. Populations that will benefit the most will be from those regions that receive investments. Especially for wind power, system-driven strategy tends to spread the installed capacity across a broader geography—creating benefits outside of Turkey's western and north-western regions, which are resource rich and already have strong grids. By comparison, in the system-driven strategy a considerable share of the solar capacity tends to shift to regions with already high economic activity. This leaves regions with less economic activity with less potential to develop renewable capacity. In terms of regional redistribution and economic equality, the policy approach should balance local value creation by considering where it is needed most.

Strategies for a system-friendly approach

Managing the integration of higher shares of variable renewable energy depends on the system characteristics such as demand, existing supply, and transmission and distribution grid capacity. This concept has been recognised by many countries. Taking this into account when wind and solar investments are planned will allow for more installed generation capacity before any major reinforcements or new lines would be required.

Strategies for stimulating the location choices of generators vary. Countries typically incentivise the system-friendly approach as part of their various policy instruments, like rewarding bidders that plan to invest in less favourable resource areas within auction frameworks or by providing additional premiums under the feed-in schemes. Technology development is also essential to ensure power plants can extract more power from lower wind speeds or solar irradiation in a more balanced way.

Often investors have a considerate approach to less resource areas since such investments are paid back over longer periods. The rapidly declining costs of renewables have already alleviated a great deal of the location issue to ensure rapid returns on investments. Technology and design criteria for power plants are also being developed. For instance, more advanced turbine technologies, efficient solar modules, better forecasting techniques, and active tracking of the sun help to maximise output even in areas with lower quality resources (IEA, 2016).

There are system integration benefits of a system-friendly approach that reduce the overall system costs. Spreading power plants more evenly across a region(s) can create a smoothening effect since the outputs of individual power plants would be less correlated. In the case of Turkey, the effect will be particularly pronounced, because of the differences in the geography and weather conditions of the country. By comparison, in a system that favours maximising outputs, surplus situations are more likely to occur, thereby requiring either curtailment of renewables or the introduction of alternative flexibility strategies that may add to the overall system costs.

Governments use various mechanisms to manage the location of wind and solar power plants in a more system-friendly way. One control mechanism is applying lower grid charges for those generators that invest in areas where distances to the grid are closer but resources are less plentiful. System value effects like smoothening can also be rewarded by providing additional profits to the generators as in the cases of Brazil, China, and Germany. During the first rounds of its auctions, Mexico has embedded a credit system to value generators that invest in areas where the most value is created (IEA, 2016,2017).

To integrate higher shares of solar and wind to its power system, Turkey will also need to find ways to ensure a more balanced location of its wind and solar capacity in terms of both technology and policies. Learning from other countries will greatly accelerate the transition.

4. Recommendations

In order to facilitate the integration of large capacities of solar and wind into the Turkish power system through smart, direct investments where the grid can best absorb these, we suggest focusing on the following for updating policies and regulations:

- Develop a regulatory framework that creates a balanced renewable energy market without limiting investments to resource-rich areas.
- Reward investors that invest in system-friendly areas by considering the impact on the economics of the projects in a technology- and location-specific manner.
- Integrate new regulatory frameworks with existing policies, e.g., for rooftop solar PV, that indirectly support a system-friendly allocation of solar and wind capacity.
- Plan for renewable energy investments in each region by taking into account land availability, site selection constraints, economic activity, local value creation, and existing grid infrastructure.
- Complement system-driven strategy with a portfolio of technologies that can maximise outputs even from less resource-rich areas and options to increase system flexibility, thereby improving secure integration of wind and solar power and further reducing operational challenges that cause curtailment and redispatch.

References

- Enerji ve Tabii Kaynaklar Bakanlığı, 2018a. Güneş. URL http://www.enerji.gov.tr/tr-TR/Sayfalar/Gunes
- Enerji ve Tabii Kaynaklar Bakanlığı, 2018b. Rüzgâr. URL http://www.enerji.gov.tr/tr-TR/Sayfalar/Ruzgar
- Erkul Kaya, N., 2018. Elektrik üretimine 6,2 milyar dolar yatırım yapıldı. Anadolu Ajansı.
- Godron, P., Cebeci, M.E., Tor, O.B., Saygin, D., 2018. Increasing the Share of Renewables in Turkey's Power System: Options for Transmission Expansion and Flexibility. SHURA Energy Transition Center, Istanbul.
- IEA, 2017. Getting wind and sun onto the grid: A manual for policy makers. OECD/IEA, Paris.
- IEA, 2016. Next generation wind and solar power - from cost to value. OECD/IEA, Paris.
- IRENA, 2016. The Power to Change: Solar and Wind Cost Reduction Potential to 2025. International Renewable Energy Agency, Abu Dhabi.
- Saygin, D., Godron, P., Cebeci, M.E., Tör, O.B., forthcoming. Supplying more than half of Turkey's total electricity from renewables: Cost-benefit analysis of the different flexibility measures. SHURA Energy Transition Center, Istanbul.
- The World Bank, 2018. Turkey: Rooftop Solar Market Assessment. The World Bank, Washington D.C.
- YEGM, 2018. Yenilenebilir Enerji Kaynaklarından Elektrik Üreten Tesislerin Kurulu Güç Gelişimi. Yenilenebilir Enerji. URL http://www.yegm.gov.tr/yenilenebilir.aspx

About Istanbul Policy Center at the Sabancı University

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

About European Climate Foundation

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

About Agora Energiewende

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

SHURA
Energy Transition Center

Bankalar Caddesi, No:2
Minerva Han Kat: 3
34420 Karaköy / İstanbul
Tel: +90 212 292 49 39
E-mail: info@shura.org.tr
www.shura.org.tr

SHURA is founded by

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

European Climate Foundation

Agora Energiewende