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DATA INTO ACTION

The south can unlock Türkiye's solar ambitions

As the hydro-rich eastern Türkiye reeled from two droughts in five years, a surge in wind and solar helped cushion the blow. Solar potential in southern provinces is key to achieving steady renewable electricity growth.

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About

Ember's analysis reveals the changes in Türkiye's electricity generation from clean sources on a province-level basis by presenting monthly generation data for 2018-2022. It identifies areas for improvement by incorporating additional data from several pathway studies, renewable generation potential calculations, and capacity applications and auctions. The report emphasizes the need for accelerated solar deployment and discusses related policy developments.

Highlights

17%

İzmir's share of national wind generation in 2022

20%

Konya's share of national solar generation in 2022

x5.1

The rise in unlicensed solar capacity applications in 2022

Executive Summary

Türkiye needs to focus on provinces with high solar potential to achieve its clean electricity targets

In 2021 and 2022, non-hydro renewable electricity generation overtook hydropower in Türkiye. By growing other renewable generation, this should become the rule instead of the exception to eliminate reliance on fossil fuels.

01 Droughts show the need for wind and solar acceleration

Volatility from droughts is a significant risk in Türkiye, which relies on hydro as the main source of renewable electricity. Hydro generation dropped by 10 TWh (-39%) in the key provinces of Şanlurfa, Elazığ and Diyarbakır from 2020 to 2021. Türkiye relies on expensive imported gas to make up for hydro deficits. Accelerated wind and solar deployment would end this risky dependence.

02 Clean power's center of gravity moves westwards

In 2022, half of the renewable electricity generation in Türkiye was hydroelectricity concentrated mainly in the east. However, non-hydro sources deployed mostly in central and western provinces accounted for 79% of the increase in clean electricity generation between 2018-2022. Aydın and İzmir, coastal provinces in the west, produced 8 TWh and 7 TWh respectively from clean sources, becoming the top two renewable generators in 2022. Konya, a solar-rich province in central Türkiye, entered the renewable generation top ten the same year with 4 TWh, 72% of which came from solar.

03 Unmet solar potential in southern provinces makes clean energy targets harder to reach

Türkiye's progress on wind and solar over the past five years has been remarkable. However, there is a mismatch between potential and actual solar generation. Ten provinces accounted for over half of solar generation in 2022, with Konya producing the lion's share (21%). Meanwhile, the shares of high-potential provinces such as Antalya and Van are only 3% and 2% respectively. Türkiye will need to incentivize solar in its underutilized southern and southeastern provinces to reach its goal of 3-4 GW of added solar capacity per year.

04 Unlicensed solar capacity applications soar in 2022

Unlicensed solar projects aimed at self-consumption have been the driver of solar growth in Türkiye. In 2022, 78% of total solar generation in Türkiye came from unlicensed power plants. With the new regulation in May 2021 abolishing the requirement for generation facilities to be at the consumption point, prosumers were given the right to build their power plants on a suitable field within the same distribution zone. Following this, yearly unlicensed solar capacity applications surged fivefold from 1.2 GW in 2021 to 6 GW in 2022.

The locus of renewable energy in Türkiye is shifting from the hydro-rich east to the west where wind and solar are prevalent. Two dry periods in five years have shown that non-hydro renewables are key to making sure Türkiye's energy transition is not hindered by droughts. Türkiye needs to utilize its sunny southern provinces more efficiently to realize its electricity transition.

Azem Yıldırım
Türkiye Analyst, Ember

Hydro

Frequent droughts expose hydro's vulnerability

Hydro is Türkiye's largest clean power generator, but two dry periods in five years have exposed hydro's increased variability and unreliability.

Türkiye's hydro power is reaching capacity

Hydro generation has historically been Türkiye's main renewable electricity source. Türkiye has the second highest hydro capacity in Europe after Norway at 32 GW. In 2022, Türkiye generated 67 TWh from hydro, just above one-fifth of total electricity generation.

In January 2023, Türkiye announced its new National Energy Plan, which includes capacity targets until 2035. The plan is the first of its kind to take Türkiye's 2053 net zero target as its basis. For hydro power, the document foresees a scenario where capacity expansion increases by 4 GW to peak at 36 GW in 2030 and then remains flat.

Other net zero pathway studies from institutions such as the Istanbul Policy Center (IPC), Europe Beyond Coal (EBC) and SHURA have lower hydropower capacity projections for the same period. IPC expects 33 GW by 2030 while EBC projects 32 GW, and SHURA does not incorporate any new hydro capacity in its pathways.

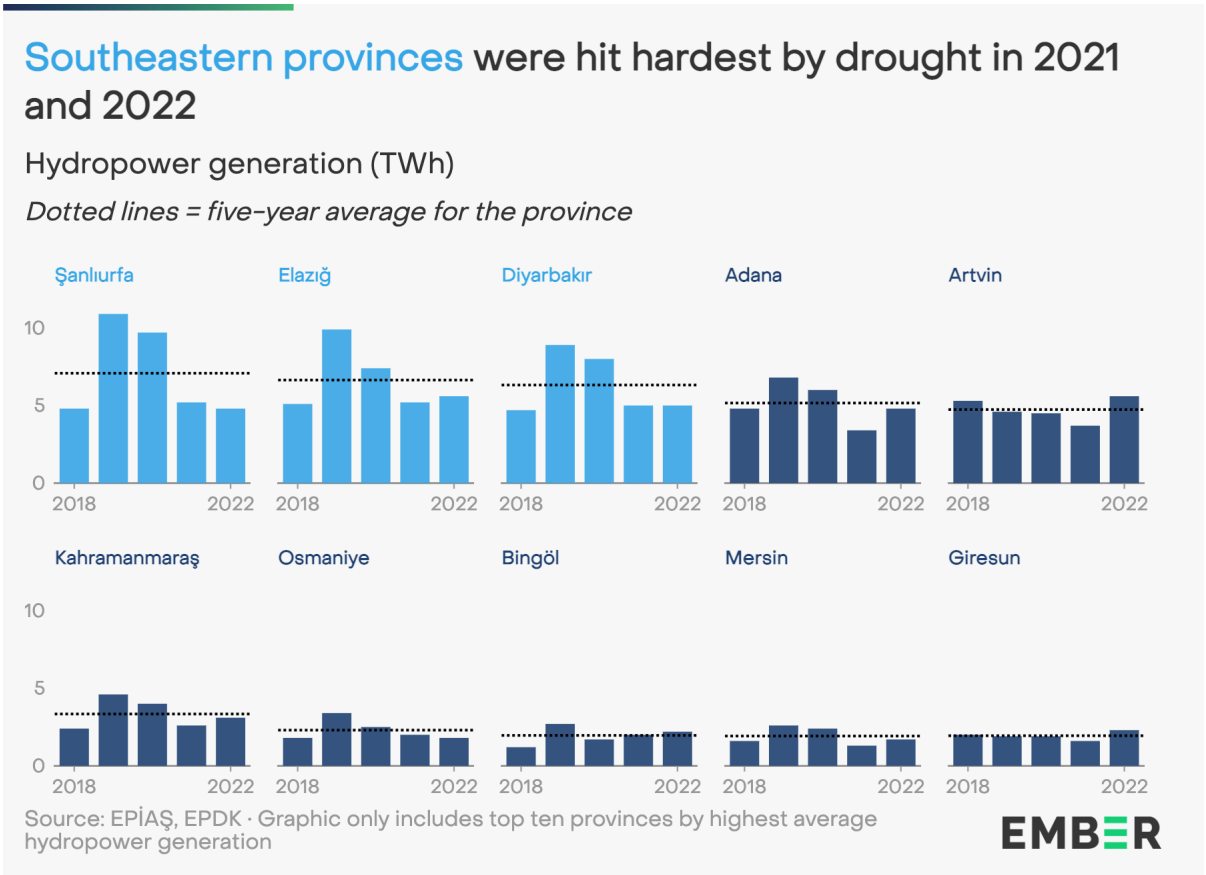
Given the limited increases in hydro capacity in the National Plan and other projections, it is clear that non-hydro renewables will lead the way in Türkiye's electricity transition.

Hydro-rich provinces hit hard by 2021 drought

2018 and 2021 were both dry years for Türkiye. Hydro generation in 2018 was around 60 TWh, 14% below the five-year average between 2018-2022. However, the drought in 2021 was the most severe. No hydro-generation facilities were spared. Across the country

precipitation was the lowest in two decades, falling from 56 TWh to 22 TWh (-29%). Though generation bounced back to 67 TWh in 2022, this was still 14% below 2020 levels.

Şanlıurfa, Türkiye's hydro leader in terms of five-year average generation, was impacted the most in 2021. Its hydro output declined almost by half (-4.5 TWh) from the previous year. Elazığ was the second most affected province, losing 2.2 TWh of hydro generation, corresponding to a year-on-year decline of 30%.

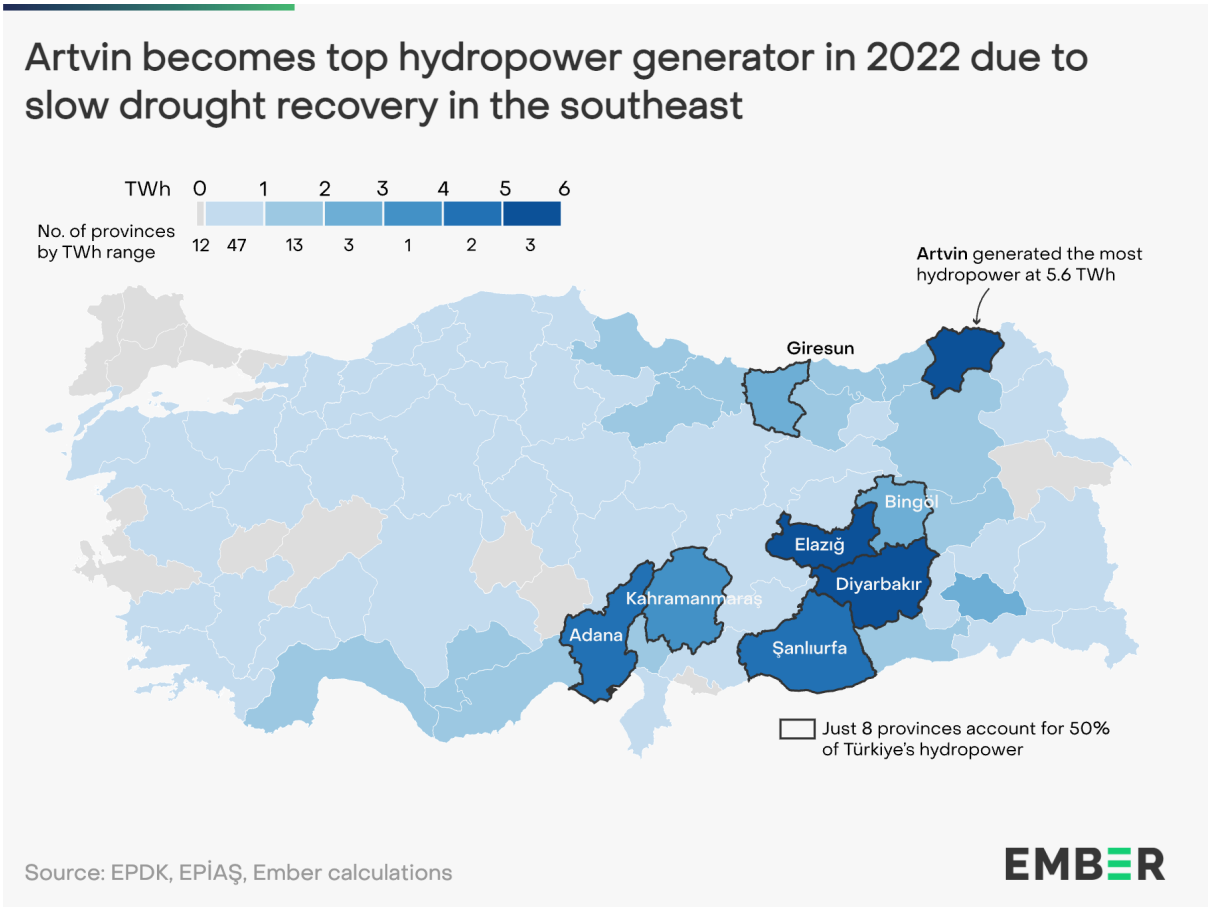


Though the south bore the brunt of the drought, the Black Sea provinces were not spared: Artvin suffered a decline of 0.8 TWh (-17%) and Giresun lost about 0.3 TWh (-14%) of its hydropower output.

The southeast lagged in 2022, other provinces bounced back

While 2022 did not repeat the punishing drought conditions of 2021, not every province saw hydro generation recover. The southeastern provinces lagged behind, recording neither a significant increase nor a decline from the previous year. Adana on the southern coast and Artvin on the Black Sea coast had the strongest recoveries. Artvin even exceeded generation in 2020 by around 1.1 TWh, moving up from fifth place of Türkiye's hydro generators in 2020 to first in 2022. The rise of Artvin to the top of this ranking was mainly due to the decline in generation in other hydro-rich provinces such as Elazığ and Şanlıurfa.

Türkiye's top five provinces for hydro generation were Artvin, Elazığ, Diyarbakır, Şanlıurfa and Adana.



Droughts slow down Türkiye's energy transition

During long periods of drought, Türkiye currently substitutes gas-fired electricity for lost hydro power. Since electricity demand for cooling also increases during hot summers,

droughts have an intense adverse effect on the share of renewable energy in Türkiye's total power generation. If drought in winter and spring means that the reservoirs of dammed hydro power plants are not replenished sufficiently, hydro generation cannot meet this rise in electricity demand for cooling in the summer. Since non-hydro renewable capacity is not currently sufficient to fill this gap, gas power generation spikes in the summers of dry years.

As capacity additions and plant modernization can only increase hydro generation to a very limited extent in the future, it is wind and solar deployment that must accelerate to eliminate the need for fossil substitutes during times of drought.

Solar

Konya solar leaps, sunny Antalya fails to reach its potential

Konya province has recorded a more than threefold growth in solar generation over five years. Sunny southern provinces must follow its lead if Türkiye is to achieve its renewables targets.

Ten provinces accounted for more than half of solar generation in 2022

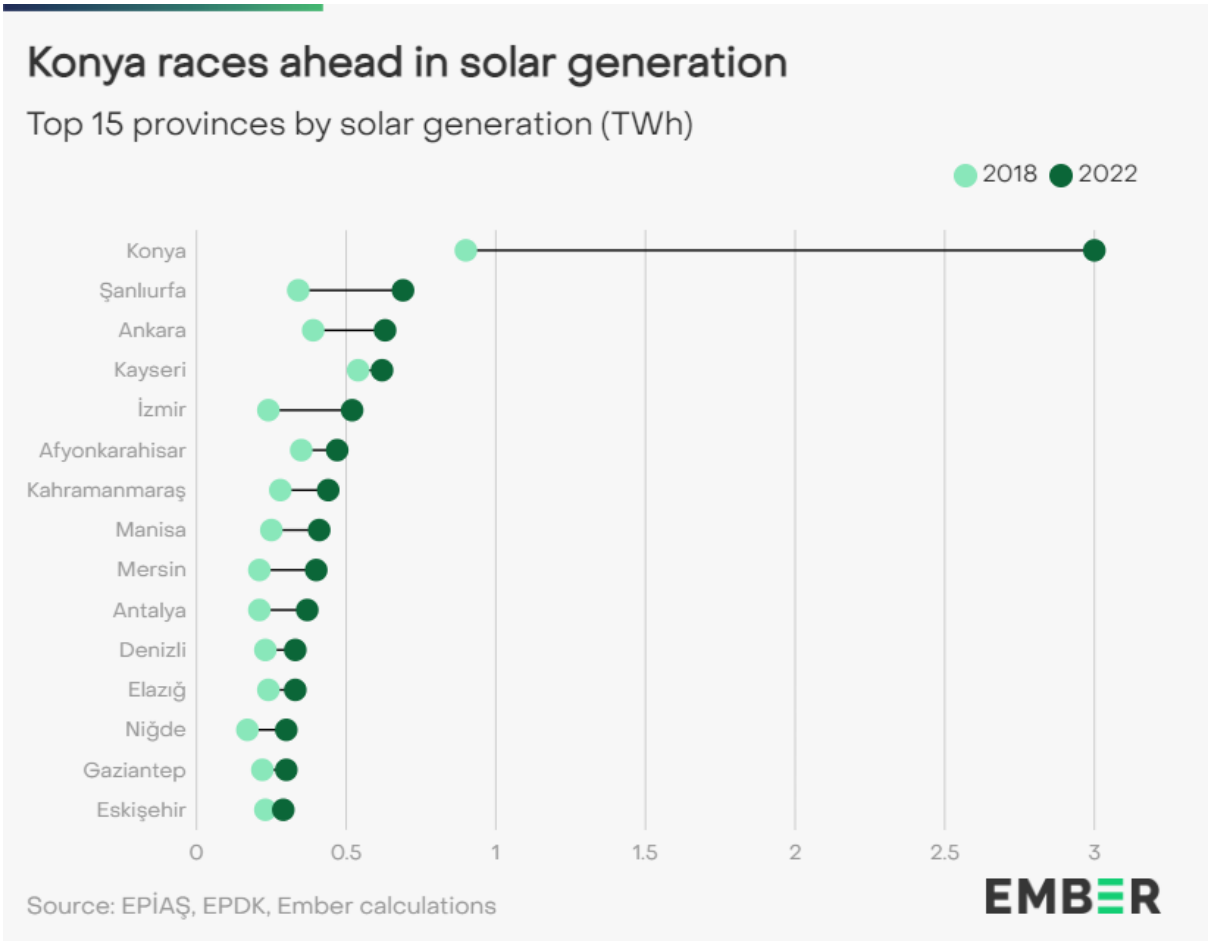
In 2022, Türkiye's top five provinces for solar generation were Konya, Şanlıurfa, Ankara, Kayseri and İzmir. All 81 Turkish provinces produced some electricity from solar in 2022 following the introduction of solar generation in the remaining 11 provinces since 2018.

One advantage of solar is its distributed potential: it can be generated where it is consumed, reducing dependence on the national grid. Despite this, solar generation remains geographically concentrated in Türkiye. The top ten provinces accounted for over half of the national solar generation in 2022.

Solar mega-project powers Konya's renewable growth

Since 2018, Konya has accounted for 33% of Türkiye's increased solar generation. The province produced 2.9 TWh of solar power in 2022, more than one-fifth of total national solar generation. One plant in Konya province, the Karapınar Solar Power Plant, drove this increase. It accounted for 63% of the 2.7 TWh total licensed solar power generation across the country in 2022.

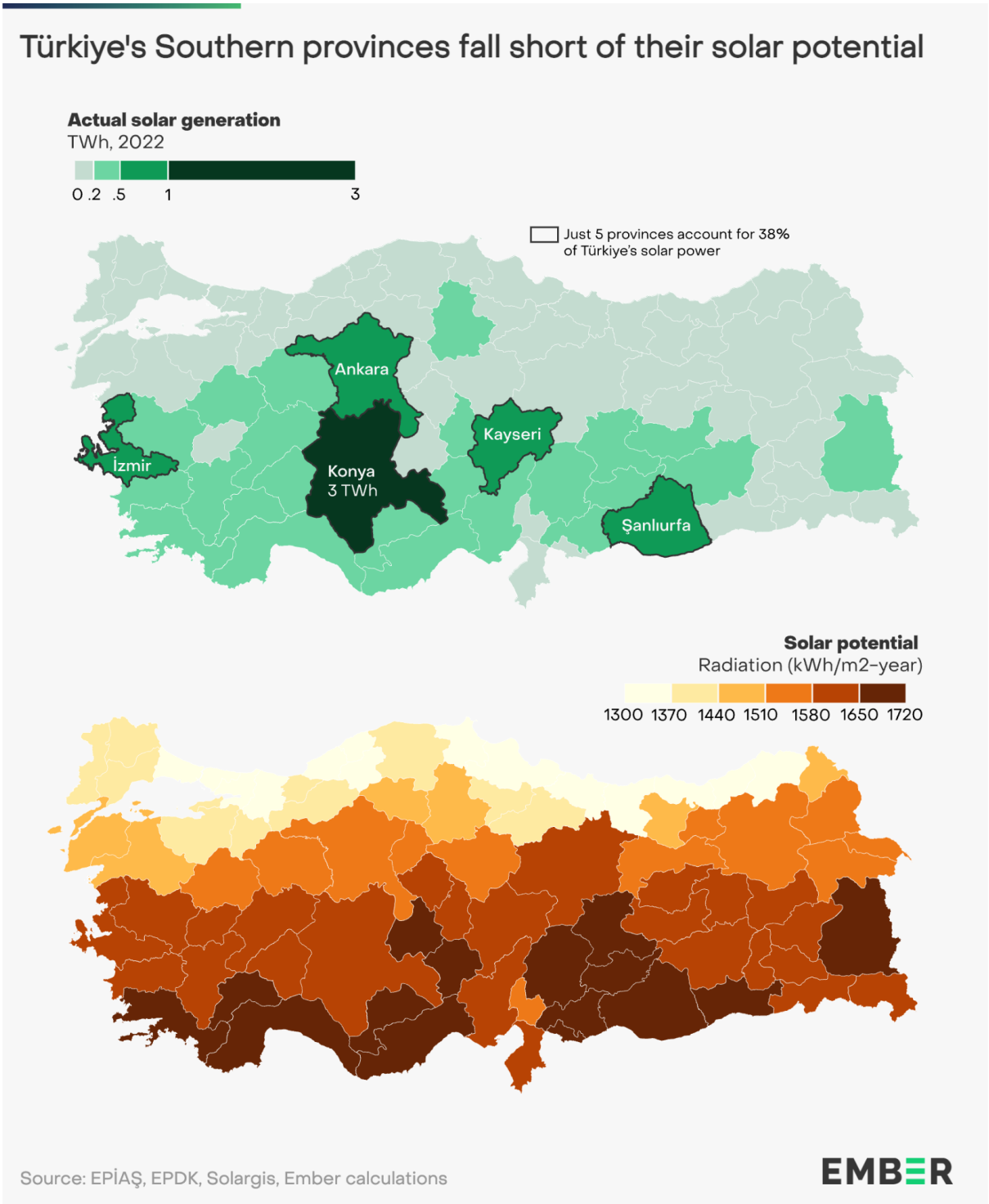
By October 2022, 90% of Karapınar's planned capacity had been installed, with the plant accounting for 57% of Konya's solar generation that year. When fully operational in 2023, Karapınar will reach a total capacity of 1350 MW, making it Europe's biggest solar power plant.



Untapped potential in the south holds back greater progress in solar

Konya is ultimately a positive outlier—the story in other provinces is less encouraging. The current state of solar generation reveals a geographical mismatch between Türkiye's overall solar potential and its actual deployment. The five provinces that experienced the highest growth in solar generation in five years—Konya, Şanlıurfa, İzmir, Ankara and Van—collectively accounted for half of the national increase in solar generation. Though Konya, Şanlıurfa and Van have high solar potential, other sunny provinces could have performed better than Ankara and İzmir.

Progress in solar deployment has also been concentrated and did not take place entirely in line with radiation potential.


Türkiye's Southern provinces fall short of their solar potential
Actual solar generation
TWh, 2022
0 .2 .5 1 3
Just 5 provinces account for 38% of Türkiye's solar power
Ankara
İzmir
Konya
3 TWh
Kayseri
Şanlıurfa
Solar potential
Radiation (kWh/m2-year)
1300 1370 1440 1510 1580 1650 1720
Source: EPİAŞ, EPDK, Solargis, Ember calculations
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Antalya stands out as a key example of unmet potential. Despite having one of the highest radiation rates in Türkiye, Antalya ranked only tenth for solar generation in 2022, generating just 3% of the country's solar electricity. Türkiye's southern coast and southeastern provinces could be producing more solar power than the İzmir-Ankara-Kayseri triangle to its north, for example.

Though Şanlıurfa was the top province in solar generation after Konya in 2022, other provinces in the southeast are lagging far behind. A notable example is Van, which has a higher potential than even Konya. Van recorded the fifth largest increase in solar generation from 2018 to 2022. However, it was still only ranked nineteenth for solar in 2022 and remains far behind provinces like Ankara (3rd) and İzmir (5th). The mountainous landscape in the east makes it harder to build utility-scale solar, but sun-rich areas such as this are suitable for smaller projects, which could still allow the region to capture potential.

The possibilities of solar for Türkiye go beyond just high solar radiation. Solar can also work in tandem with hydro to help alleviate the risk posed by droughts. Increased solar generation would reduce demand for hydro power during summer, allowing for more flexibility for hydro to be used in winter and reducing the need to import gas. The fact that the hydro-rich southeastern provinces offer high solar potential opens up avenues for floating solar solutions as well. Türkiye has the world's ninth largest potential for floating solar at 171 TWh per year, more than ten times the current generation from solar.

New unlicensed regulation spurs solar capacity applications

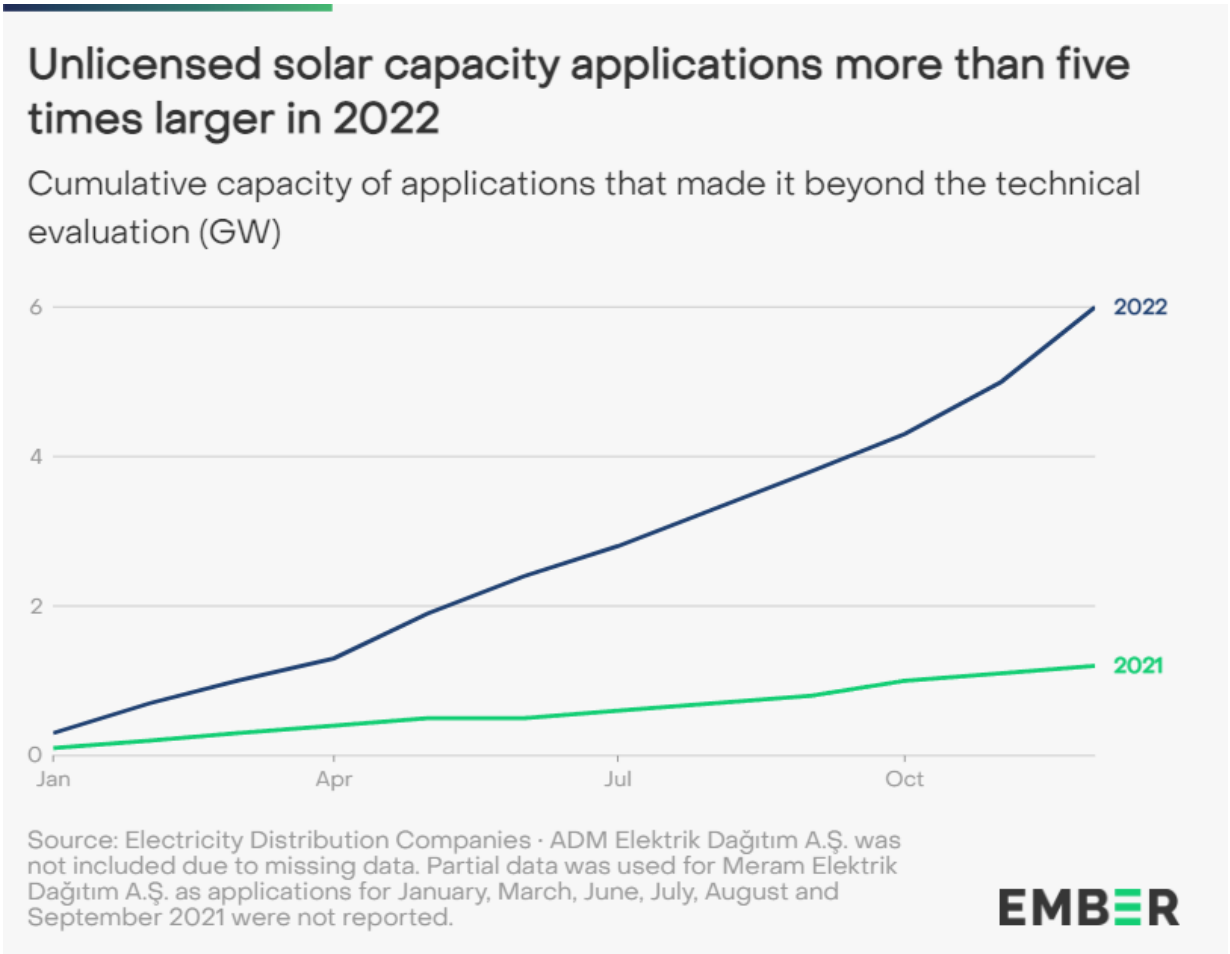
In Türkiye, unlicensed solar projects have mostly driven capacity expansion, rather than licensed utility solar. This was mainly due to the country auctioning only 1 GW of licensed solar capacity every year. Since it was not possible to build licensed capacity outside of this auction, most of Türkiye's solar capacity is made up of unlicensed power plants. In 2022, Türkiye had 8 GW of unlicensed solar capacity corresponding to 84% of total solar capacity.

'Unlicensed' electricity generation refers to projects aimed at meeting self-consumption needs rather than selling electricity to the grid. Despite the absence of licensing requirements, applicants still have to go through a bureaucratic process involving multiple institutions to get an unlicensed project approved.

Two changes in the unlicensed generation regulation further increased the attractiveness of this type of solar development. First, the requirement for the generation facility to be at the

consumption point was abolished in May 2021. In addition to rooftops and building facades, prosumers can now build their power plants on a suitable field within the same distribution zone, which usually spans several provinces. At the same time, the fixed cap of 5 MW for each application was abolished. The regulation now allows sales up to the annual electricity consumption to the grid as surplus power generation, which makes solar plants that provide up to two times the prosumer's yearly consumption viable.

This change in the unlicensed generation regulation led to an increase in unlicensed solar project applications in sunny provinces. In the distribution region covering the southwestern provinces of Antalya, Isparta and Burdur, for instance, 106 MW of the total 137 MW of unlicensed solar applications in 2021 were submitted after this regulation came into effect.



The second major regulatory change in August 2022 removed the geographical constraint entirely, allowing net metering between consumption points and power plants in different distribution regions. However, the effects of this change were not reflected in unlicensed capacity application statistics in 2022 since applications that fall under its scope only began to be processed in March 2023.

Nevertheless, the 2021 changes to regulation already had a significant positive effect on capacity applications. Year on year, the total capacity of applications that made it beyond the initial technical review rose by more than 4.8 GW, with more than 6 GW of unlicensed solar applications processed.

However, these numbers only represent the applications that passed the initial stages of the approval process, with further grid feasibility evaluations required before receiving final approval. The relevant regulation requires approved projects to be completed in one to two years depending on technical specifications. Changes to unlicensed solar generation in 2023 will reveal if the updated policy has been successful in driving solar deployment in underutilized provinces.

Capacity auctions have become more geographically distributed

Türkiye's policy tool to coordinate and incentivize utility-scale wind and solar power plant deployment is the Renewable Energy Resource Area (abbreviated as YEKA). Under this approach, the Ministry of Energy determines areas in which certain capacities of renewable power plants can be built. These capacities are then awarded through auctions with duration or generation-based power purchase guarantees and domestic manufacturing obligations.

The first YEKA auction was held in 2017 for 1 GW solar capacity in Konya's Karapınar district. This is where the Karapınar power plant was built, the only completed YEKA project so far.

There have been two other YEKA auctions for solar since 2017, each allocating 1 GW of capacity. However, unlike the first competition for Karapınar, the auctions that followed were designed to allocate smaller shares of capacities dispersed throughout multiple provinces.

The second solar YEKA competition that was carried out (referred to as the 'mini-YEKA'), allocated 1 GW capacity across 36 provinces with a maximum of 50 MW per province. Provinces with high potential such as Antalya, Gaziantep and Van were among those that were allocated this maximum capacity.

In the most recent solar YEKA in 2022, 15 auctions for 50-100 MW capacity were held for solar development in Şanlıurfa, Hatay and Niğde. The revision from fewer, large capacity auctions to smaller capacity tenders indicates that the YEKA policy for solar has taken a more decentralized approach.

Since Türkiye's solar potential is distributed more homogeneously compared to other power generation sources, decentralized allocation should be beneficial. Limiting YEKA auctions to a few provinces or a single one risks not taking advantage of provinces with high potential.

High potential, slow progress

Among targets outlined in Türkiye's National Energy Plan, those for solar capacity are the most ambitious. The plan aims for solar to become the energy source with the largest capacity by 2035, with the 9.4 GW capacity in 2022 rising to 32.9 GW by 2030 before reaching 52.9 GW in 2035.

Annual solar capacity additions will need to triple from current levels to achieve this target. However, the government's solar capacity target is still lower than the capacity Ember calls for to halve fossil fuel imports for power generation by 2030, which is 40 GW. Yearly solar capacity additions will need to quadruple to achieve this target.

Though Türkiye has higher photovoltaic potential than most European countries, its electricity generation from solar was only 15.3 TWh or 4.7% of total generation in 2022. To put into context, Türkiye's generation is currently on par with countries that have lower solar potential, such as Poland and Ukraine.

Wind

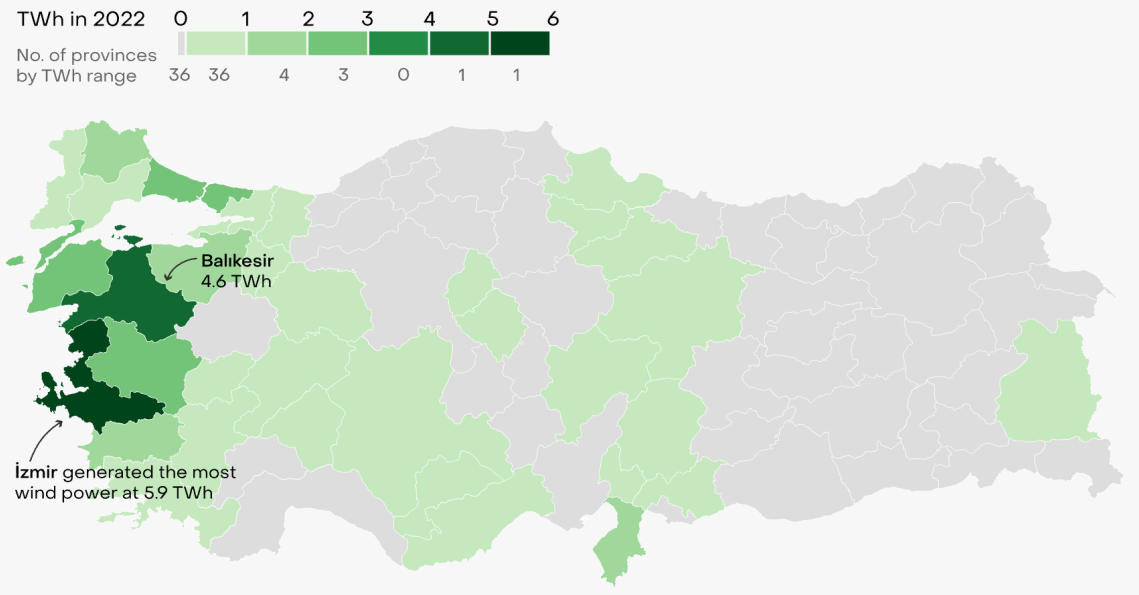
İzmir, Çanakkale and İstanbul have the wind in their sails

Western provinces on the Aegean and Marmara coasts drive the increase in wind generation.

Western provinces lead for wind generation

Wind is geographically concentrated in Türkiye, with the five provinces that produce the most wind power accounting for 53% of total wind generation. 34 Turkish provinces (42%) generate no electricity from wind at all.

İzmir and Balıkesir generated 30% of Türkiye's wind power in 2022



Source: EPİAŞ, EPDK, Ember calculations

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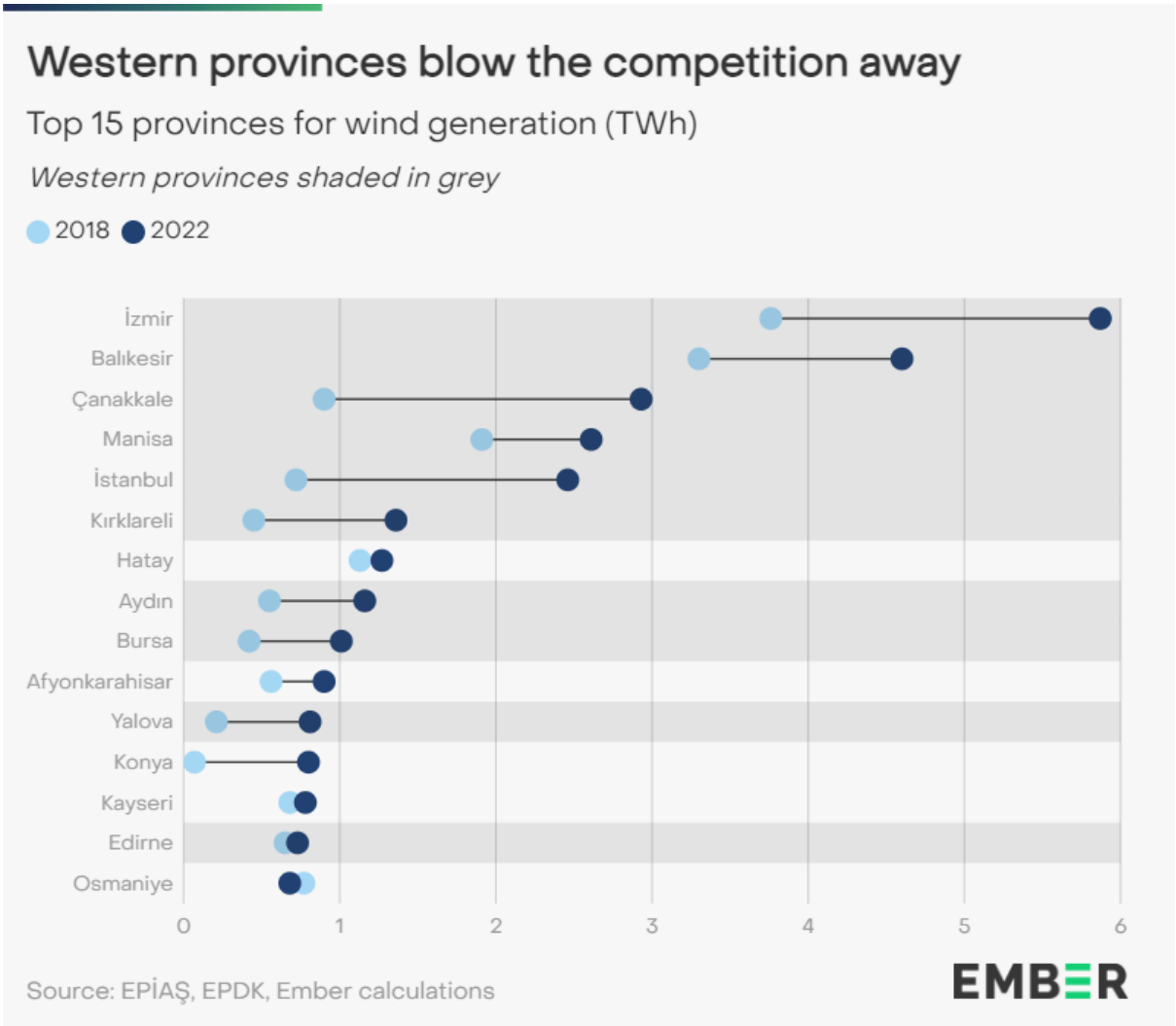
The leading province for wind generation is İzmir, home to a metropolis situated on the windy Aegean coast. İzmir's wind power generation was 5.9 TWh in 2022, representing 17% of the country's total wind generation. Balikesir, Çanakkale and Manisa (provinces also in the Aegean region) follow İzmir.

İzmir, Çanakkale and İstanbul make up more than a third of recent wind growth

İzmir, Çanakkale and İstanbul were the top three provinces that recorded the highest increases in wind power generation between 2018 and 2022. Collectively, they increased generation from wind by 5.9 TWh, corresponding to 39% of the national wind growth.

İzmir recorded the largest increase in wind generation, with yearly wind power output rising from 3.8 TWh in 2018 to 5.9 TWh in 2022 (+56%).



July 2022 was an extraordinary moment for wind nationally, with the wind capacity factor reaching 51% the highest in five years. In İzmir, this led to 800 GWh of generation, almost double that of the province's monthly average of five years. July 2022 was also a record month nationally, with 4.18 TWh generated from wind.

Remarkable runner-ups to İzmir's wind growth include Çanakkale and İstanbul. Çanakkale is the province that produces the most electricity in Türkiye, though most of its generation is sourced from coal. Çanakkale's generation from wind increased by a huge 226% (2TWh) from 2018 to 2022.

İstanbul's progress is also striking since it is the only province that saw exponential growth in wind generation. In total, its wind generation rose from 0.7 TWh in 2018 to 2.5 TWh in 2022 (+242%), the greatest percentage increase of the top five provinces.

Konya is also worth mentioning since, like İzmir, the province ranks highly for both wind and solar. Though Konya's solar generation grew the most in absolute terms, its share in the province's renewable generation has actually declined since 2018. A closer look reveals that the share of wind in total renewable generation in Konya rose from 7% in 2018 to 19% in 2022. In absolute terms, generation from wind rose by a factor of more than ten from 74 GWh in 2018 to 804 GWh in 2022 in Konya.

Years of delays resulted in no auctioned wind capacities being built

Türkiye has mainly relied on capacity auctions and feed-in tariffs for new wind deployment. Unlike solar, more than 99% of wind generation was sourced from licensed power plants between 2018 and 2022. YEKA auctions have also started supporting wind deployment.

Since 2017, there have been three YEKA auctions for wind power capacity adding up to 2.9 GW in total. The auctions covered a wide range of provinces but 60% of the allocated capacity went to western provinces with high wind potential: Edirne, Kırklareli, Çanakkale, Balıkesir, Aydın and Muğla.

The first wind YEKA auction allocated 1 GW in two provinces in the Thrace region of Türkiye in the northwest, and two others in central Anatolia. The second auction in 2019 allocated 250 MW each to Aydın, Muğla, Balıkesir and Çanakkale, which are coastal western provinces with high wind potential. The third YEKA auction in 2022 allocated smaller capacities to more than twenty Anatolian provinces totaling 850 MW.

None of the auctioned wind YEKA projects have so far been completed. The first wind YEKA auctioned in 2017 is expected to begin its construction only in 2023. The long delays in project development signal the fact that the YEKA model needs an upgrade.

Türkiye needs more ambitious wind targets

Wind is one of Türkiye's largest sources of renewable electricity, despite a lower wind potential than that of solar. In 2022, the country generated 35 TWh of wind, corresponding to 11% of total electricity generation.

The National Energy Plan aims for 18 GW of wind capacity by 2030, up from 11 GW at the end of 2022. This is not a sufficiently ambitious target given that Ember analysis has shown that at least 30 GW of wind is needed by 2030 to halve fossil fuel imports for electricity generation.

Progress on renewables

Other renewables cushioned the blow from hydro, now they must take the lead

Türkiye has access to diverse renewable energy sources, and it has progressed in all of them. Generation from non-hydro renewables must accelerate to achieve steady clean electricity growth.

Three provinces generate almost all geothermal electricity

Türkiye ranks fourth worldwide and first in Europe for geothermal capacity at 1.7 GW in 2022. Geothermal produced 3% (10 TWh) of Türkiye's electricity in 2022.

Geothermal generation is concentrated in western Türkiye, and only six provinces have geothermal capacity. Three of these provinces, Aydın, Manisa and Denizli, accounted for 98% of national geothermal electricity generation in 2022. Aydın produced 75% of its 7.5 TWh renewable electricity generation from geothermal, which put it at the number one position in terms of total renewable electricity generation in 2022.

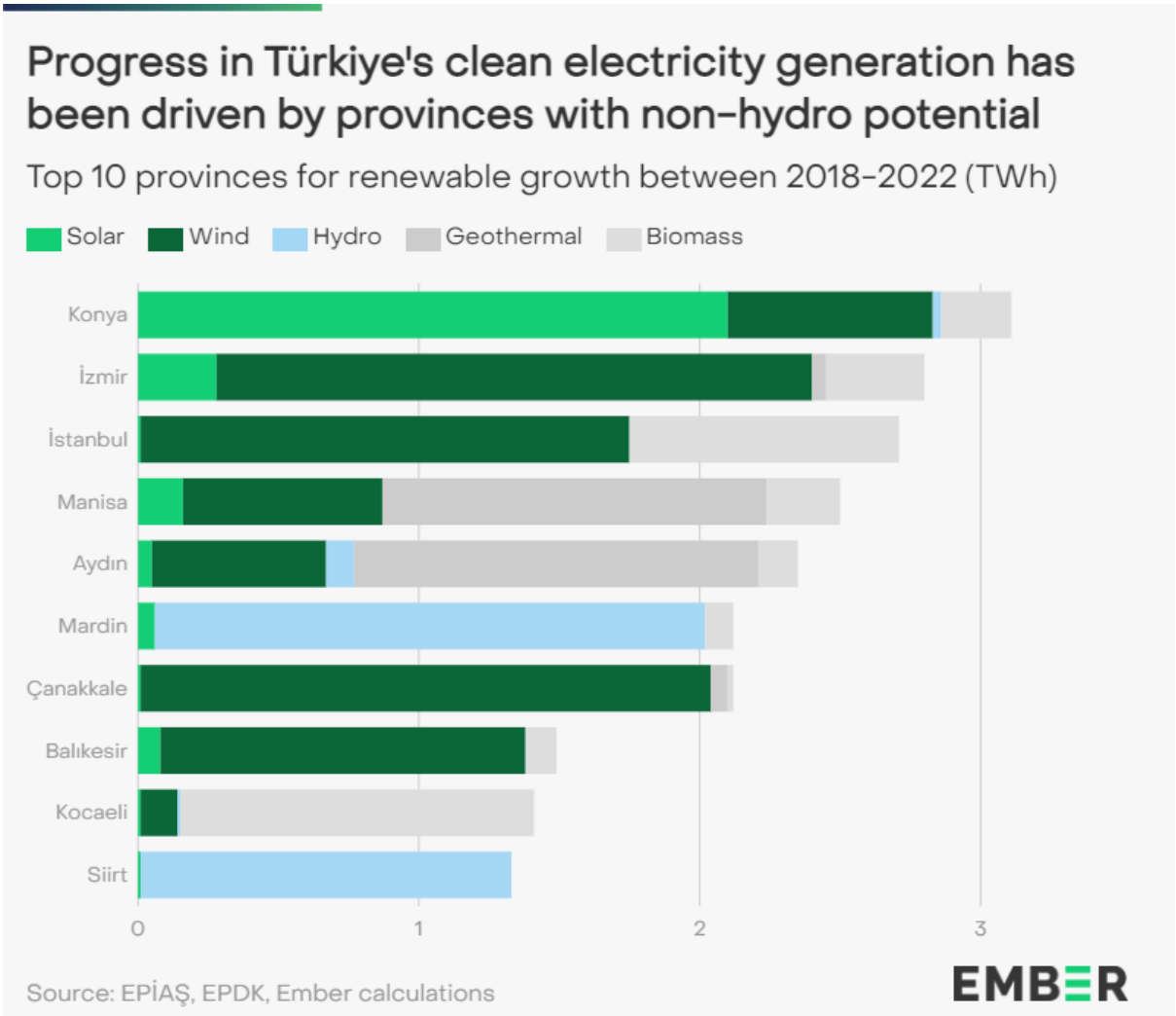
Six provinces generated almost half of Türkiye's biomass electricity

All but nine provinces of Türkiye have biomass power capacity. In 2022, Türkiye generated 8.9 TWh of electricity from this source, corresponding to 2.7% of the total generation. İstanbul was the biggest biomass generator, with 14% of its electricity coming from biomass (1.3 TWh). It was followed by Kocaeli (1.3 TWh), Ankara (0.5 TWh), Izmir (0.4 TWh), Balikesir (0.4 TWh) and Afyonkarahisar (0.4 TWh). All six provinces together generated 4.3 TWh of biomass electricity, 48% of the national total.

Konya, İzmir and İstanbul were Türkiye's renewables trail blazers

Konya, İzmir and İstanbul have accounted for 23% of the total increase in renewable electricity generation since 2018. The growth of wind generation in İzmir and the growth of solar generation in Konya were almost equal at 2.1 TWh in this period.

However, renewables growth in these two provinces was not limited to a single source. In addition to being the wind leader of Türkiye, Izmir also found itself a place on the solar leaderboard. Konya similarly had the sixth-highest increase in wind generation, in addition to being the top province in solar generation. İstanbul's renewables growth was mainly from wind and a rapid increase in biomass generation. These pushed Türkiye's most populous province into the top three provinces for renewables.

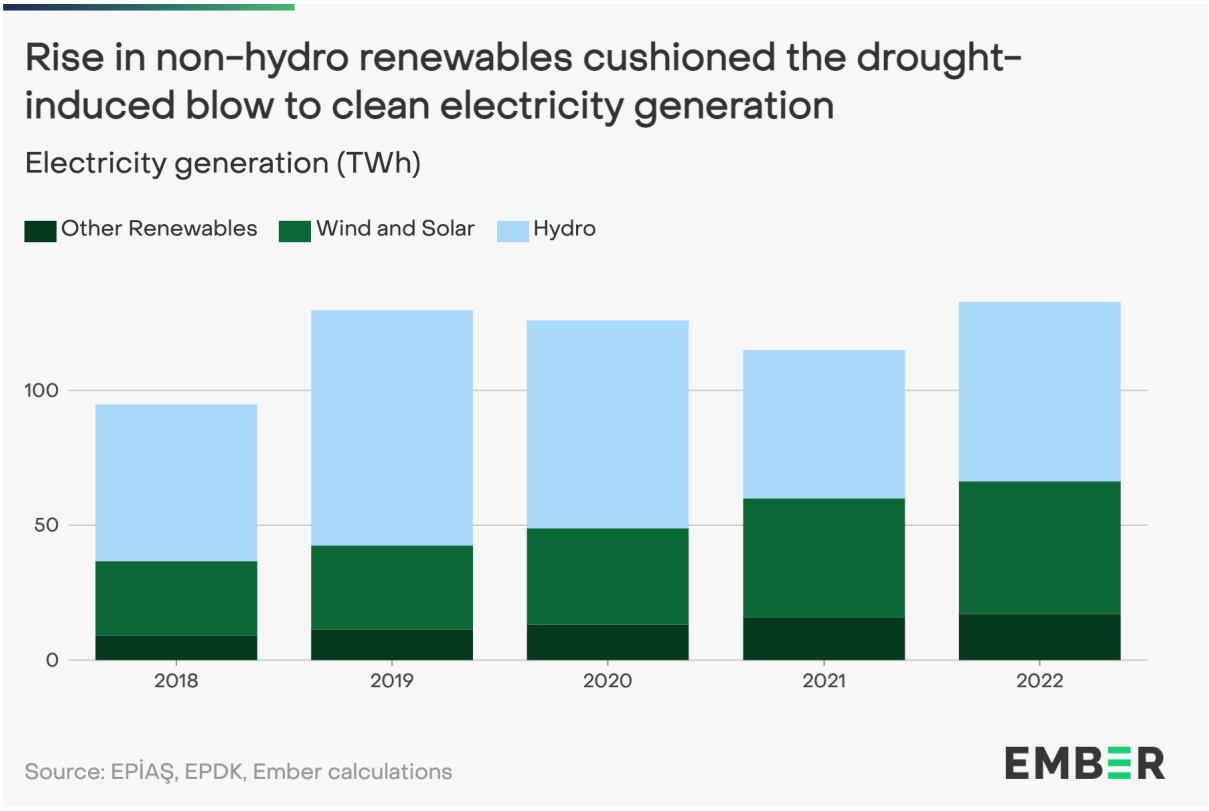


The top ten provinces that generated the most from renewable sources accounted for 57 TWh (42%) of renewable electricity generation in 2022. Aydın took the top spot with its extraordinary geothermal energy generation. The presence of Elazığ, Artvin, Şanlıurfa, Adana and Diyarbakır on this list shows that half of the leaderboard is still covered by hydro-rich provinces.

The rise of non-hydro renewables lessened the impact of drought

Over the past five years, droughts and their fallout have shown that accelerated deployment of wind and solar capacity is needed to support Türkiye entering a path of steadily growing clean electricity generation. Droughts have consistently caused a net drop in Türkiye's clean electricity generation, necessitating a rise in fossil electricity generation and hindering the country's electricity transition. This was the case most recently in both 2020 and 2021.

As of 2023, hydro is still Türkiye's main source of renewable energy in terms of capacity at 32 GW. Though other renewables surpassed hydro in terms of combined generation in the past two years, this was mainly caused by the decline in hydropower in 2021.



Türkiye generated a record amount of electricity from renewable sources in 2022 despite the fact that hydro generation did not recover to pre-drought levels.

Wind and solar stepped up to fill the gap and lessen the impact of low hydro output on total renewable electricity generation. Türkiye must now accelerate wind and solar deployment to mitigate the future risks of volatile hydropower output, hit its renewable electricity targets and ensure energy security.

Supporting Materials

Data

For Türkiye's 2018-2022 licensed generation data *"real-time-generation"* web services of the Turkish power market operator's (EPİAŞ) Transparency API are used. This data was then combined with electricity market production license data from the Energy Market Regulatory Authority (EPDK) using fuzzy matching and checked manually.

For unlicensed generation, EPDK's monthly electricity generation reports are used.

The solar radiation statistics for the solar capacity map are based on Solargis data for Türkiye. Provincial averages were calculated by Ember via a Python script.

Unlicensed project application data is taken from the websites of individual electricity distribution companies. ADM Elektrik Dağıtım A.Ş., which covers Aydın, Denizli and Muğla, was not included in the calculations due to missing data. For Meram Elektrik Dağıtım A.Ş., which covers Konya, Aksaray, Niğde, Kırşehir, Nevşehir and Karaman, partial data was used as applications for January, March, June, July, August and September 2021 were not reported.

Acknowledgments

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Image credit:
Ihsan Gercelman / Alamy Stock Photo