

Hybrid plants push solar capacity past wind in Türkiye

With 510 MW already installed, hybrid power plants will play an important role in achieving Türkiye's solar targets.

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About

This analysis examines the installed capacity, project pipeline and allocated grid capacity of hybrid solar power plants in Türkiye at the end of 2023.

Explore monthly hybrid solar capacity data in our [Türkiye electricity data tool](#).

Hybrid power plants can help unlock Türkiye's solar potential

Hybrid power plants generate electricity from a primary and secondary source connected to the grid at the same location. The implementation of hybrid power plants and the conversion of existing plants to hybrids became possible in Türkiye through a [regulatory amendment](#) in 2020. As of the end of 2023, solar was the secondary source for all 240 operational and planned hybrid power plants in Türkiye.

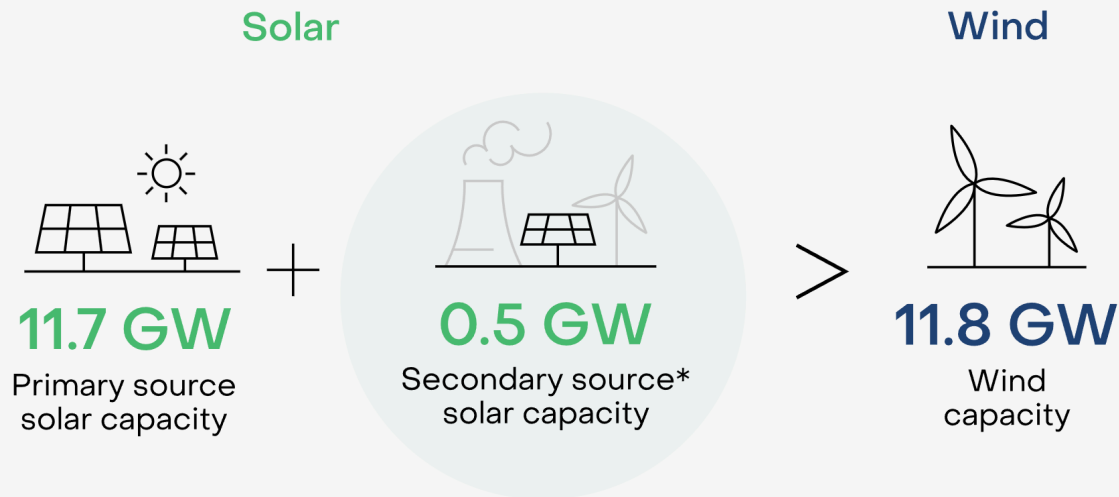
As part of a hybrid plant, solar provides extra power generation and reduces infrastructure costs, as it connects to the grid from the same point as the primary source. Hybrid solar power plants can help Türkiye achieve its clean energy targets by allowing solar potential to be utilised together with other renewable generation.

Solar capacity surpasses wind with hybrid power plants

According to [official installed capacity statistics](#), Türkiye's solar capacity reached 11.7 GW and wind 11.8 GW by the end of 2023. However, these data do not include secondary solar capacity installed in hybrid power plants. According to the Energy Market Regulatory Authority's (EMRA) [electricity generation licence database](#), Türkiye has installed 510 MW of secondary solar capacity as of 2024. Therefore, at 12.2 GW, total solar capacity has surpassed wind.

The fact that hybrid capacity is not included in official statistics undermines the accuracy of analysis and planning based on this data. Constituting 4.2% of the total installed solar capacity, hybrid solar capacity should be included in the official statistics, as its significant presence impacts the capacity ranking based on resources.

Türkiye's solar capacity surpassed wind with hybrid installations in 2023



Source: EPDK, TEİAŞ, Ember
 *Hybrid power plants generate electricity from a primary and a secondary source connected to the grid at the same location.

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Hybrid solar capacity is concentrated in wind power plants

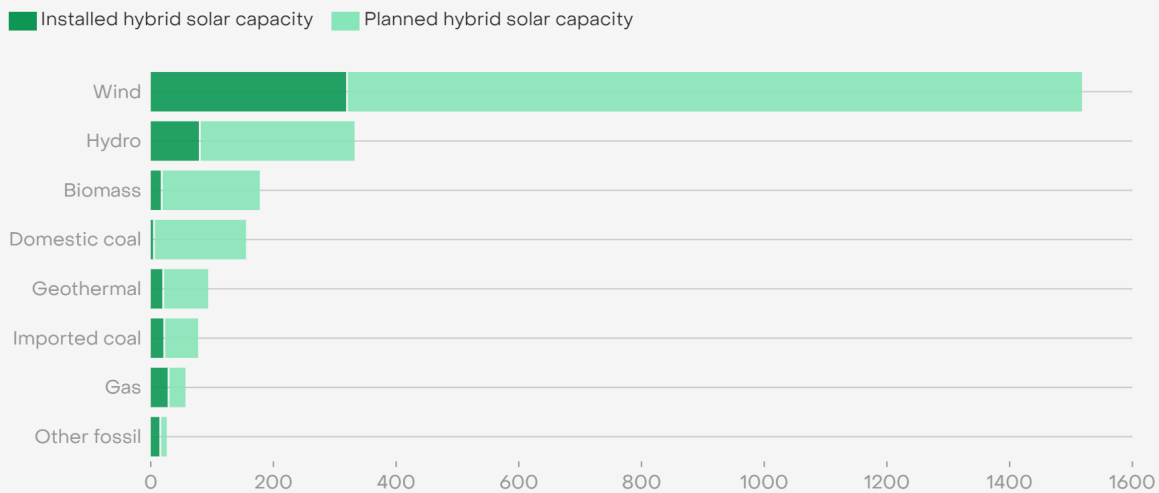
Regarding the primary resource type in hybrid plants, wind power installations dominate. 63% of the secondary solar capacity is installed in 14 plants that have wind as their primary source.

Solar and wind are complementary resources due to the inverse relationship between their [hourly generation](#) patterns. In Türkiye between 2021 and 2023, wind and solar generation's hourly correlation ranged from -0.08 to -0.14. Therefore, a more stable generation profile can be maintained in wind-solar hybrid power plants since generation from one source is relatively higher when the other is underperforming.

Though hydro comes second after wind with 80 MW of secondary installed solar capacity. All of this capacity is located at the Aşağı Kaleköy Hydroelectric Power Plant (HEPP), the only hydro-solar hybrid plant in the country. The remaining 110 MW hybrid solar capacity is located in power plants with other primary sources.

Türkiye's installed and planned hybrid solar capacity is concentrated in wind plants

Solar capacity in hybrid power plants by primary source type (MWm, 2023)



Source: EPDK
 Hybrid power plants generate electricity from a primary and secondary source connected to the grid at the same location. Domestic coal refers to domestically sourced lignite, hard coal and asphaltite. Imported coal refers to imported hard coal. Other fossil includes fuel-oil and diesel.

While hybrid power plants are present in 28 provinces, most of the capacity is concentrated in specific ones. Uşak (82 MW), Bingöl (80 MW) and Sivas (50 MW) have the highest hybrid solar capacity, each hosting one hybrid power plant. Together, these three provinces account for 42% of the total hybrid solar installed capacity. Additionally, Konya (36 MW) and Karaman (40 MW), which have both wind generation and [high solar potential](#), contribute another 15% of the capacity.

Hybrid solar generation close to 800 GWh

Taking into account the installed capacity data of hybrid power plants and the [solar potential](#) of the provinces where they are situated, the estimated annual generation is calculated to be 798 GWh. This amount corresponds to 4.2% of Türkiye's total solar energy production in 2023.

According to the [new regulation](#) introduced in October, electricity generation from secondary sources must be reported annually by 10th January. On November 1, [hourly electricity generation](#) data for the secondary source in hybrid power plants started to be published. However, hybrid solar generation is still included as part of the generation from the primary source in official data before November 2023.

As hybrid solar generation nears the threshold of TWh output, amalgamating its data with that of other sources compromises the precision of past generation data, a concern exacerbated by the increasing hybrid capacity.

Hybrid capacity in the pipeline at 16% of total solar capacity

Permitting processes have been completed for a capacity equal to approximately four times the current installed capacity of hybrid solar power plants. As of the end of 2023, there was 1.9 GW of approved hybrid solar capacity yet to be installed. In other words, there is a project stock equivalent to 16% of all installed solar capacity in Türkiye. Of this capacity, 62% was allocated to wind power plants and 13% to hydroelectric power plants.

60% of the hybrid solar capacity in the pipeline is concentrated in ten provinces that stand out in terms of their wind generation and solar potential. Among the top five provinces, Çanakkale (178 MW), Manisa (138 MW) and Balıkesir (122 MW) lead both in terms of project stock and [in wind power generation](#). Konya, which has the largest project stock at 212 MW, and Kahramanmaraş, which ranked eighth with 82 MW, are among the cities with high solar potential.

Floating solar can be the driver of hybrid capacity development

Although Türkiye has [80 GW of floating solar potential](#), no floating solar plants have yet been installed as part of a hybrid plant. Türkiye's only completed hydro-solar hybrid plant, Aşağı Kaleköy HEPP, has [ground-mounted](#) solar panels.

Secondary solar installation in hydroelectric power plants has multiple advantages. These include the availability of grid infrastructure at the facility and the ability to install floating solar panels on dammed hydro plant reservoirs without the need for suitable land. Moreover, floating solar and hydropower also support each other in terms of electricity generation. Since the panels installed on the water surface [reduce evaporation](#), the stored water can be used more efficiently for hydroelectricity generation. The cooling effect of water also [increases the generation efficiency](#) of the panels.

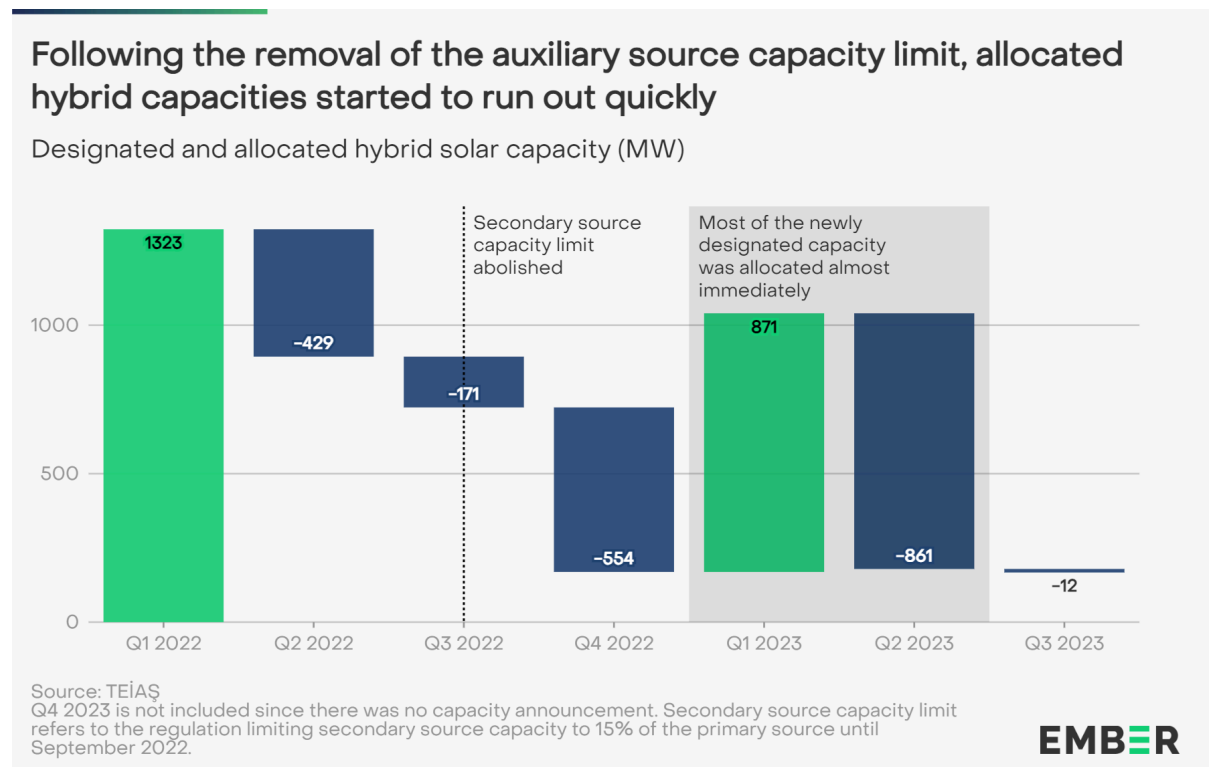
Türkiye took the first step towards utilising floating solar potential through [a bill submitted in January](#) allowing floating solar installations on dammed hydro reservoirs. The proposal paves the way for the designation of power plant reservoirs as [Renewable Energy Resource Areas](#) (YEKA) allowing associated floating solar tenders, in addition to the installation of allocated secondary solar capacity on water surfaces at hybrid power plants.

State-owned hydroelectric power plants with large reservoirs can install floating solar panels through YEKA tenders. Atatürk, Karakaya, Keban, Ilisu and Birecik, operated by the Electricity Generation Corporation (EÜAŞ), are among the largest hydroelectric power plants in Türkiye. Assuming that panels are installed on 10% of the water surface, they have [17 GW of floating solar potential](#), with 7.7 GW located in the Atatürk Reservoir alone.

Also, these five dammed hydro power plants, which have a total reservoir area of 2,129 square kilometres, are advantageously located in provinces (Şanlıurfa, Diyarbakır, Elazığ and Mardin) that have some of the [highest solar potential](#) in the country.

Türkiye allocates 2.4 GW of hybrid capacity in three years

Despite the regulation enabling hybrid power plants being published in March 2020, [only 100 MW of hybrid solar capacity](#) had been installed by April 2022. From 2022 onwards, new capacities were announced annually and the announced capacities were quickly distributed.



In March 2022, the allocation of [1.3 GW of hybrid capacity was announced](#), with a limitation that secondary installations would not exceed 15% of the primary source capacity. One third of this capacity (429 MW) was distributed in just three months. In the third quarter of the

year, capacity allocation slowed down to 171 MW. The [removal of the 15% cap](#) in September 2022 accelerated capacity allocation, with power plants utilising 554 MW in the last quarter.

The increase in capacity requests following the removal of the secondary source capacity limit shows that this practice had curbed the development of hybrid power plants. In fact, by the end of 2023, the average ratio of capacity provided by the secondary source in hybrid plants was 30% of the primary source capacity.

The remaining 161 MW of capacity for hybrid plants from 2022 was [increased to 1 GW](#) in March 2023. 83% of this total capacity was allocated in the second quarter of 2023. However, within just one month, 720 MW of the capacity made available for eight out of the 12 capacity allocation regions had been depleted. Further capacity allocations in these regions could accelerate the deployment of new hybrid plants.

Clarifying capacity planning can enable more hybrid power plants

In addition to hybrid solar capacity not being included in official capacity statistics, neither the [National Energy Plan](#) nor the [capacity projections](#) from the transmission system operator, TEİAŞ, mention the role of hybrid plants in planned solar capacities. In fact, the [1 GW of capacity](#) announced to be allocated in 2021 by prioritising hybrid power plants was determined based on the remaining capacity from cancelled wind projects, not on solar capacity planning. There is a need for a more transparent capacity allocation process and comprehensive planning that includes floating solar power and anticipates hybrid power plant installations.

The [regulatory amendment in October 2023](#) is a positive development towards making renewable energy targets more concrete. This amendment requires specifying solar and wind capacities separately at the regional level, in capacity projections starting from April 2024. An energy strategy that also considers hybrid power plants will facilitate Türkiye's goal to reach its [target of 53 GW of solar capacity by 2035](#).

Supporting Materials

Methodology

Hybrid solar capacity

Hybrid solar capacity is taken from the Energy Market Regulatory Authority's (EMRA) [Electricity Market Generation Licences](#) database. The 'Capacity in Operation' data published under facility information is used for installed capacity, while the difference between 'Capacity in Operation' and 'Installed Capacity' data is used for project pipeline analysis. Hybrid power plant capacity data referenced in this report is in MWh.

Hybrid solar generation potential estimate

To calculate the generation potential, the installed capacity of hybrid solar by province was calculated and multiplied by the [province-level solar potential](#) data compiled by Ember from [Solargis](#) data.

Floating solar capacity potential of Atatürk, Karakaya, Keban, Ilisu and Birecik HEPPs

Data was provided by Muhammed İmran Kulat from the General Directorate of State Hydraulic Works, from his article "[A sound potential against energy dependency and climate change challenges: Floating photovoltaics on water reservoirs of Turkey](#)". The reported floating solar capacity potentials for each HPP, assuming 10% of the reservoirs are covered by panels, are as follows: Atatürk (7.7 GW), Karakaya (2.2 GW), Keban (4.4 GW), Ilisu (2.7 GW) and Birecik (400 MW).

Acknowledgements

Thank you

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Cover photo

Rural Solar panels and wind turbines via Roy Conchie / Alamy Stock Photo

Links

Access to government data via the hyperlinks may be restricted outside Türkiye.

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