



Approfondimento n. 26/ottobre 2023

**From grey to green:
Türkiye's energy transition(s)**

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Con il sostegno di



Fondazione
Compagnia
di San Paolo

Türkiye's energy sector

Türkiye, a land nestled between the East and West, finds itself not only at the geographical crossroads of Europe and Asia but also at the epicenter of regional energy dynamics. Its strategic position bridges the divide between abundant energy reserves and major consumer markets. To the east, lies nearly 60% of the world's proven oil and natural gas reserves, encompassing the vast realms of Russia, Central Asia, and the Middle East. To the west, lie the energy-hungry nations of the European continent, eagerly awaiting the sustenance that powers their industries and economies. In this intricate dance of energy flows, Türkiye sees itself as a vital hub, a conduit between the resource-rich lands and the energy-thirsty nations, shaping the very currents that drive the world's energy landscape.

Yet Türkiye is far from a mere crossover point along regional energy transit routes. It is a populous nation where 100% of the population has access to electricity. It is also an industrializing country with growing demand for energy. Türkiye's energy demand has been steadily mounting, driven by economic growth, industrialization, urbanization, and concurrently rising standard of living. It also possesses a sizeable and rapidly growing energy sector in its own right, one which plays a significant role in regional energy markets.

Between 1990 and 2021, Türkiye's population expanded from just over 54 million to almost 85 million peopleⁱ. Over the same period, Türkiye's economy witnessed rapid growth, partly as a result of the expansion of the industrial sector. This economic boom caused the nation's Gross Domestic Product to surge from \$151 billion in 1990ⁱⁱ to \$819 billion in 2021ⁱⁱⁱ. Concurrently, the share of Turkish citizens living in cities grew substantially as part of an urbanization trend, rising from 59% in 1990 to 77% in 2022^{iv}. Moreover, the combination of industrialization, urbanization, and generally improving living standards led to a doubling in Türkiye's annual energy use per capita, which grew from 10,345 kilowatt hours per person in 1990 to 22,370 kilowatt hours per person in 2021^v.

As a consequence of rising population coupled with increased urbanization and energy use per person, Türkiye's total national energy consumption has expanded more than three-fold over the past three decades, climbing from 562 Terawatt hours in 1990 to 1,896 Terawatt hours in 2021^{vi}. More dramatically, electricity demand in Türkiye grew almost twice as quickly as total energy use, increasing a remarkable six-fold between 1990 and 2022. Specifically, electricity consumption surged from just 57 Terawatt hours in 1990^{vii} to 328,9 Terawatt hours in 2022^{viii}. In fact, between 2000 and 2020 alone, Türkiye's electricity demand more than doubled^{ix}, growing at an average annual rate of 4.4%^x.

Indeed, according to Türkiye's own Ministry of Foreign Affairs, the country's energy demand grew faster than that of any other member nation of the Organization for Economic Cooperation and Development (OECD) over the past two decades, and Türkiye ranked second only to China in terms of growth of electricity and natural gas demand^{xi}. This rapid rise underscores Türkiye's significantly growing appetite for energy in recent decades.

Energy sources and supply

The economic growth that Türkiye has sustained over the past decades has been largely powered by fossil fuels, especially oil, natural gas, and coal. Although the proportional dependency on fossil fuels has slowly declined since 1965, they represented 93% of all energy use^{xii}. In 2022, fossil fuels still accounted for 81% of Türkiye's total annual primary energy consumption. Specifically, 30% of energy use originated from oil, 26.3% from natural gas, and 24.9% from coal^{xiii}.

With regards to electricity generation specifically, Türkiye's mix of energy sources has been transitioning away from fossil fuels more quickly than its broader energy mix. In 2008, fossil fuels provided almost 83% of Türkiye's total electricity generation. But thanks to an impressive growth in renewable electricity generation over the following decade and a half, the proportion of power

derived from fossil fuels in Türkiye had fallen to just 58% by 2022. The majority of fossil fuel-based electricity now comes from coal, which accounted for 34% of generation in 2022, followed by natural gas at 23.2%^{xiv}.

However, the continued prominent presence of highly carbon-intensive coal in Türkiye's electricity mix means that the carbon emissions intensity of the country's power generation remains rather high, exceeding 400 grams of carbon dioxide equivalent greenhouse gases per kilowatt hour of electricity produced. This carbon intensity is on par with electricity generation in nations such as Germany, Serbia, and Ireland, which also still partially rely on coal for power generation^{xv}.

In order to satisfy its rapidly growing appetite for energy, Türkiye relies substantially on imported fuels. The country currently imports 99% of its natural gas demand, 93% of its oil, and 58% of its coal. Official government estimates indicate that imports account for as much as 74% of Türkiye's total primary energy consumption^{xvi}. This heavy reliance on foreign fuels poses considerable risks to the nation's energy security and broader economic stability. Vulnerabilities or fluctuations in global energy markets, geopolitical tensions that threaten supply chains, and potential price swings could all conceivably impact both the consistent availability and affordability of energy within Türkiye. In 2022, the surge in worldwide oil and natural gas prices precipitated by Russia's invasion of Ukraine caused Türkiye's annual expenditure on imported energy to skyrocket by 90% compared to the previous year, costing Turkish taxpayers \$96.55 billion^{xvii}.

Cognizant of the risks imposed by such substantial import dependency, the government in Ankara has for the past decade actively formulated strategies intended to enhance energy diversification, promote the development of domestic energy resources, and strengthen energy efficiency measures. Officials rightly view such policies as crucial to ensuring Türkiye's future energy security and economic prosperity.

Diversification of electricity generation sources

One area in which Türkiye has made notable strides in recent years is the rapid growth in renewable electricity generation. Electricity generation from renewable sources has staged impressive growth over the past decade, more than doubling between 2012 and 2022. As a result of this renewable expansion, the share of electricity derived from renewables reached 42% in 2022^{xviii} - thereby surpassing Ankara's stated target of achieving a 38.8% renewable power generation share by 2023, as initially outlined under its Eleventh Development Plan covering 2019 to 2023^{xix}.

In addition to already achieved renewable electricity growth, Türkiye is also planning to install three new nuclear power plants in order to further reduce its reliance on imported fossil fuels for power generation. The first of these plants, inaugurated in April 2023, is known as the Akkuyu Nuclear Power Plant, sited on Türkiye's southern coast in Mersin Province. The facility will comprise four reactor units with a total installed electrical generation capacity of 4.8 Gigawatts. The very first unit of the Akkuyu Nuclear Power Plant is scheduled to come online and begin delivering electricity by the end of 2023^{xx}, which will further assist in diversifying Türkiye's power generation fuel mix.

Moreover, authorities in Ankara have also adopted policies aimed at reducing the nation's consumption of imported fossil fuel supplies, especially coal and natural gas. For instance, Türkiye possesses substantial domestic coal reserves and now aims to boost the production of lignite coal in particular, prioritizing its use for electrical power generation. Simultaneously, domestically extracted hard coal will increasingly be channeled to industrial sectors rather than power production^{xxi}.

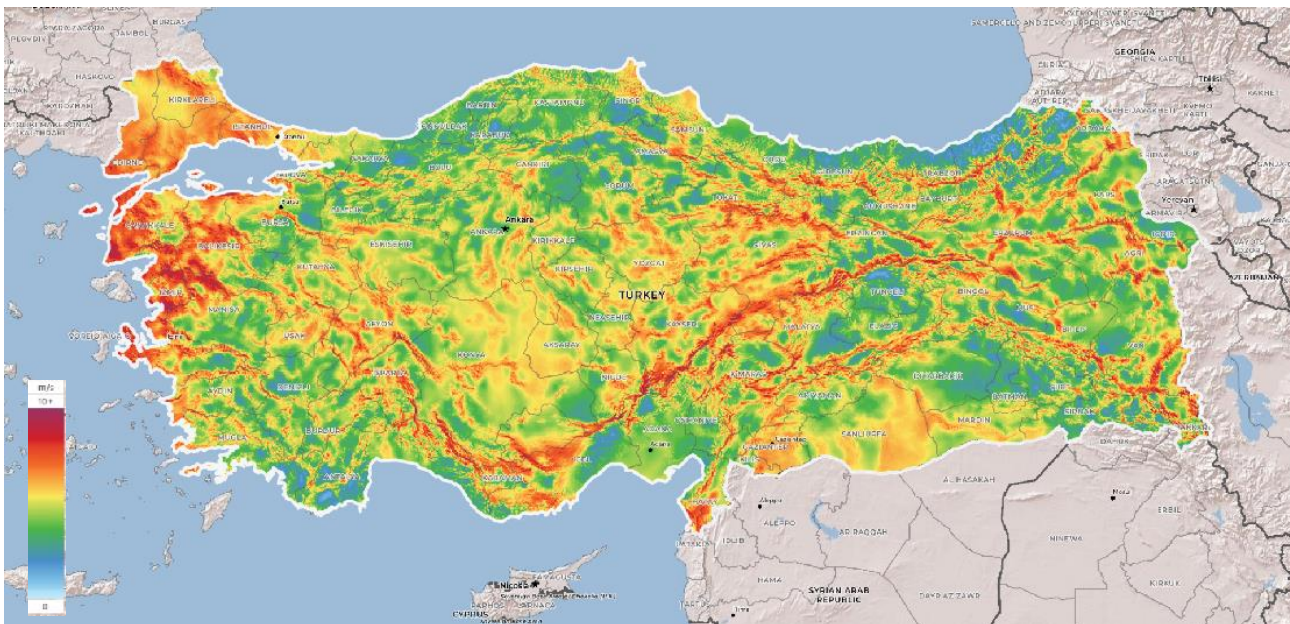
Additionally, intensified efforts have focused on expanding upstream oil and natural gas exploration and production activities in recent years. These endeavors resulted in the major discovery of the Sakarya natural gas field beneath the Black Sea in 2020, with current assessments suggesting the reserves could contain as much as 710 billion cubic meters of exploitable natural gas deposits^{xxii}.

Türkiye successfully began production at Sakarya earlier this year, and some analysts estimate that once full-scale production is achieved, the gas from this Black Sea field could potentially meet as much as 30% of the country's annual natural gas consumption needs, thereby significantly boosting its energy independence^{xxiii}.

Lastly, authorities have also devised policies aiming to improve national energy efficiency. The government developed and adopted a National Energy Efficiency Action Plan that sets a target of reducing the country's total primary energy consumption by 14% below projected business-as-usual levels by the year 2023. However, the results achieved thus far through implementing this action plan have been mixed, indicating that Türkiye still has substantial room for improvement in energy efficiency across economic sectors.

Renewable energy potential

The impressive growth exhibited by renewable electricity generation over the past decade can be partially attributed to Türkiye's favorable geographic, topographic, and climatic conditions, which have endowed it with abundant renewable energy potential. The country is rich in areas suitable for solar, wind, hydropower, and geothermal energy projects.



Mean wind speed at 100m in Türkiye. Source: The World Bank's Global Wind Atlas

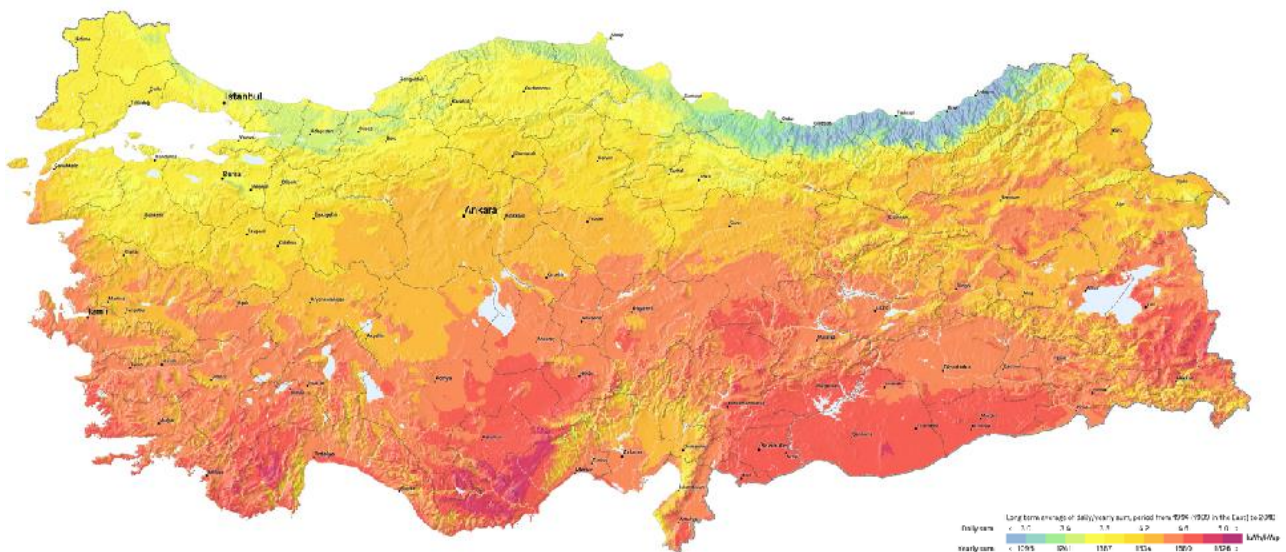
Of all renewable sources, hydropower has formed the backbone of Türkiye's renewable energy production for decades. In fact, until the early 2000s, hydropower from river dams represented the only form of renewable energy exploited in Türkiye. The country's mountainous terrain coupled with an abundance of rivers have conferred significant potential for hydropower generation. By some estimates, the total technically viable hydropower potential across all suitable sites in Türkiye approaches 216-Terawatt hours of electricity production per year. Moreover, even when narrowing down to locations where hydropower is financially and economically feasible, Türkiye still possesses an estimated 158-Terawatt hours per year of exploitable hydroelectric generation potential.

Hydropower offers the benefit of providing continuous and stable electricity output, unlike intermittent solar and wind power that rely on favorable weather conditions. This unique advantage and its ability to act as an electric battery was demonstrated earlier this year when Türkiye's natural gas supplies from Iran were suddenly cut for a period of ten days in January 2023. Turkish

authorities were able to compensate for the gas supply disruption and meet electricity demand by ramping up power generation from its network of hydroelectric dams^{xxiv}.

As of 2022, Türkiye had 78 large operational hydroelectric power plants scattered across its landmass^{xxv}. Their combined installed generation capacity amounts to 31.6 Gigawatts, which produced 67.1-Terawatt hours of electricity in 2022 – approximately matching the total annual electricity consumption of Austria^{xxvi}. Looking ahead, if all currently planned and under construction hydropower projects are completed, it is anticipated that Türkiye's total hydroelectric generation capacity could eventually reach up to 46 Gigawatts, enabling 157.6-Terawatt hours of annual power generation. For perspective, 157.6-Terawatt hours roughly equals either Norway's or Pakistan's entire national annual electricity consumption. Furthermore, this planned capacity would essentially exhaust Türkiye's estimated economically feasible hydropower potential^{xxvii}.

In addition to plentiful hydropower resources, Türkiye is also endowed with substantial wind energy potential, especially along the Marmara coast and other western regions where wind conditions are most favorable^{xxviii}. If all land areas exhibiting average wind speeds above 7 meters per second could be utilized for wind power projects, analysts estimate that Türkiye may be able to support up to 48 Gigawatts of total installed generation capacity. Under ideal conditions, this could enable wind turbines to produce as much as 130-Terawatt hours of electricity annually – roughly equivalent to meeting the entire current electricity demand of the United Arab Emirates^{xxix}. Of course, the caveat with wind power remains its intermittent generation profile, which fluctuates based on seasonal and diurnal wind variability, unless combined with an energy storage system.



Photovoltaic Power Potential. Source: World Bank's Solar Resource Map

Experts likewise note major potential for solar power generation across the southern and southeastern swaths of Anatolia and along Türkiye's Mediterranean coastline, where solar irradiation levels are highest in the country. One study suggests that if all flat terrain receiving a minimum of 1,650 kilowatt hours per square meter of solar radiation annually were covered in photovoltaic solar panels, the resulting projects could potentially generate approximately 380 Terawatt hours of electricity every year. For perspective, 380 Terawatt hours exceeds the entire current annual electricity consumption of regional rival Iran^{xxx}. However, similar to wind, solar power suffers intermittency issues, only generating electricity during the daytime unless paired with energy storage systems.

Thanks to its unique geology, Türkiye also boasts substantial geothermal energy potential. The country ranks seventh globally in total geothermal resources, which are estimated at 4.8 Gigawatts of thermal capacity and about 1 Gigawatt of electricity generation potential^{xxxvi}. Among European nations, Türkiye's geothermal reserves are unparalleled. As of 2022, installed geothermal power capacity within Türkiye had reached 1.7 Gigawatts^{xxxvii}, all of it concentrated along the country's western regions where most known geothermal reservoirs are located. Of the 14 currently operational geothermal electricity plants in Türkiye and 6 more under development, all are located in western provinces.

Recent developments in renewable energy

Over the course of many years, Türkiye has made significant strides toward harnessing its abundant renewable energy potential through policies aimed at raising the proportional share of renewables in the nation's energy mix. While initially driven mostly by goals of strengthening energy security and reducing reliance on expensive imported fossil fuels, since Ankara announced its objective to achieve net-zero greenhouse gas emissions by 2053, decarbonization and climate change mitigation have emerged as additional motivators for renewables development.

Among renewable sources, solar and wind power have witnessed the most rapid capacity growth in recent years. Beginning from almost nil in 2014, installed solar power generation capacity surged to 9.4 Gigawatts by 2022 through the addition of new photovoltaic solar farms. As a result, annual electricity derived from solar jumped to 15.84 Terawatt hours in 2022. Onshore wind power capacity experienced similarly brisk growth, albeit initiated earlier than solar. Wind turbines first began generating power in Türkiye in 2005, and accrued installed capacity reached 11.4 Gigawatts by 2022, producing 35.1 Terawatt hours^{xxxviii}.

In contrast to accelerated solar and wind capacity additions, the expansion of hydropower generation has decelerated over the past decade as suitable dam sites become fully tapped. Following a period of relatively rapid large dam construction in the early 2010s, growth in installed hydropower capacity has flattened out in recent years as it approaches its maximum capacity potential.

Overall, the combined growth from all types of renewable energy technologies has substantially shifted Türkiye's electricity generation mix over the past decade. The renewable proportion of total power production rose from just 39% in 2012 to exceed 54% by 2022^{xxxix}. Renewables expansion has been further promoted through government incentives like feed-in tariffs for renewable power plants, including wind, solar, biomass, hydro and geothermal, along with domestic manufacturing incentives that support local production of components such as solar panels.

Türkiye's current energy transition road map

In October 2021, Türkiye's political leadership formally announced a commitment to reach net-zero greenhouse gas emissions across the economy by 2053. Subsequently, in April 2023, Ankara submitted an updated Nationally Determined Contribution to the United Nations under the Paris Climate Agreement, committing to reduce emissions 41% below projected business-as-usual levels by 2030. The document also set a target to peak Turkish emissions by 2038 at the latest.

A confluence of economic, political, and social factors is driving Türkiye's shift toward a more accelerated decarbonization policy. Reducing costly imported fossil fuel dependence and positioning itself to attract greater flows of international climate financing are two key economic motivations. Meanwhile, impending European Union regulations like the Carbon Border Adjustment Mechanism threaten tariffs on imports from countries without robust climate policies, thus exerting political pressure on Ankara. Lastly, changing social preferences among Turkish voters and the corporate sector have shifted the political tide toward climate action since 2021^{xxxv}.

In tandem with its climate commitments, Ankara authorities released an updated National Energy Plan in January 2023 laying out their projected vision for Türkiye's energy system evolution through 2035 and 2053, aligned with the country's broader development plans and climate goals.

The plan forecasts that under current policies, Türkiye's total national energy demand would grow 39% by 2035. Factoring in continued economic development and industrialization, the report projects per capita energy consumption to rise 24% by 2035 and 41% by 2053^{xxxvi}. The National Energy Plan also estimates that electricity demand would surge from 328.9 Terawatt hours in 2022^{xxxvii} to 510 Terawatt hours in 2035 – a level comparable to the present electricity consumption of France or Germany. As electrification of sectors like transportation proceeds, the plan foresees the proportional share of electricity rising from one-fifth of final energy use today to fully one-quarter by 2035, ascending further to 56% by 2053^{xxxviii}.

To meet surging electricity demand across economic sectors coupled with new demand from green hydrogen production, Türkiye anticipates needing to double its current electricity generation capacity to 189.7 Gigawatts by 2035. Moreover, approximately three-quarters of this new power generation capacity addition needs to originate from renewable energy sources, especially utility-scale solar and wind projects^{xxxix}.

The plan foresees an increase of the share of renewable energy sources in generation capacity. Specifically, the National Energy Plan outlines a target to raise the overall share of renewable sources in electricity generation from 54% in 2022^{xl} up to 64.7% by 2035, climbing further to 69.1% by 2053. This substantial renewable increase includes an expansion of installed solar power generation capacity from 6.7 Gigawatts in 2020 to 52.9 Gigawatts by 2035, at which point solar would supply 27.9% of Türkiye's total electricity. Over the same time horizon, onshore wind power capacity would rapidly scale up from 8.8 Gigawatts to 29.6 Gigawatts by 2035, contributing 15.6% of generation.

To accomplish these ambitious solar and wind targets, planners estimate Türkiye must install an average of 3.1 Gigawatts per year of new solar capacity and 1.4 Gigawatts per year of new wind power until 2035. By comparison, between 2020 and 2022, the country has averaged about 1.35 Gigawatts per year of new solar and 1.3 Gigawatts per year of new wind capacity – meaning wind deployment is on track while solar installations are advancing at less than half the necessary pace thus far^{xli}. However, both the announced plans and the existing project pipeline suggest progress may accelerate, as Türkiye already has 56 solar power projects^{xlii} encompassing 7 Gigawatts of combined capacity^{xliii} in planning or under construction. Another 83 wind power projects^{xliv} totaling 4.5 Gigawatts of capacity are similarly progressing through planning and construction^{xlv}.

The envisioned renewable energy expansion also entails marginal capacity increases from hydropower and geothermal energy. Installed hydropower capacity would grow from 31 Gigawatts today to 35.1 Gigawatts by 2035, representing 18.5% of Türkiye's generation capacity. Geothermal and biomass would together increase from 3.4 Gigawatts to 5.1 Gigawatts by 2035, contributing 2.7% of power generation capacity^{xlvi}. Türkiye currently has 9 hydropower projects encompassing 2.9 Gigawatts of capacity under development^{xlvii}. Additionally, 6 new geothermal power facilities are in the pipeline in western regions, which would add 0.4 Gigawatts of capacity if completed^{xlviii}.

Beyond renewables, nuclear power capacity currently under construction is expected to total 3.8% of all generation capacity by 2035, providing an impressive 11% of electricity production^{xlix}.

The National Energy Plan also envisions some growth in fossil fuel-based generation through 2035, with coal and gas capacity each expanding by 3 and 10 Gigawatts respectively.^l Türkiye is currently planning 10.4 Gigawatt of coal-powered plants.^{li}

The National Energy Plan also envisions some growth in fossil fuel-based generation through 2035, with coal and gas capacity each expanding by 3 and 10 Gigawatts respectively. However, energy planners would like to see electricity from coal and gas plants peak around 2030, declining by 2035 to levels comparable to today and declining further toward 2053. Yet, they also emphasize that

existing coal capacity will not face early retirement, but rather continue operating through its technical lifetime as reserve capacity provide grid flexibility and reliability^{lii}.

Due to currently high costs, deploying carbon capture systems at coal and gas plants is not envisioned before 2035. However, this might change depending on cost and technology development and the plan could be revise to give coal a higher share in electricity generation than currently proposed – at the expense of nuclear power - albeit with lower carbon emissions^{liii}.

Türkiye's storage and hydrogen road map

In concert with its National Energy Plan, Türkiye recently developed a comprehensive Hydrogen Technologies Strategy and Roadmap to guide scaled up deployment of energy storage solutions aimed at balancing the country's expanding fleet of intermittent renewable generators. Alongside grid interconnections with neighbors, flexible demand-side management, and pumped hydropower storage, batteries and green hydrogen production feature prominently in Türkiye's envisioned flexibility portfolio.

Both batteries and hydrogen offer viable storage mediums for renewables integration, with hydrogen offering particular advantages for decarbonizing heavy industry and freight transport. Türkiye plans to dramatically scale up hydrogen production from electrolysis powered entirely by zero-carbon electricity. This "green" hydrogen would then displace fossil fuel usage across the economy.

Energy planners set a target for Türkiye's battery energy storage capacity to reach 7.5 Gigawatts by 2035, alongside 5 Gigawatts of electrolyzer capacity for green hydrogen production. If realized, hydrogen output from 5 Gigawatts of electrolysis could reach approximately 0.75 million metric tons per year – on par with targets set by the UK, Italy, Denmark, and Sweden for 2030. In the longer term, electrolyzer capacity for green hydrogen production is envisioned to rapidly expand to a staggering 70 Gigawatts by 2053, enabling output of up to 10.5 million tons annually.

Additionally, blending green hydrogen into natural gas networks is slated to curb fossil gas consumption. The National Energy Plan forecasts 3.5% green hydrogen to be mixed into gas supplies by 2035, rising substantially to 12% by 2053^{liv}.

With domestic hydrogen demand in Türkiye estimated to reach 1.9 million tons by 2050^{lv}, export markets beckon. Which means that the majority of the hydrogen produced could be available for export to the European Union. European officials have already indicated strong interest in Türkiye serving as a green hydrogen supplier. The European Commission openly appealed to Türkiye to aid its effort to import 10 million tons of green hydrogen annually by 2030, and Germany has specifically expressed an interest in a hydrogen pipeline to Türkiye to meet its industrial energy needs^{lvi}.

The energy transition and the quest for energy independence

Import dependence and associated energy security risks have served as the primary motivator behind Türkiye's historical energy development policies. The country's lack of domestic fossil fuel resources compared to rapidly growing energy demand has led to high and generally rising import reliance since 1970, with momentary exceptions like the 1980 military coup and the 2008 global financial crisis^{lvii}. Although broad economic growth resumed after 2010 and energy demand again began outstripping modest domestic supply growth, Türkiye's expanding renewables production coupled with a push for greater coal output helped temper import dependency increase^{lviii}. This overall trend toward substituting imports with local resources is expected to persist going forward as nuclear power and renewables continue displacing fossil fuels, especially in the power sector.

However, beneath these long-term transitions, Türkiye remains deeply reliant on imported fossil fuels under its current energy plans extending to 2035. Despite elevated renewables and nuclear targets, the National Energy Plan paradoxically also envisions expanded natural gas and coal

burning for power generation through 2030. The transportation sector remains dependent on fossil fuels with Türkiye taking its first steps in its transition towards electric mobility. Electric vehicles represented less than 1% of car sales in 2022. While green hydrogen stands poised to eventually displace some fossil fuel consumption across the industrial sector, its scaled-up availability is not projected until after 2035.

This has left Ankara trying to find ways in which it can secure enough natural gas and coal supplies. It managed to marginally increase its coal production but it was its attempts to secure natural gas sources that has the most geopolitical impact.

Ankara has therefore continued seeking to secure reliable and affordable fossil fuel supplies in the interim to buttress its economy. Domestic coal production saw minor increases, but natural gas supply diversification has commanded greater policy attention given Türkiye's heavy reliance on gas imports. As of 2021, most of the country's natural gas originates from Russia, Iran, Azerbaijan, and LNG cargoes from Algeria and Qatar. Given Russia provided 45% of Türkiye's 2021 gas demand alone, its supply policy has inevitably impacted Ankara's delicate geopolitical balancing acts, especially since the Ukraine war. In this context, the sizable natural gas reserves discovered beneath the Black Sea at the Sakarya field were deemed strategically valuable, with the potential to satisfy up to 30% of national gas demand at full production. While not a panacea, Sakarya does enhance Türkiye's energy security and supply flexibility.

However, Türkiye's ambitions to serve as a regional natural gas hub also hinges on eastern Mediterranean reserves access and collaboration between regional countries. This was rendered more complex by bitter disputes with Greece and Cyprus over territorial claims and exploration rights, and over the territorial waters and Exclusive Economic Zones in the Aegean and Mediterranean Seas, a long rift between Ankara and Tel Aviv, and the conflict in Libya, where the side supported by Türkiye was at war with that supported by Egypt, United Arab Emirates, and France^{lix}. Ankara's exclusion from the Eastern Mediterranean Gas Forum dealt a blow to its attempts to become the region's natural gas hub. Ultimately, these complex regional energy disputes rooted in unresolved political conflicts will likely continue linking Türkiye's energy policy with its foreign policy for years to come.

Conclusion

Türkiye's quest for energy independence and reduced import dependency has been a key driver shaping its energy policy and regional geopolitics. While renewables and domestic fossil fuels offer a path to greater self-sufficiency, Türkiye will remain reliant on imported gas for years to come, which influences Ankara's foreign policy decisions. The successful exploration of the Sakarya gas field in the Black Sea could provide greater energy security when production ramps up. However, tensions with Greece, Cyprus and regional rivals over eastern Mediterranean gas deposits have hindered Türkiye's ambitions to be a regional energy hub.

Expanding renewables and green hydrogen production would provide Türkiye with greater energy self-sufficiency and more independence, and could bolster Türkiye's position as an energy supplier to Europe. However, natural gas will likely remain its Achilles heel in the medium term, and its natural gas imports will keep it entangled with Russian the Eastern Mediterranean, and the Middle East for the foreseeable future. Looking ahead, the pace of Türkiye's energy transition will impact its energy independence, which will influence its regional relations for years to come.

End notes

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