# How much gas capacity does Greece need?

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## Summary

The earliest possible complete decarbonization of electricity production has become a necessity for both climate and economic reasons. The National Energy and Climate Plans (NECPs) of several EU Member States that aim to reduce the carbon footprint of their electricity sector to zero by 2030 or 2035 already convey this need. Partly driven by the lignite phase-out, the continuous increase in the penetration of renewable energy sources (RES) will deprive gas-fired plants of operating hours and revenues; therefore, hereafter and until the completion of the energy transition, gas plants will play a progressively smaller role. Under these circumstances, it is likely that their economic viability will depend on subsidies in the form of capacity mechanisms. However, as these subsidies are paid by consumers, it is important that they are either avoided altogether or limited to the lowest possible levels. Furthermore, according to the latest pan-European Resource Adequacy Assessment by entso-e, Greece is among the nine European countries with the highest gas capacity at risk due to declining economic performance.

Therefore, it is important to examine whether the 7,885 GW of total gas plant capacity outlined by the NECP under consultation (for 2030) is indeed the minimum possible or whether this provision will lead to costly subsidies for gas plants. In the absence of an updated national Resource Adequacy Assessment, this matter can be approached by analyzing historical data.

The present analysis concerns only Greece and is based on the hourly entso-e data for the period between 2019 and the first half of 2024, during which the development of renewables surged. Our analysis calculates the total thermal capacity of gas and lignite plants that was required to meet domestic electricity needs for every hour of the examined period. The main conclusions are summarized as follows:

- Over the past 1.5 year, meeting domestic demand has ***never required more thermal power plant capacity than that currently available by gas plants*** (6 GW). In the past 3.5 years, domestic demand exceeded 6 GW for just 1 hour.
- ***The maximum thermal power plant capacity required to meet domestic demand has been steadily decreasing*** (-27.6% compared to 2019) and, in the first half of 2024, was reduced to 5.1 GW, nearly 2.8 GW below the gas plant capacity outlined for 2030 by the NECP.
- Between 2019 and the first half of 2024, ***thermal power plants produced 5.86 TWh at times when Greece was a net exporter of electricity; therefore, in theory, this quantity and its accompanying $CO_2$ emissions -estimated at 3.56 Mt- could have been spared***.
- Greece's reliance on renewables is increasing at a steady rate. For 43, 105 and 119 hours in 2022, 2023 and the first half of 2024 respectively, net exports exceeded thermal power plant production; thus, during those hours, ***domestic needs could have been met almost entirely by renewables***.

Given the further development of RES and new electricity storage infrastructure, it is reasonable to expect that the maximum thermal power plant capacity required to meet domestic needs will remain on its downward course. Therefore, the 7,885 GW of gas-fired plant capacity that is outlined in the NECP under revision for 2030 should be reviewed and the retirement of existing gas-fired plants should be considered. In any case, carrying out an updated Resource Adequacy Assessment should constitute an urgent priority for Greece.

# Introduction

With the share of Renewable Energy Sources (RES)[1] in meeting demand more than doubling in recent years -from 21.4% in 2019 to 48.7% in the first half of 2024- the "green" shift of Greece's electricity system is undeniably gaining momentum. Given that limiting greenhouse gas emissions is now both an EU and a national legal commitment[2], this trend will persist. This is further reinforced by the fact that mature RES technologies -wind and photovoltaics- are by far the cheapest for electricity production; this is suggested by both levelized cost of energy (LCOE) comparative analyses between different electricity production technologies[3] and a recent analysis correlating the lowest prices in the Greek wholesale electricity market with high shares of RES and low thermal power plant participation[4].

Renewables' continued growth has already reduced the earnings of thermal power plants[5] in the interconnected system. Indeed, lignite- and fossil gas-fired plants have seen a drop in their operating hours and an accompanying decline in revenues from the electricity market.

In fact, thermal power plants' finances are expected to worsen. The latest pan-European Resource Adequacy Assessment by the European Network of Transmission System Operators for Electricity (entso-e)[6], which took into account the draft National Energy and Climate Plans (NECPs) submitted by Member States in 2023, suggests that, as early as 2025, the economic viability of gas-fired plants with a total capacity of 28.6-39 GW across Europe will be at risk; the corresponding figure for 2028 is projected at 22.5-32.9 GW.

Greece is among the nine European countries with the largest capacity at risk for decommissioning due to their declining economic performance. According to the first scenario examined, market conditions in Greece are likely to lead to the retirement of gas plants totaling 1.36 GW, 1.41 GW and 3.73 GW in 2025, 2028 and 2030 respectively. The second scenario shows slight variation, with the gas plant capacity at risk amounting to 1.31 GW, 1.40 GW and 3.50 GW in 2025, 2028 and 2030 respectively.

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[1] In the interconnected grid, excluding large hydro plants and including an estimate of the contribution of self-producers based on their installed capacity.
[2] National Climate Law GG A. 4936/105/27.05.2022.
[3] Lazard, 2024 LCOE+ Report, https://bit.ly/3TdbIsA.
[4] Mantzaris, N., energypress.gr, 2.8.2024. "Gas in electricity production: Greece diverging from Europe", https://bit.ly/4gtXAoF .
[5] Given the retirement of all lignite plants by 2028 at the latest (2026 according to PPC), the thermal power plant capacity contributing to meeting domestic demand until the energy transition is completed, will be produced exclusively by gas-fired plants; in fact, gas has been the dominant fossil fuel in Greece's production mix since 2019. Therefore, the conclusions of the present analysis refer to the total gas plant capacity planned for Greece from 2030 onwards. Nonetheless, the analysis was based on historical data of the period 2019-2024, during which lignite was still present in the electricity mix; thus, the thermal power plant capacity reflected in the results refers to the sum of both lignite- and gas-fired plant capacity.
[6] entso-e, European Resource Adequacy Assessment, 2023 Edition: https://bit.ly/3yp18rl.

In addition, by 2026, Greece's Public Power Corporation (PPC) plans to retire a total capacity of 1 GW of gas plants, as reflected in its most recent three-year business plan for the period 2024-2026[7].

Nevertheless, the revised NECP submitted to public consultation[8] does not dictate any gas plant retirement by 2030. Instead, the plan provides for two new gas plants (877 MW and 840 MW, respectively) -now under construction- to be added to the current fleet (6,037 GW), bringing the total installed capacity in 2030 to 7,885 GW. Thus, compared to the previous NECP (2019)[9], which outlined a 6.9 GW fleet of gas-fired plants, the revised NECP provides for an extra new gas plant and no plant withdrawal.

Various sources[10,11] have suggested that this increase in total capacity dictated by the revised NECP was deemed necessary for the country's energy adequacy. This interpretation is supported by a relevant quote found in an earlier summary of the draft NECP, which was presented in August 2023[12], prior to the draft's formal submission to the European Commission. In particular, this text refers to a recent Resource Adequacy Assessment carried out by ADMIE, the Greek Independent Power Transmission Operator (IPTO), which shows that "... *based on conservative assumptions, the addition of these three gas plants[13] to the existing fleet - together with the contribution of storage and demand response units- is adequate to reliably meet the electricity load under all possible climate scenarios and allows for adequate reserve capacity from 2025 to 2040*". Thus, this NECP summary suggests that 7,885 GW of gas-fired plant capacity in 2030 is sufficient to ensure Greece's resource adequacy; nonetheless, it is not expressly stated whether this capacity is in fact also necessary. Given that the aforementioned Resource Adequacy Assessment was never published, its results and assumptions are unknown; therefore, the thermal power plant capacity that will be required to meet domestic needs in 2030 and beyond remains unknown.

At the same time, as stated in the entso-e RAA, ensuring the economic viability of gas plants at risk of decommissioning -if they are indeed necessary for the country's energy security- will require some form of assistance in the form of a Capacity Remuneration Mechanism (CRM). This financial assistance will burden Greece's consumers, with an amount that will depend on the number and capacity of plants to be included in the subsidy scheme. Therefore, in order to shield the

[7] PPC, Capital Markets Day, 23 January 2024, σελ. 24: https://bit.ly/3LVI9b4.
[8] National Energy and Climate Plan - Revised Edition - August 2024 - Draft Revised Edition, October 2023: https://bit.ly/4e5KtYN.
[9] National Energy and Climate Plan, December 2019, p. 276: https://shorturl.at/03ZJV.
[10] Energypress.gr, 5.7.2024. "Papadopoulos (Public Gas Corporation of Greece, DEPA): security and adequacy are the two requirements of the energy transition", https://bit.ly/47dXTzH.
[11] Euro2day, 13.6.2024. "Energy: Germany opens a window of opportunity for gas plants", https://bit.ly/4dOPNQA.
[12] National Energy and Climate Plan, Summary - Proposal, August 2023, p. 26: https://bit.ly/3A6jgqf.
[13] The third unit mentioned is the new 826 MW plant in Agios Nikolaos, Boiotia, which has been in operation since December 2022. The present analysis includes this plant in the 6,037 GW currently installed.

national economy, as well as households and businesses from unnecessary financial burdens, the total gas plant capacity to be included in such a mechanism should be the minimum necessary for ensuring resource adequacy.

In the absence of a Resource Adequacy Assessment, historical data can be analyzed in order to determine the aforementioned required thermal power plant capacity.

# Historical Data Analysis

The following analysis utilized hourly data from the entso-e database on the two fossil-fueled electricity production technologies -namely lignite and gas- in Greece's interconnected system. The analysis focused on the period January 2019-June 2024, during which renewables experienced rapid growth, and examined how the peak usage levels of the country's existing thermal power plants were affected. Furthermore, the analysis calculated whether thermal power plant operation met domestic demand and/or the needs of neighboring countries. Based on the hourly data for each year, histograms were drawn to indicate the number of hours that lignite and gas plants' thermal capacity usage was within a certain range of values.

Based on the way in which the integrated European electricity market works, the thermal capacity produced each hour can be used to meet exclusively domestic needs, as well as be exported to cover part of the demand in neighboring countries. The objective of the present analysis was to estimate the thermal capacity required solely to meet domestic demand; thus, in addition to the histogram reflecting the actual total use of thermal power plants in Greece to meet both domestic needs and exports, a second histogram was drawn to record domestic use alone. This calculation was based on the assumption that, during the hours that Greece was a net exporter, thermal power plant production intended for domestic use could be reduced -in theory- to the point of zero net exports. Figures were obtained by combining Greece's hourly data on thermal power plant production with the corresponding electricity imports and exports recorded at the country's five interconnections with its neighbors (Bulgaria; Italy; North Macedonia; Albania; and Turkey). Both the minimum thermal capacity required for the spinning reserve and certain inflexible gas-fired electricity production needs arising from industrial activities, were not taken into account in this calculation. Therefore, the results of this analysis provide an initial estimate of the thermal capacity that was required to meet exclusively domestic electricity demand.


***Figure 1**: Total thermal power plant capacity actually used (pink) and thermal power plant capacity required to meet domestic demand (blue) for the period 2019-2024 (1st half), based on entso-e production and import-export data. The vertical line depicts the current total gas plant capacity.*

Figure 1 presents the evolution of thermal power plant capacity distribution over the 5.5-year period between January 2019 and June 2024. For comparison purposes, each histogram also shows the current total installed capacity of gas plants (6.037 GW). Our observations are as follows:

- In 2019, when RES met slightly over a fifth of electricity demand (21.4%)[14], thermal power plant production -almost in its entirety- met domestic needs. For 116 hours, the thermal capacity required exceeded the current total gas plant capacity; for a few hours it even reached the maximum value of 7.06 GW.

- Similarly, in 2020, the year of the lockdown, thermal power plants operated almost entirely to meet domestic demand. Nonetheless, due to both RES development (27.4%)[14] and a significant reduction in demand (-3.9% compared to 2019), thermal power plant capacity exceeded the current gas plant capacity solely for 14 hours.

- For the first time in 2021, thermal power plant operation was not dedicated exclusively to meeting domestic needs. For certain hours, Greece was a net exporter and could have avoided part of its fossil-fueled electricity production at the expense of net exports. In addition, for the first time in 2021, the thermal capacity required to meet both domestic needs and exports never exceeded the currently installed gas capacity (6,037 GW).

- In 2022, RES met 37% of the demand in the interconnected grid[14]. Had the share of renewables been smaller, electricity prices would have climbed even higher due to the gas supply price explosion that followed Russia's invasion of Ukraine. As domestic demand was largely met by RES, a significant part of domestic thermal power plant production was channeled to exports; as a result, the two histograms differ significantly. It is worth noting that the discrepancy is more pronounced at high thermal power plant capacity values, indicating that exports took place mainly during the hours when most thermal power plants were in operation. Nevertheless, for just one hour in 2022, the thermal power plant capacity required to meet domestic demand slightly exceeded the currently installed gas plant capacity (6,042 MW vs 6,037 MW). Most interestingly, however, for the first time in 2022, Greece recorded 43 hours with zero thermal power plant capacity requirements to meet domestic demand (left side of the histogram). Presumably, during these hours, the country's needs could have been met via clean energy with no thermal power plant in operation, subject to the aforementioned assumptions.

- In 2023, the year in which clean energy (RES and large hydro) overtook fossil fuels (lignite and gas)[14] for the first time, the frequency of zero thermal capacity requirements to meet domestic demand rose significantly. Net exports exceeded thermal production for a total of 105 hours. Moreover, the maximum hourly thermal power plant capacity required to meet domestic demand was 5.6 GW, which is significantly lower than the current installed capacity of gas plants and far below the 7.885 GW dictated in the revised NECP under consultation.

[14] The Green Tank, Trends in electricity production, https://bit.ly/4d9tNi8.

- In the first half of 2024, the frequency when no thermal power plant was needed to meet domestic demand more than doubled compared to the previous year; in particular, for 119 hours Greece's needs could have been met almost entirely with renewables. It should be noted that 494 GWh of RES were rejected during that period. Therefore, if the country had storage infrastructure, made better use of renewables and hindered these curtailments, the need for thermal power plant operation to meet domestic demand would have been even lower. Finally, over the first half of 2024, the maximum thermal power plant capacity required to meet domestic demand was 5.1 GW, which is simultaneously below 2023 levels, 0.9 GW below the currently installed gas capacity and almost 2.8 GW below the total gas capacity planned for 2030 according to the revised NECP under consultation.

Figure 2 presents the evolution of the key statistics of the aforementioned results over time. Between 2019 and the first half of 2024, a 33.3% decrease was recorded in the median thermal power plant capacity required to meet domestic needs (from 3,086 GW in 2019 to 2,058 GW in 2024). Over the same period, Greece's maximum thermal power plant capacity requirement was reduced by 27.6%, from 7.06 GW in 2019 to 5.1 GW in the first half of 2024. The standard deviation in the histograms shows small variations between 947 MW (2020) and 1173 MW (in 2022) with a mean of 1047 MW.

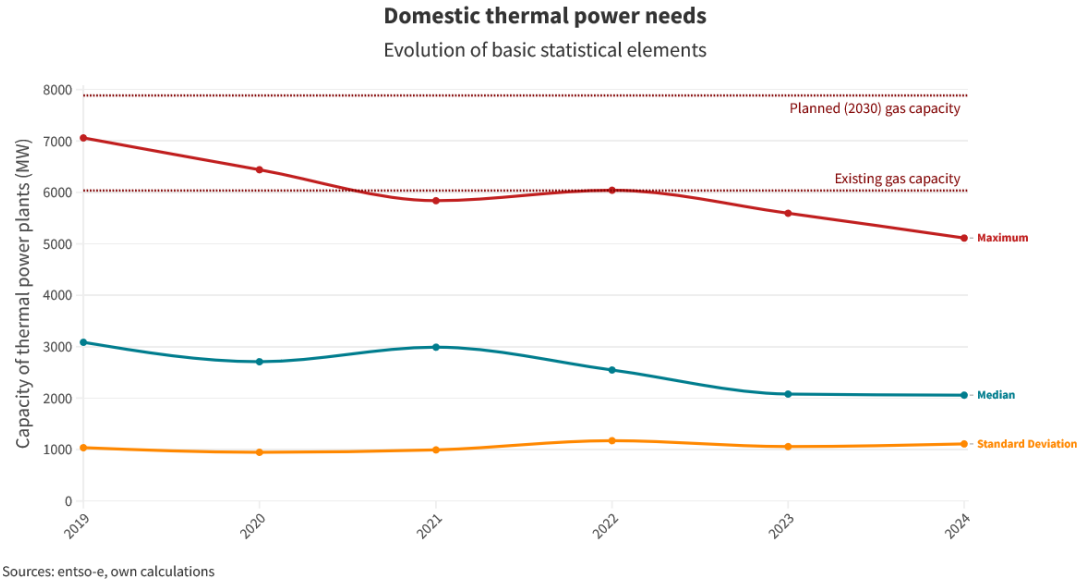
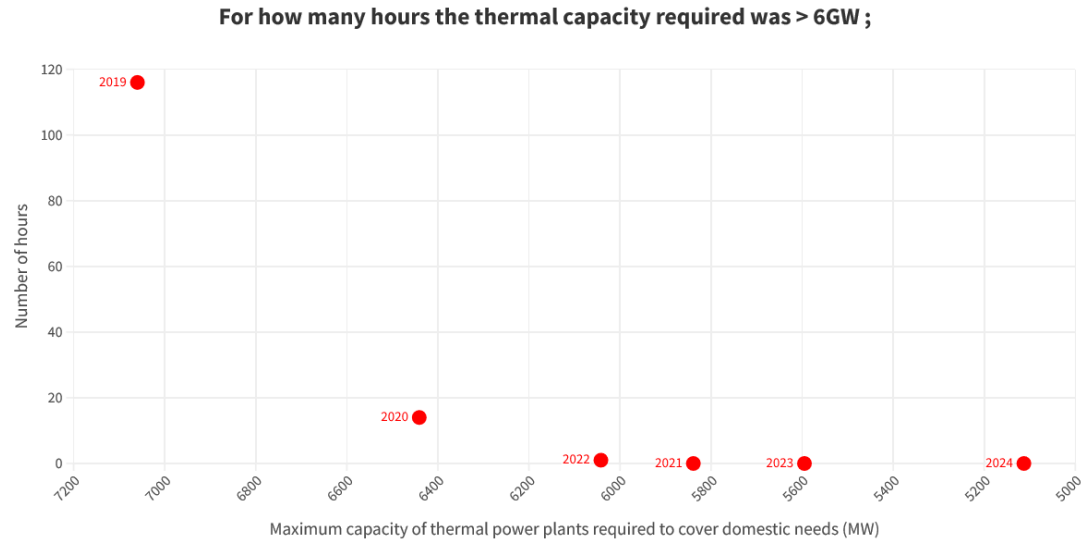



***Figure 2**: Evolution of key statistics regarding the thermal power plant capacity required exclusively to meet domestic demand.*

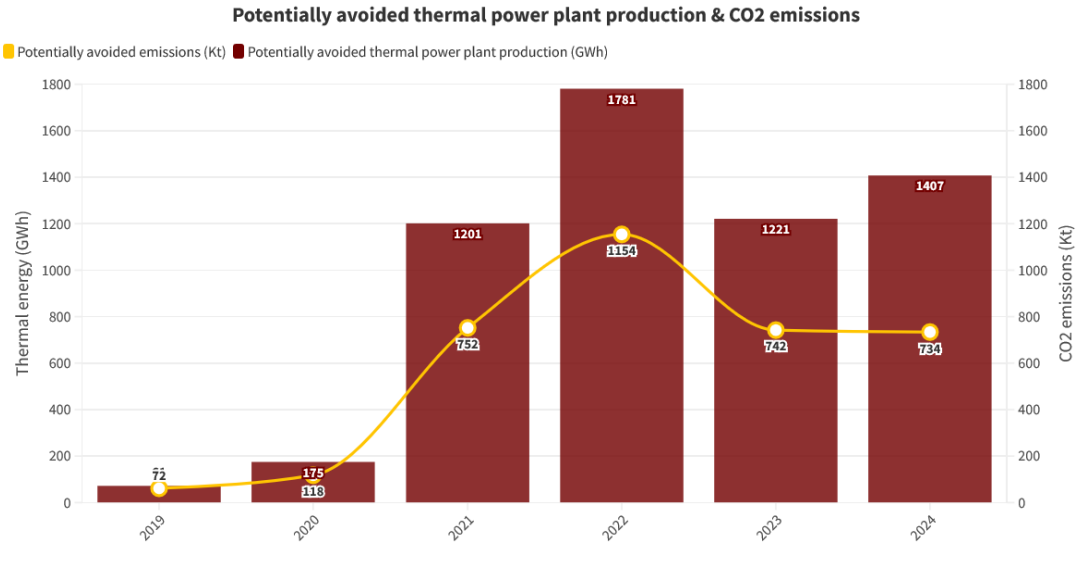
Figure 3 relates the maximum thermal power plant capacity required to meet domestic demand to the number of hours it exceeded 6,037 GW, which is the total installed capacity of existing gas plants. The graph clearly illustrates that, over the past 1.5 year, domestic demand from thermal power plants never exceeded the available gas plant capacity; furthermore, looking at the past 3.5 years (since 2021), the existing gas capacity only fell short for 1 hour in 2022.




Sources: entso-e, own calculations

***Figure 3**: Correlation of the number of hours when thermal power plant capacity required to cover domestic demand exceeded the currently existing gas capacity (6,037 GW), with the maximum thermal power plant capacity required to meet domestic demand.*

The data on both thermal production and net export quantities for every hour that Greece was a net exporter allows the determination of the thermal power plant production that could have been spared -in theory- had the objective been meeting solely domestic demand. These quantities, together with estimates of their corresponding $CO_2$ emissions[15], are presented in Figure 4.




Sources: entso-e, ADMIE, EU ETS, own calculations

[15] Carbon intensity estimates per electricity production technology are used to calculate carbon dioxide emissions. These estimates are obtained by combining the annual ETS emission data per thermal power plant with the corresponding electricity production data.

***Figure 4**: Thermal power plant production and corresponding $CO_2$ emissions that could have been averted had thermal power plant production been exclusively intended for meeting domestic demand.*

Over the entire period between 2019 and 2024, the fossil fuel-fired electricity production and corresponding $CO_2$ emissions that could have been avoided amounted to 5.86 TWh and 3.56 Mt respectively. Surplus thermal electricity production in both 2021 and 2023 amounted to 1.2 TWh. The largest surplus of thermal electricity production (1.78 TWh) was recorded in 2022 and can be directly linked to a drop in that year's net electricity imports, which dropped to a 10-year low (3.45 TWh). This year is projected to exceed 2022; in particular, midway through 2024, surplus thermal electricity production has already reached 1.4 TWh, while net imports have recorded a new six-month low at just 342 GWh.

# Conclusions

Given the retirement of all lignite plants by 2028 at the latest (2026, according to PPC), the thermal capacity contributing to meeting domestic demand until the energy transition is completed will be produced exclusively by gas-fired plants; in fact, gas has been the dominant fossil fuel in Greece's production mix since 2019. Therefore, the conclusions of the present analysis refer to the total gas plant capacity planned for Greece from 2030 onwards. Nonetheless, the analysis was based on historical data of the period between 2019 and 2024, during which lignite was still present in the production mix; thus, the thermal capacity reflected in the results refers to the sum of both lignite- and gas-fired plant capacity.

The results of the analysis clearly show that the rapid development of renewables in Greece reduces both the total annual fossil fuel-based thermal production needs and the maximum hourly values of thermal capacity required to meet domestic demand. The latter values also determine the thermal power plant capacity that must be available at any hour of the year for resource adequacy purposes. In particular, during the first half of 2024, the maximum thermal capacity required to meet domestic demand was 5.1 GW, which is more than 900 MW lower than the current total gas plant capacity installed (6,037 GW) and nearly 2.8 GW below the total gas plant capacity planned for 2030 according to the revised NECP currently under consultation.

According to the latter document, RES development will be further accelerated, meeting and surpassing the projected increase in domestic demand; at the same time, electricity storage infrastructure is also expected to grow. Thus, it is reasonable to expect that the maximum thermal capacity required to meet domestic needs at any hour of the year will continue its downward trend.

Therefore, in order to avoid unnecessary and costly subsidies to gas-fired plants that will burden consumers and the national economy, **the maximum gas-fired plant capacity of 7,885 GW for 2030 that is dictated in the revised NECP under**

**consultation should be reviewed; furthermore, the possible retirement of existing gas-fired plants should be seriously considered**.

For this reason, **it is recommended that a Resource Adequacy Assessment be carried out by the Greek IPTO (ADMIE)**. This assessment should be based on the entso-e methodology and take into account the newer NECP projections regarding the evolution of domestic demand, the significant reduction in the use of gas in electricity production (-45.5% in 2030 compared to 2022) and the development of renewables and energy storage technologies. In fact, given that investment interest in both renewables and storage infrastructure is high and far exceeds NECP projections, additional -more ambitious- scenarios should also be explored.

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