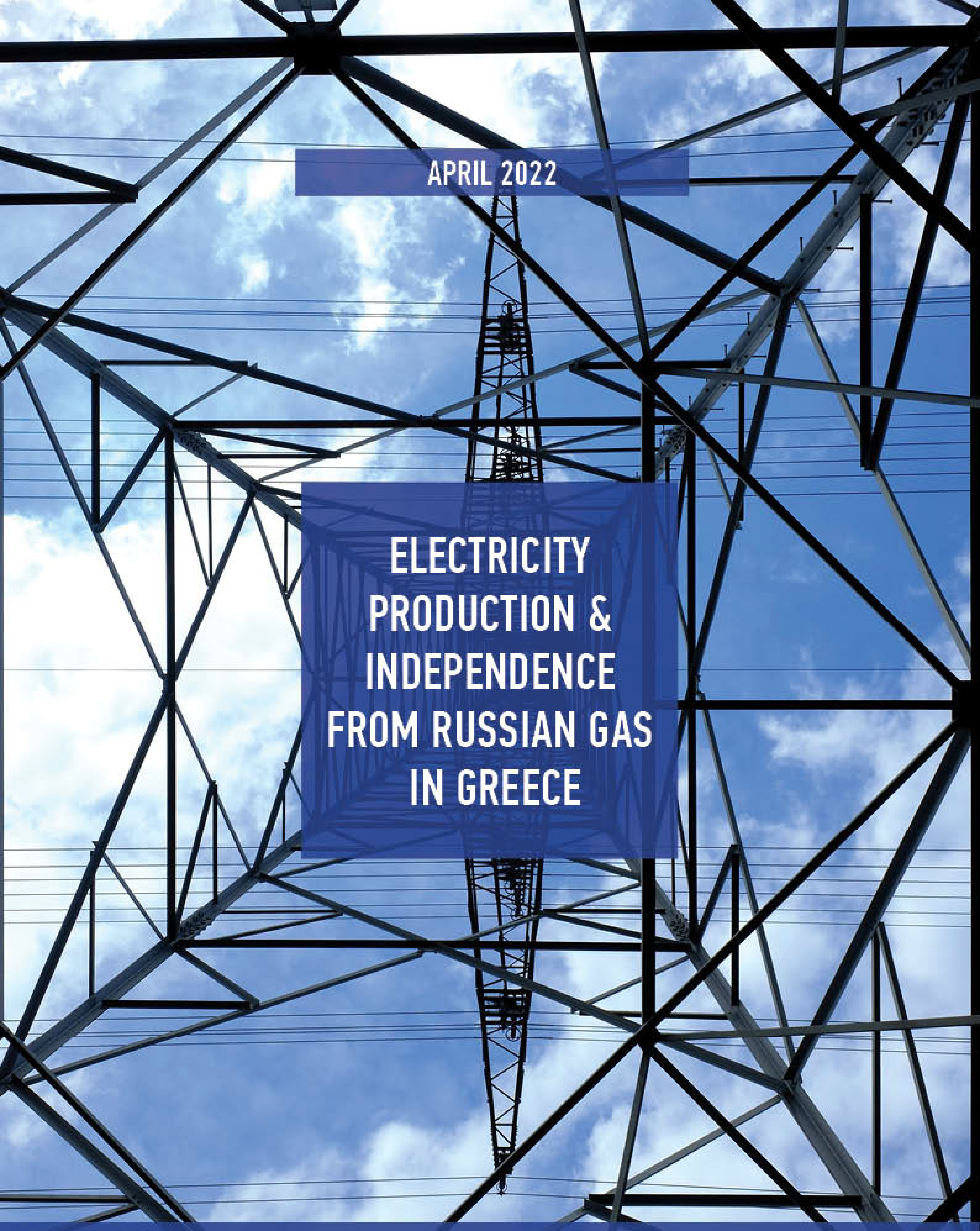

APRIL 2022

ELECTRICITY PRODUCTION & INDEPENDENCE FROM RUSSIAN GAS IN GREECE

The Green Tank Policy solutions for a sustainable future

Electricity Production & Independence from Russian gas in Greece

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For citation:
The Green Tank (April, 2022) "Electricity Production & Independence from Russian gas in Greece"

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Introduction

If the war unleashed by Russia on Ukraine on 24 February 2022 has revealed anything, it is that Europe's dependence on fossil fuels seriously undermines its ability to put an end to it. Since the beginning of the war, the EU-27 has already paid Russia more than 35 billion euros[1,2] for fossil fuels; if we continue at this rate, this amount will exceed 200 billion euros by the end of 2022. The lion's share corresponds to fossil gas with 62% of the total amount, followed by oil and coal with 35% and 3%, respectively.

The EU's ability to make a decisive contribution to peace, as well as to successfully protect the European economy from the consequences of war, is clearly and directly linked to the rate at which it shall achieve independence from the fossil fuels it imports from Russia, and particularly fossil gas. To this end, the European Commission announced on March 8 the RePowerEU plan[3], which aims, inter alia, to reduce dependence on Russian gas by 2/3 -namely, 100 billion cubic meters (bcm)- by the end of 2022. Sixty per cent of this reduction will be achieved via the supply of gas from other sources (LNG and other pipelines), while the remainder via accelerating the development of renewable energy sources (RES) in electricity production, the installation of heat pumps, the production of biomethane and green hydrogen, as well as through additional measures to boost energy efficiency. A few days later in Versailles[4], both the President of the European Commission and the Heads of Member States set a target of complete independence from imports of all Russian energy products (gas, oil and coal) by 2027. In addition, an independent analysis[5], carried out by four think tanks, demonstrates that the potential for developing RES, replacing fossil fuel-based heating systems with heat pumps, and increasing energy efficiency in the EU-27 is being underestimated in the European Commission's plan. Thus, complete independence from Russian gas (155 bcm in 2020) is feasible by 2025, and, what is more, without the need to build new fossil gas storage infrastructure.

Until 2019, Greece's reliance on fossil gas, and Russian gas in particular, was below the European average. However, the sharp increase in its use in recent years, especially in electricity production, made the country vulnerable to the energy price crisis that has been raging since the second half of 2021 and worsened following the start of the war in Ukraine. As a result, and so soon after its decision to phase out lignite, Greece finds itself once again at an energy crossroad, having to choose between structurally different paths.

In order to make a constructive contribution to the relevant public debate, we conducted the present analysis; our aim is to quantitatively assess the potential of decoupling from Russian fossil gas that accompanies different policy options. We focused on the power sector for a specific reason: Greece uses more than 2/3 of the fossil gas consumed domestically for electricity production. This percentage is much higher than the corresponding European

[1] Europe Beyond Coal, Russian fossil fuel tracker: https://beyond-coal.eu/russian-fossil-fuel-tracker/
[2] Euronews, 6.4.2022, "EU has spent €35bn on Russian energy since the war began and just €1bn on aid to Ukraine – Borrell", https://bit.ly/3JPjsJQ
[3] European Commission 8.3.2022. "REPowerEU: Joint European Action for more affordable, secure and sustainable energy", https://bit.ly/3jI84Vg
[4] CNN, 11.3.2022 "Europe sets 2027 deadline to end reliance on Russian oil and gas", https://cnn.it/3KR570C
[5] Ember, E3G, RAP, Bellona, 23.3.2022, "EU can stop Russian gas imports by 2025", https://bit.ly/3M5HzW8

average. Therefore, in Greece's case, the substitution of fossil gas in electricity production by other technologies is more impactful for achieving independence from Russian gas, compared to other European countries where the share of electricity production in fossil gas end-uses is much lower.

In the next section, the exposure level of EU Member States to Russian fossil gas and fossil gas as a whole is presented, using Eurostat data. Subsequently, the evolution across time of the diversification of sources from which Greece obtains fossil gas is presented, based on Eurostat data, along with the corresponding distribution of end-uses of the imported fossil gas, based on the data of The Hellenic Gas Transmission System Operator S.A. (DESFA). Having defined Greece's levels of dependence on Russian gas, based on the most recent data, four scenarios are then developed regarding the evolution of the electricity production mix and the potential for fossil gas substitution for the period 2022-2030, which constitutes the duration of implementation of the National Energy and Climate Plan (NECP). The first scenario is the existing official planning of the country, as outlined in the NECP; it stipulates an exact time line for the retirement of existing lignite plants, a 61% share of renewables in gross final electricity consumption by 2030, and a high share of fossil gas in the energy mix. The second scenario is based on a reversal of the lignite phase-out plan; it examines the potential of maximizing the use of lignite in order to displace fossil gas from electricity production. The third and fourth scenarios maintain the lignite phase-out program exactly as described in the existing NECP, but substitute fossil gas in electricity production with a forward-bearing development of wind and photovoltaics, with the ultimate goal of attaining, respectively, a 70% and 75% penetration of RES in gross final electricity consumption (GFEC) by 2030. The former scenario, aiming at a 70% penetration of RES in the GFEC, is in line with the relevant commitments of the Minister of Environment and Energy[6] regarding RES integration in electricity production by 2030 -to be set during the revision of the NECP- while the latter scenario reflects more ambition. For each scenario, the attainable reduction of electricity generated from fossil gas is calculated in relation to the amount of primary energy from Russian fossil gas that covered part of domestic fossil gas consumption in 2021. Furthermore, the climate footprint -in terms of CO_2 emissions- of the respective four electricity mixes for the entire period 2022-2030 is also estimated.

[6] Ministry of Environment and Energy 5.2.2022. Interview of Kostas Skrekas, Minister of Environment and Energy, to journalist Christos Kolonas for the "Ta Nea Savatokiriako" newspaper, https://bit.ly/37lOagg

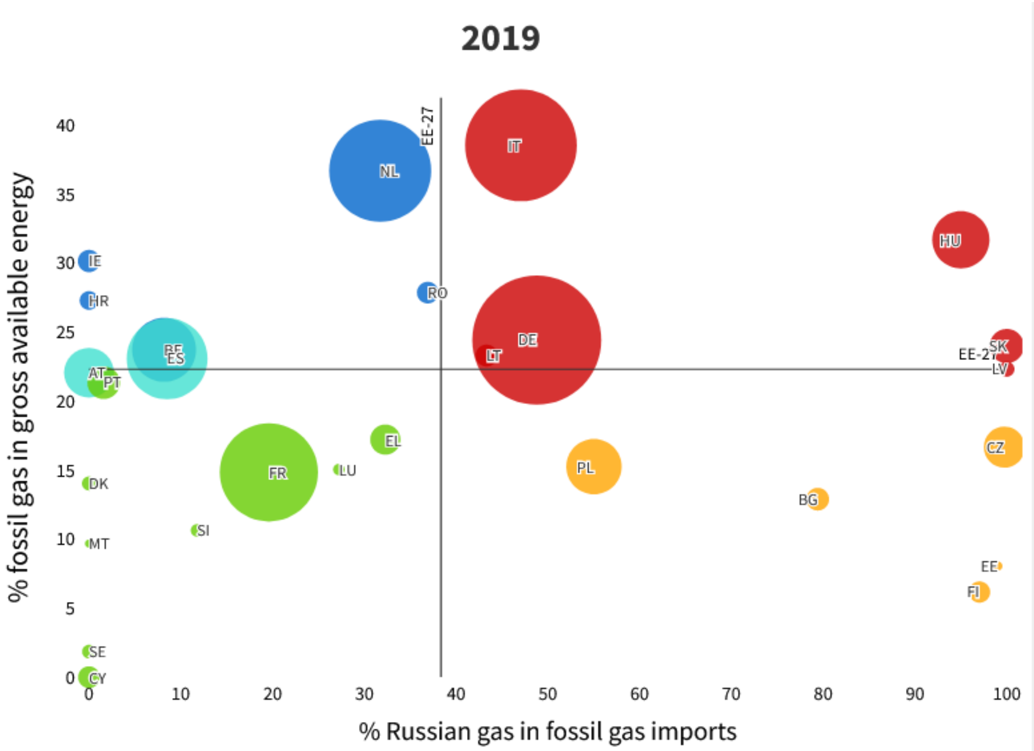
Dependence on Russian gas in the EU-27

While the aforementioned plans (such as RePowerEU) concern the EU-27 as a whole, the difficulty of decoupling from Russian fossil gas varies considerably among countries. The two figures below illustrate, for two consecutive years (2019 and 2020), the position of the 27 Member States with respect to two key parameters, describing the degree of dependence of the 27 European economies on fossil gas overall (share of fossil gas in gross available energy) and Russian gas in particular (share of Russian gas in total fossil gas imports). In addition, the size of each circle reflects the level of total imports in absolute terms.

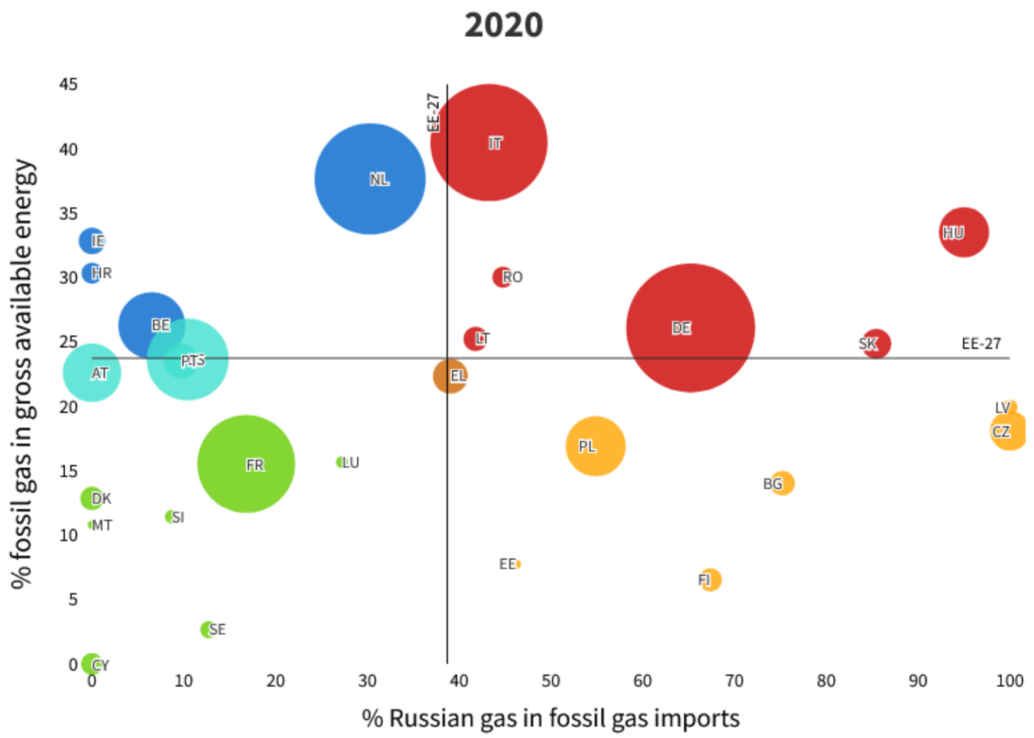
As shown in these figures, the EU-27 averages on these two parameters create four quadrants. Member States in the top-right quadrant face the greatest challenge, as both the reliance of their economies on gas overall and the share of fossil gas imported from Russia exceed the European average. Member States in the bottom-right quadrant have a higher-than-average dependence on Russian gas imports; nonetheless, their economies overall rely on fossil gas less than the EU-27 average. Member States in the top-left quadrant are more dependent on fossil gas than the European average but less exposed to imports from Russia. Finally, Member States displayed in the bottom-left quadrant are in the most favorable position since both the dependence of their economy on fossil gas and the share of Russian gas in their imports are below the European average.

Among the large EU-27 economies, it is evident that primarily Germany and Italy, and secondarily the Netherlands, face the greatest challenge in decoupling from Russian gas; on the contrary, France's economy is consistently below the European average with regard to dependence on both gas overall and Russian gas in particular.

As also illustrated in the following figures, the Member States that moved in the wrong direction from 2019 to 2020 are Germany, Romania and Greece. On the one hand, Germany increased its exposure to Russian gas (from 49% of imports in 2019 to 65% in 2020), keeping the share of gas in gross available energy nearly stable; on the other hand, Romania and Greece showed large increases in both parameters, with the most significant changes observed in the case of Greece.



Sources: Eurostat [nrg_ti_gas] & [nrg_bal_s]



Sources: Eurostat [nrg_ti_gas] & [nrg_bal_s]

Figure 1: Percentage of fossil gas in the gross available energy and percentage of Russian fossil gas in total imports for the years 2019 (above) and 2020 (below). Source: Eurostat

Greece

Specifically, in Greece, the use of gas in gross available energy increased by more than 5 percentage points between 2019 and 2020 (from 17.2% in 2019 to 22.3% in 2020), while the share of Russian gas in imports increased by 7 percentage points from 32.2% in 2019 to 39% in 2020. As a result, while Greece was clearly among the EU-27 countries with the lowest dependence on both Russian gas and fossil gas overall in 2019, only a year later it converged onto the European average on both parameters.

Nonetheless, as illustrated in the figure below, the share of Greece's fossil gas imports originating from Russia had been significantly higher during the past decade. In particular, during the period 2011-2018, it fluctuated between 56% (2012) and 66% (2018), before it fell to 32% and 39% in 2019 and 2020, respectively. The significant diversification of supply sources of fossil gas and especially LNG in recent years played a decisive role in this decrease in dependence on Russia. LNG, in particular, accounted for more than half of the imported quantity in 2019 (54.7%) and 2020 (52.8%).

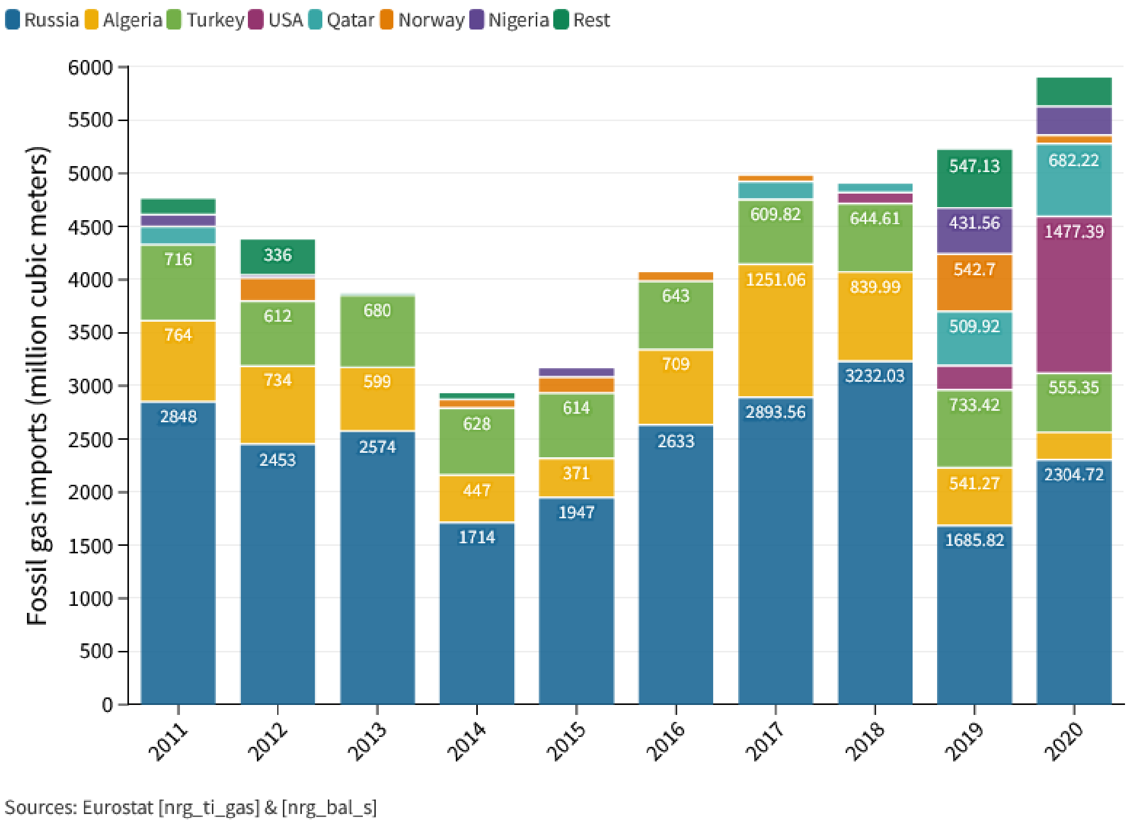


Figure 2: Time evolution of fossil gas supply sources in Greece. Source: Eurostat

Overall, Greece has imported fossil gas from 17 countries in different years over the past decade; the greatest diversification occurred in 2019, with fossil gas imports originating from 12 countries. In aggregate, the lion's share was delivered by Russia, accounting for 55% of Greece's imports throughout the decade, followed by Algeria and Turkey with shares of approximately 15% each. However, it is noted that Greece's second largest source of gas imports -after Russia- in 2020 was the U.S. with 1.48 bcm of LNG.

On the other hand, despite the decrease in the share of imports from Russia observed in 2019 and 2020, the absolute quantity of imported Russian gas in 2020 remained at high levels (2.3 bcm), as overall gas use and imports in Greece experienced a surge (+24% between 2011 and 2020). Especially after 2014, the role of gas has been continuously reinforced every year, with the exception of 2018 when imports were slightly lower than in 2017. Therefore, the beneficial reduction of reliance on Russian gas, which had resulted from the diversification of fossil gas supply sources, was partially offset by the increase in overall gas consumption.

End uses of fossil gas in Greece

In order to assess Greece's prospects for independence from Russian gas, it is necessary to consider each of the end uses of gas separately. Based on official data from the DESFA[7] regarding the three-year period 2019-2021, approximately 2/3 of fossil gas are used in electricity production, with quantities rising every year (+28% between 2019 and 2021). Gas use by households and businesses accounts for 19% of domestic consumption, while large industries utilize the remaining 15%, on average. As shown in Figure 3 below, this distribution among the three end-use categories has remained nearly stable over the past three years. Greece's distribution of fossil gas uses is very different from that of the EU-27, where domestic use in buildings dominates with 35%, followed by electricity and heat generation (31%) and industrial consumption (23%)[5].

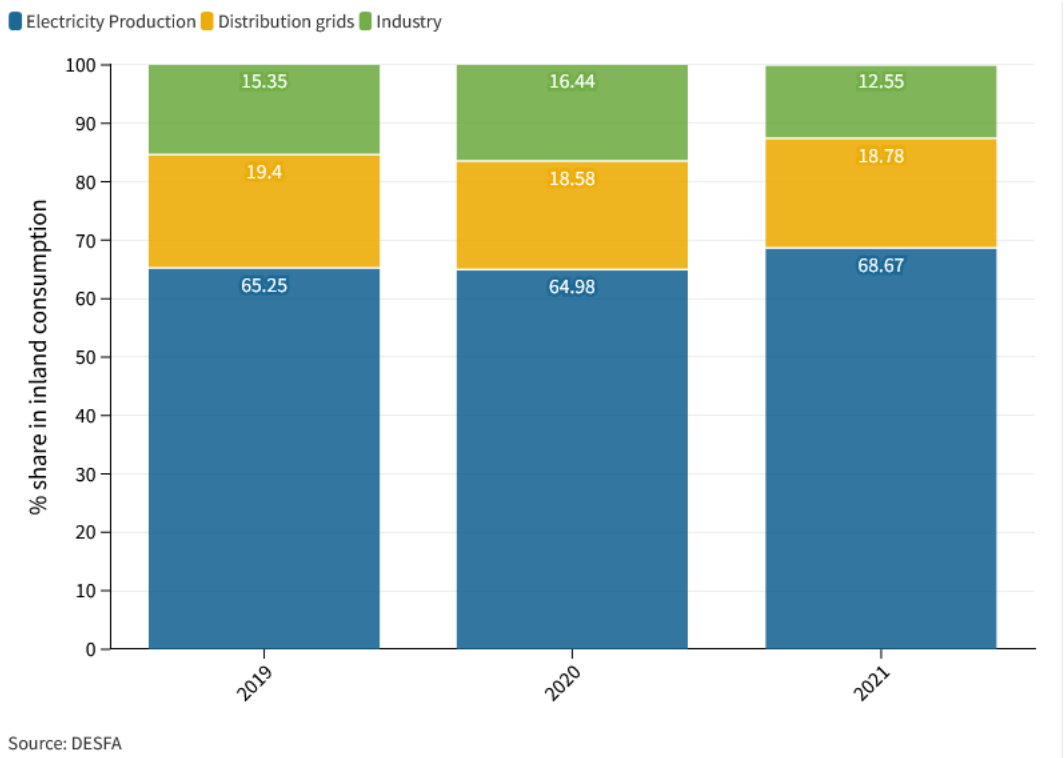


Figure 3: Distribution percentages of fossil gas end uses (2019-2021) Source: The Hellenic Gas Transmission System Operator S.A. (DESFA)

[7] DESFA https://www.desfa.gr/

The same data show that, during the period 2019-2021, Greece injected each year an average of 42.2 TWh of fossil gas into power plants. According to the official data of the DESFA, the total domestic consumption of primary energy from fossil gas peaked in 2021 reaching 70 TWh[8] and 45% of this energy entered Greece through the Turkstream pipeline (through the Sidirokastro station), which is supplied by Russia. Moreover, part of the gas imported from Turkey also originates from Russia, and, therefore, should be added to that coming directly from Russia. According to the DESFA, Greece's imports from Turkey in 2021 amounted to 5.17% and in the same year Turkey imported 45% of its gas from Russia[9]; thus, it is estimated that a combined total of approximately 33.4 TWh (47.8%) of the primary energy from fossil gas consumed by Greece in 2021 came from Russia.

[8] DESFA, 19.1.2022 "DESFA data regarding natural gas consumption in 2021" https://bit.ly/3KRGq4b
[9] Mees, 4.3.2022, "Turkey 2021 Gas Imports: Ukraine War Puts Russia Reliance In Focus", https://bit.ly/3xy4ndd

Scenarios for decoupling from Russian gas

Greece uses the largest share of imported fossil gas for electricity production; therefore, substituting gas with alternative technologies institutes increased potential for decoupling from Russian gas, in comparison to other European countries, where electricity production is less dominant in fossil gas end-uses.

There are two structurally different approaches to fulfilling this target, namely gas substitution. The first approach suggests that fossil gas should be replaced by domestic lignite; this proposition has enjoyed strong support in the public debate since the autumn of 2021, as fossil gas supply prices started to spike. The second alternative advocates the substitution of fossil gas in electricity production by renewable energy sources, and, particularly, by the more mature technologies, namely wind and photovoltaics. This solution is based on the fact that electricity production from RES is not only the most climate and environmentally friendly option, but also the most cost-effective, compared to that based on fossil fuels, especially nowadays. In order to assess the above alternatives quantitatively, the following 4 scenarios were developed:

NECP Scenario (S1-NECP): This scenario reflects Greece's official energy plan towards 2030, which is currently in force. The evolution of the power sector in terms of all technologies, net imports, self-consumption and final electricity demand is adopted exactly as in the existing NECP (see Table 1). Thus, based on the latter, a RES share in gross final electricity consumption (GFEC) of almost 61% is achieved by 2030, while all existing lignite plants are retired by 2023, and only Ptolemaida V operates between 2024 and 2028. It is reminded that the NECP is currently under review, since the 42% reduction in total GHG emissions by 2030 -compared to 1990 levels- sought by the existing NECP falls significantly short of the new national target of reducing net emissions by at least 55% by 2030, as reflected in the draft national climate law. With regard to the intermediate years between 2022 and 2030, for which the NECP does not provide data, it is assumed that the figures evolve linearly between the years adjacent to those with specific available data (i.e. 2022, 2025, 2027 & 2030).

Table 1: Sources covering electricity demand in GWh. Source: current NECP

Technology/Year	2022	2025	2027	2030
Lignite	5199	4536	4538	0
Fossil gas	21894	19169	16229	18304
Oil	2723	2209	1892	828
Wind	10090	12610	14398	17208
Photovoltaics	5967	8202	9712	11816
Hydroelectric energy	6410	6528	6581	6596
Bioenergy	539	772	974	1575
Solar thermal energy		257	258	260
Geothermal energy			252	631
Net imports	5165	4946	4752	4578
Self-consumption	1602	1398	1276	708
Total demand	57986	59228	59586	61797

"Return" to lignite scenario (S2-Lignite): In this scenario, all quantities of electricity are taken to be as in the existing NECP (see Table 1), with the exception of the electricity produced from lignite and fossil gas. Each year's electricity sum is considered constant and equal to the projections in the existing NECP, but the ratio of these two fossil fuels in the electricity production mix differs. The ratio is chosen in order to maximize the use of lignite, which is, however, subject to certain legal restrictions. In particular, the recent decision by the Director General of Environmental Policy of the Ministry of Environment and Energy allows for the operation of lignite plants for a maximum number of hours with weaker emission limit values (ELV) than those established by the 2017 Best Available Techniques (BAT)[10]. Table 2 lists the hours of this derogation from EU law for each of the existing lignite plants, as granted by the Ministry of Environment and Energy in December 2021, along with the respective valid time period.

Table 2: Maximum allowed operating hours of existing lignite power plants and period of validity. Source: Decision of the Ministry for Environment and Energy (ΑΔΑ: 9ΨΧ04653Π8-ΞΧΩ)

Steam Electric Power Station	Net capacity (MW)	Hours	Period
Agios Dimitrios I-II	548	7500	1.7.2020-30.6.2025
Agios Dimitrios III-IV	566	13600	1.8.2021-31.12.2023
Agios Dimitrios V	342	35600	1.8.2021-31.12.2025
Meliti I	289	11000	1.8.2021-31.12.2023
Megalopoli IV	256	35600	1.8.2021-31.12.2025

Utilizing the data of the Independent Power Transmission Operator S.A. (IPTO), the hours during which the units operated until 31.12.2021 are first calculated and then subtracted from the total available hours. Subsequently, based on each plant's capacity, the maximum allowed electricity production is calculated and equally distributed to each year within the derogation period. "Ptolemaida V", the new PPC lignite plant, is assumed to be in full commercial operation as of January 1, 2023, each year running for 7365 hours and producing 4536 GWh, in line with the projections of the existing NECP. This plant's operation with lignite as a fuel is assumed to cease in 2028, in compliance with the NECP provisions and the relevant commitments made by the Greek Prime Minister during his speech at the UN in September 2019[11]. In order to obtain the quantity of fossil gas-fueled electricity production corresponding to each year, the maximum allowed annual amount of lignite-generated electricity is subtracted from the sum of the two energy sources that the NECP provides for in a given year.

Figure 4, below, shows the evolution of the electricity production mix up to 2030, based on the first two scenarios: S1-NECP and S2-Lignite; the figure also includes the corresponding data of the period 2011-2021, based on the official data of IPTO and the Hellenic Electricity Distribution Network Operator S.A. (HEDNO) regarding, respectively, the interconnected grid and the non-interconnected islands.

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[10] DECISION BY THE DIRECTOR GENERAL OF ENVIRONMENTAL POLICY OF THE MINISTRY OF ENVIRONMENT AND ENERGY, ENTITLED: Approval of applications for the Steam Electric Power Stations of Atherinolakkos (Units I-II), Meliti (Unit I), Megalopolis (Unit IV), Agios Dimitrios (Units I-II, III-IV, V) of PPC S.A. and its subsidiaries to be subject to the provisions of articles 12.4 and 27.1 of JMD 36060/1155/E.103/2013 (GG B 1450), as in force, ΑΔΑ: ΨΗΙ34653Π8-ΑΓΒ, https://bit.ly/3M8VeLZ

[11] 23.9.2019 "Speech by Greek Prime Minister Kyriakos Mitsotakis at the Climate Summit", https://primeminister.gr/2019/09/23/22241

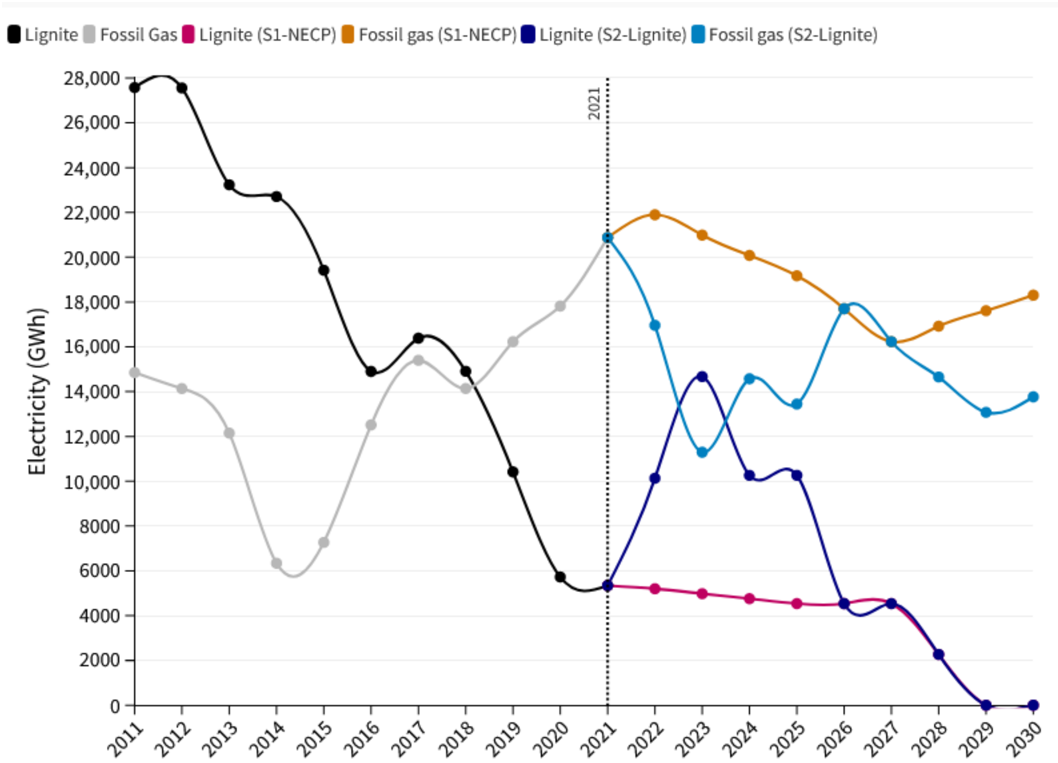


Figure 4: Evolution of the electricity produced by lignite and fossil gas, based on the S1-NECP an S2-Lignite scenarios. The electricity production from these energy sources for the period 2011-2021 is shown in full lines (sources: IPTO, HEDNO), while dotted lines show the corresponding projections of the two scenarios. S1-NECP is presented in shades of red (red, orange), while S2-Lignite is presented in shades of blue (blue, light blue)

The two scenarios differ significantly during the period 2022-2025. In the lignite scenario (S2-Lignite), lignite-fueled plants run at the maximum allowed level, complying with the derogation granted by the Ministry of Environment and Energy, while the operation of fossil gas plants is reduced accordingly. In the NECP Scenario (S1-NECP), lignite follows the downward trend of recent years, however, at a slower pace, as Ptolemaida V enters commercial operation in 2023; on the other hand, gas levels rise, so as to cover lignite's decline. Nonetheless, from 2026 onwards, the two scenarios converge, as the existing lignite units' allowed operating hours are exhausted and lignite-based electricity production exclusively from Ptolemaida V is regulated by the existing NECP and, therefore, identical in both cases.

<u>Achieving a 70% RES penetration in gross final energy consumption (GFEC) scenario (S3-RES70%):</u> In this scenario, all electricity quantities are adopted from the existing NECP (see Table 1), with the exception of electricity produced from wind, photovoltaics and fossil gas. Specifically, it is assumed that the contribution of the two most mature RES technologies is so significant that all RES combined -including all technologies and large hydroelectric stations- shall have a share of 70% in GFEC by 2030, which is also in line with the relevant commitments of the Minister of Environment and Energy[6]. Assuming that the GFEC in this scenario is that set forth by the existing NECP, in order for RES to reach a 70% share in 2030, in that same year, an estimated 5,67 TWh of electricity will be required from wind and photovoltaics in addition to the stipulations of the existing NECP. Here, it is also assumed that all additional electricity from wind and photovoltaics shall equivalently reduce the contribution of fossil gas. In other words, the sum of electricity generated from wind, photovoltaics and fossil gas is considered constant

and as projected by the existing NECP; only the relative contribution of these three technologies is assumed to change.

The capacity of wind and photovoltaics required in addition to that stipulated by the existing NECP in order to achieve a 70% share in GFEC in 2030 was assumed to be shared equally between the two technologies, while the respective load factors were estimated according to the NECP data. Under these assumptions, and starting from an installed capacity of 4.65 GW (wind) and 4.18 GW (photovoltaics) in 2021, the total installed capacity of wind and photovoltaics in 2030 was calculated at 8.42 GW and 9.12 GW, respectively; therefore, this scenario foresees 1.42 GW of additional capacity per technology by 2030, compared to current NECP projections.

In order to achieve a faster decoupling from Russian gas, a forward-bearing timetable was selected regarding the installation of wind and photovoltaics. Thus, according to this scenario, the largest part of new capacity of renewables is installed in the next three-year period (2022-2024), with an installation rate of 1 GW per technology per year. Consequently, 3 GW of wind and 3 GW of photovoltaics will be installed by 2024, accounting for 80% and 61%, respectively, of the total new capacity required by 2030. In the period 2025-2030, the remaining capacity required from each technology is added linearly but at a much slower rate (130 MW of wind and 250 MW of photovoltaics per year).

It should be emphasized that the assumption of 1GW of wind and 1 GW of photovoltaics being installed each year during the first three years is consistent with the latest available planning of the Renewable Energy Sources Operator & Guarantees of Origin S.A. (DAPEEP)[12], as described in the latest Special RES Account report. DAPEEP estimates that 910 MW of new wind and 950 MW of new photovoltaics will be installed during 2022. Furthermore, it should be underlined that DAPEEP's assumptions on RES penetration are often conservative and surpassed by reality. Notably, in 2019, DAPEEP predicted[13] that 440 MW of wind and 350 MW of photovoltaics would be installed in 2020. Yet, the capacity ultimately installed was 536 MW and 447 MW, respectively[12], thus, exceeding the aforementioned predictions by 22% (wind) and 28% (photovoltaics).

Achieving a 75% RES penetration in gross final energy consumption (GFEC) scenario (S4-RES75%): This scenario employs the same assumptions as the previous one (S3-RES70%); it only differs in that the targeted share of RES in the GFEC in 2030 is 75%. Following the same reasoning as in S3-RES70%, the additional amount of electricity from wind and photovoltaics required to achieve this target is calculated at 8.79 TWh; the total installed capacity of wind and photovoltaics in 2030 should be 9.2 GW and 9.9 GW respectively, namely, 2.2 GW of additional capacity per technology by 2030, as compared to current NECP projections. The timetable selected for the installation of wind and photovoltaics during the first three years was taken to be identical to S3-RES70% (i.e. 1 GW per year per technology); subsequently, a linear increase in capacity was implemented at a lower rate (260 MW of wind and 380 MW of photovoltaics per year) until the final target in 2030.

[12] DAPEEP, 31.3.2022 "Monthly Sheet of Special RES & CHP Account, November-December 2021" https://bit.ly/37VmOxJ
[13] DAPEEP, 27.3.2020 "Monthly Sheet of Special RES & CHP Account, November-December 2019" https://bit.ly/3Me2OoR

Finally, it is noted that the gross final electricity consumption might be set higher in the revised NECP, as compared to the current plan, due to the need for a more widespread electrification of transport, industry and heating in buildings, so as to meet the new climate target of a 55% reduction of net greenhouse gas emissions by 2030. In this case, the electricity generated by RES, which is included in scenarios S3-RES70% and S4-RES75% would correspond to GFEC shares lower than 70% and 75%, respectively.

Figure 5, below, presents the evolution of the electricity mix for the two scenarios that aim at an increased RES share in GFEC. For comparison purposes, we also include the NECP scenario; the scenario favoring lignite has been presented in the previous figure.

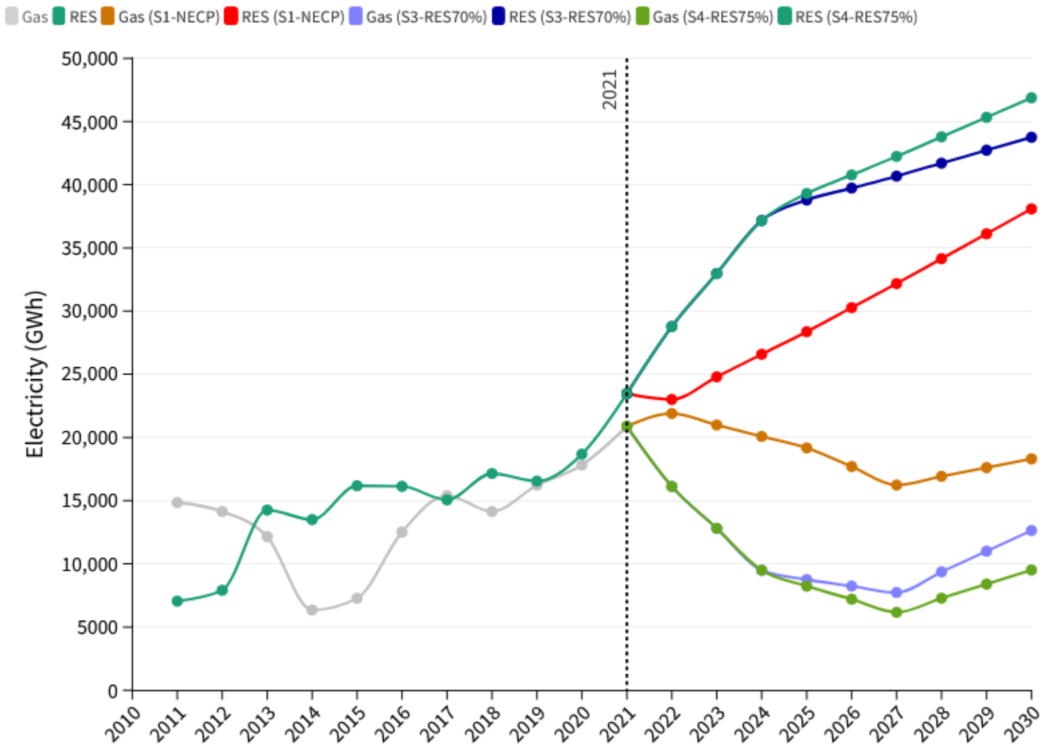


Figure 5: Evolution of the electricity produced by RES and fossil gas, based on the S1-NECP, S3-RES70% and S4-RES75% scenarios. The electricity production from these energy sources for the period 2011-2021 is shown in full lines (sources: IPTO, HEDNO), while dotted lines show the corresponding projections of the three scenarios. S1-NECP is presented in shades of red (red, orange); S3-RES70% is presented in shades of blue (blue, light blue); S4-RES75% is presented in shades of green (light green, dark green)

All three scenarios lead to a clear reduction in fossil gas. In fact, with regard to the trend of an aggressive surge in fossil gas use that has been observed especially in recent years, the two scenarios with the highest penetration of RES (S3-RES70% and S4-RES75%) foresee its complete and immediate reversal from 2022 onwards; the existing NECP, on the other hand, projects a peak in fossil gas electricity production in 2022 and a decrease from 2023 onwards. The S3-RES70% and S4-RES75% scenarios run identical up to 2024, as they were designed, and differ only in their projections for the period 2025-2030. Moreover, all scenarios foresee a partial gas spike between 2028 and 2030. This is due to the fundamental planning included in the existing NECP, according to which the electricity deficit that will arise between 2028 and 2030 -following the complete lignite phase-out- shall be partially covered by fossil gas (in addition to renewables).

Reducing dependence on Russian gas

In the next step of the analysis for each of the 4 scenarios, we estimated the levels of independence from Russian fossil gas attained in relation to the 2021 imports of primary energy in the form of Russian gas (33.4 TWh). Specifically, for each year within the period 2022-2030, first, the difference between the gas-fueled electricity production of that year and that of 2021 (20.873 TWh, according to HEDNO data[14]) was calculated. Next, taking into account this difference and considering the average efficiency of fossil gas power plants to be equal to 50%, the corresponding amount of primary energy from fossil gas saved in that given year was calculated; finally, this figure was expressed as a percentage of the total amount of primary energy from Russian fossil gas that covered domestic consumption in all sectors in 2021 (electricity production, distribution grids and industry). Figure 6, below, presents the time-evolution of the percentages of primary energy savings from Russian fossil gas for all 4 scenarios.

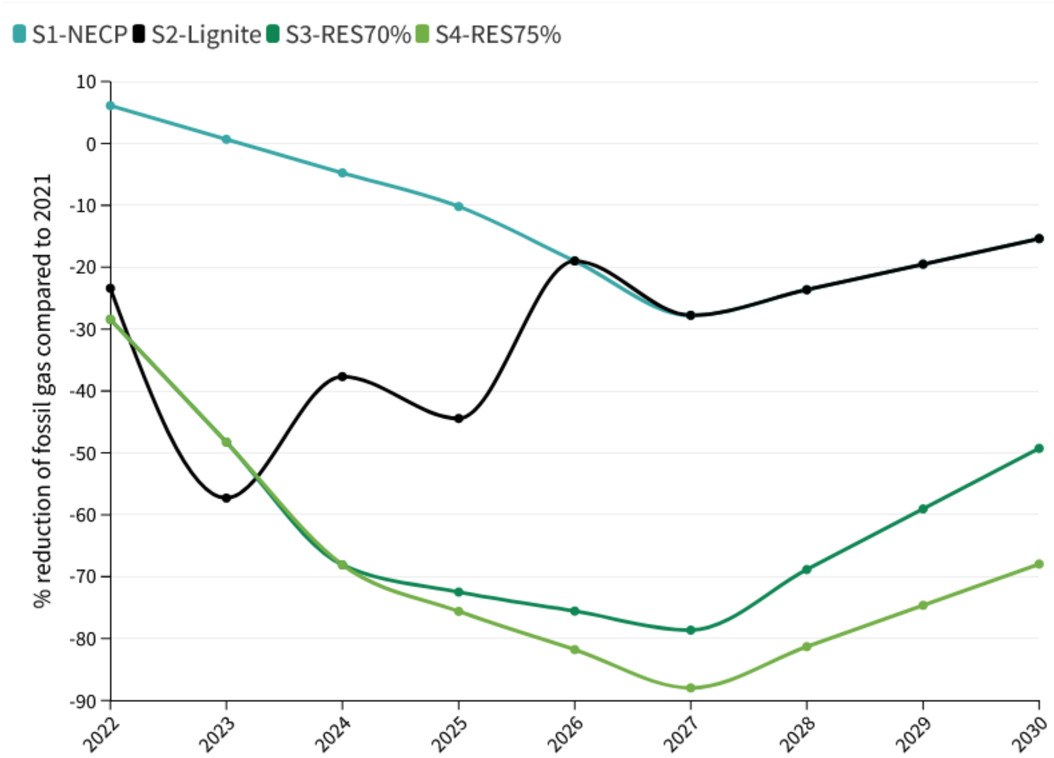


Figure 6: Time-evolution of the percentages of Russian fossil gas primary energy savings, according to the 4 scenarios considered.

All scenarios, with the exception of the "return" to lignite scenario (S2-Lignite), manifest a peak in the reduction of Russian gas use in 2027; this is due to the fact that, in 2027, the use of fossil gas in electricity production reaches its minimum for the entire period (see Figure 6) and, therefore, Russian gas savings are maximized. In contrast, in the case of S2-Lignite, the minimum use of gas occurs in 2023. In that year, all currently existing lignite plants are still allowed to operate, while Ptolemaida V also enters the picture; as a result, 2023 marks the peak of lignite-based electricity production for the period 2022-2030 with 14.7 TWh (reaching lignite-based electricity production levels of the year 2018).

[14] IPTO, Monthly Energy Sheet, December 2021, https://bit.ly/3rshMzG

However, despite the fact that gas reduction peaks early on in S2-Lignite, the absolute value of this maximum reduction in 2023 (-57.3%) is much lower than the corresponding values observed in the 2 RES-based scenarios in 2027, namely, -78.6% in S3-RES70% and -88% in S4-RES75%. Moreover, with regard to the four-year period 2022-2025, when both the existing lignite plants and new Ptolemaida V are assumed to operate at their maximum potential, dependence on Russian gas is cumulatively reduced by 40.7% in the case of S2-Lignite, compared to 54.3% and 55.1% in S3-RES70% and S4-RES75%, respectively. Furthermore, the implementation of a forward-bearing development of RES in the first three years in both RES-based scenarios (S3-RES70% and S4-RES75%) achieves 68.1% of Russian fossil gas primary energy savings in 2024; in fact, this occurs as a direct outcome of the installation of 1 GW of new capacity per year and per technology (wind and photovoltaics).

Scenario comparison with regard to the possibility of an immediate reduction of dependence on Russian gas within 2022 is of particular interest. According to S2-Lignite, lignite combustion in 2022 could be increased to the -legally allowed- maximum, adding more than 10 TWh to the system (nearly double the amount of lignite-based electricity production seen in 2020 and 2021); nonetheless, the results show that, even in this case, Russian gas savings -namely -23.4%, as compared to 2021 levels- will be inferior to those resulting from the installation of 2 GW of new RES capacity (-28.4%), namely 1 GW of wind and 1 GW of photovoltaics.

The scenarios also differ significantly in terms of the average reduction in dependence on Russian fossil gas achieved over the entire period 2022-2030. In the case of S1-NECP, it is merely 12.6%, while the corresponding value for S2-Lignite is 29.8%. It should be noted that, if the operation of Ptolemaida V were extended beyond 2028, as suggested by various sources, the additional reduction in dependence on Russian gas in the period 2022-2030 would be limited to seven additional percentage points (37.3%). The two scenarios of increased RES penetration, on the other hand, foresee a much greater independence from Russian gas. More specifically, according to the scenario aiming at a 70% RES share in the GFEC in 2030, the average Russian gas savings for the period 2022-2030 approximate 61%, while the corresponding figure in the case of S4-RES75% is 68.2%.

Climate footprint

In addition to Russian fossil gas savings, the 4 scenarios were also compared in terms of carbon dioxide emissions for the period 2022-2030. Based on the historical data of the EU Emissions Trading Scheme (ETS) and the electricity production data of HEDNO, the carbon intensity of lignite and fossil gas power plants was calculated as the average of the five-year period 2016-2020. Given that, in the S1-NECP, S3-RES70% and S4-RES75% scenarios, the only operating lignite plant after 2023 is Ptolemaida V, the carbon intensity used in the respective calculations was lower and equal to 1tCO_2/MWh; in the case of S2-Lignite, where it is assumed that certain of the existing lignite plants operate until 2025, this reduced carbon intensity value was used only for the period 2026-2028. Based on these assumptions, the entire period’s (2022-2030) electricity production mix emissions were calculated for each of the 4 scenarios and are presented in Figure 7, below, along with the historical emissions of lignite and fossil gas power plants, cumulatively, from the start of ETS operation in 2005 until 2021.

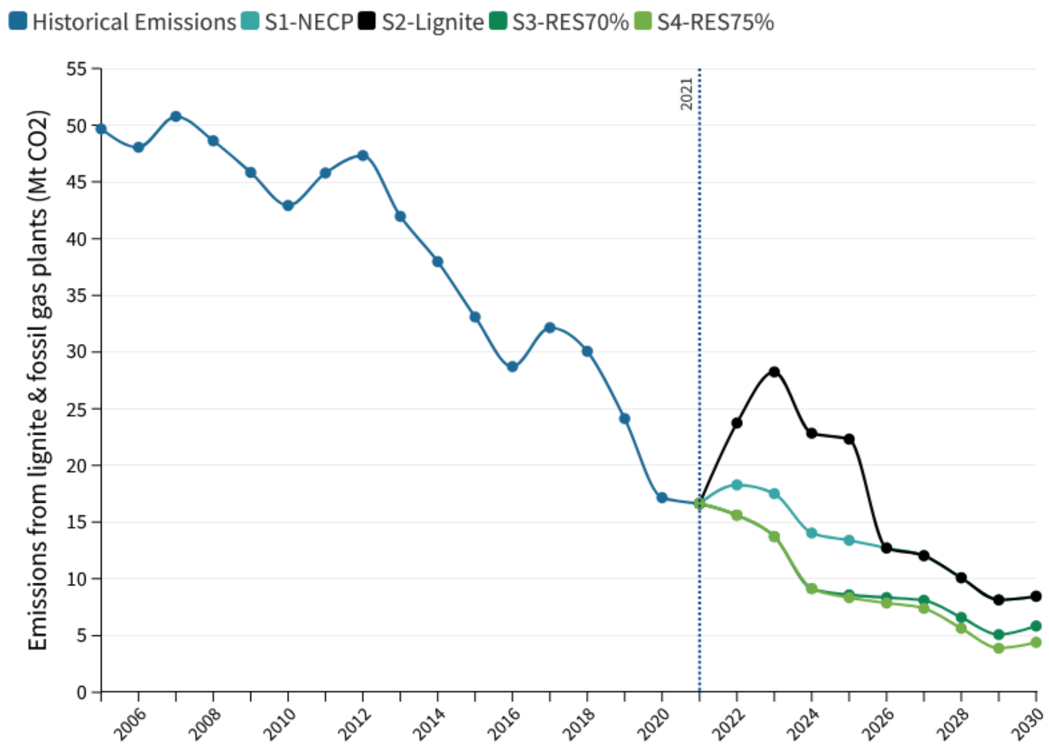


Figure 7: Estimated CO_2 emissions in million tonnes during the period 2022-2030 for each of the 4 scenarios and historical emissions during the period 2005-2021 (source: ETS)

In the "return" to lignite scenario (S2-Lignite), a highly significant increase in emissions is observed during the four-year period 2022-2025; thereafter, during the period 2026-2030, emissions converge on NECP levels, due to the exhaustion of all permitted operating hours of existing lignite plants. In contrast, the two RES-based scenarios remain on the power sector's emission reduction path that has been forged especially in recent years. These two scenarios are differentiated only in the period 2025-2030, with S3-RES70% and S4-RES75% leading to 5.8 million tonnes and 4.4 million tonnes of CO_2 emissions in 2030, respectively.

This expected increase in CO_2 emissions during the four-year period 2022-2025 in the case of S2-Lignite is sufficient to significantly differentiate the cumulative emissions of the four scenarios for the entire period 2022-2030, as illustrated in Figure 8. More specifically, the lignite-based scenario leads to cumulative emissions of 149 million tonnes of CO_2 (or 154 million tonnes if Ptolemaida V is kept in operation until 2030); this is nearly double the amount corresponding to the more climate-ambitious scenario, namely S4-RES75%, which foresees 76 million tonnes of cumulative CO_2 emissions. The S3-RES70% scenario, which is in line with the government's 2030 commitments, projects a total of 81 million tonnes of CO_2 emissions, namely, approximately 34 million tonnes and 68 million tonnes less than the emissions foreseen by the existing NECP and the "return" to lignite scenario, respectively. Therefore, shifting back towards lignite during the four-year period 2022-2025 and deviating from the path leading to a 70% RES penetration in gross final electricity consumption by 2030 will cost Greece, cumulatively, more than 2/3 of its 1990 net emissions (101 million tonnes of CO_2 equivalent).

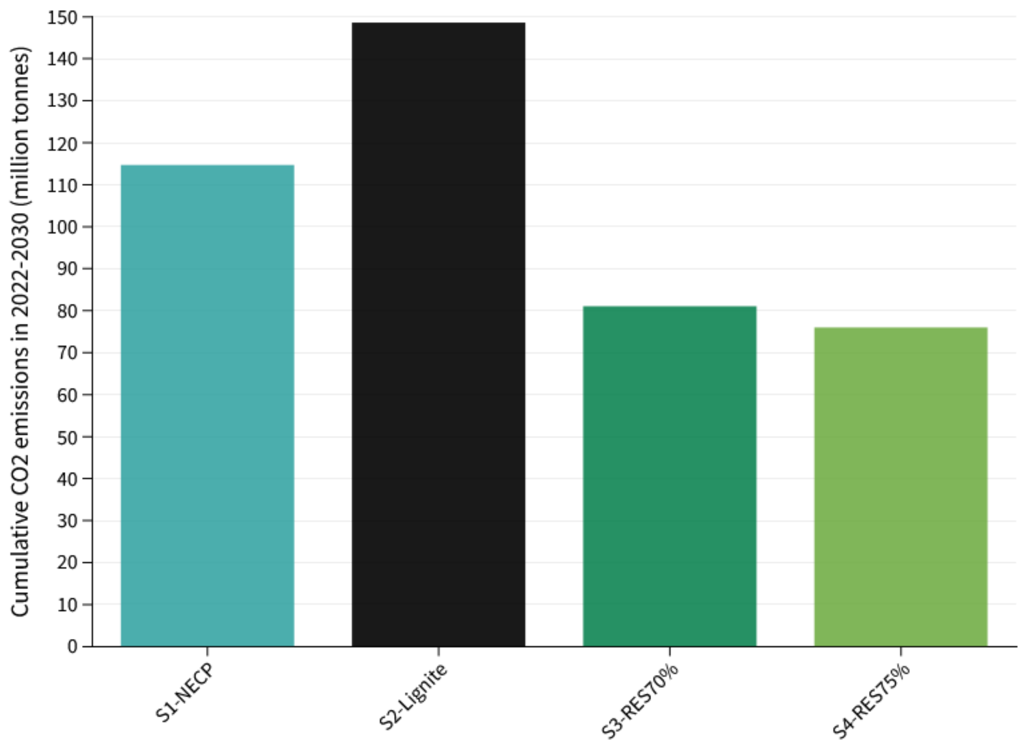


Figure 8: Estimation of cumulative CO_2 emissions in million tonnes over the period 2022-2030 for the 4 scenarios considered

Furthermore, under the (possibly conservative) assumption that -on average, for the period 2022-2030- the price of carbon on the emissions exchange will be at today's prices (80€/t), a return to lignite would burden the wholesale electricity market by 2030 with approximately an additional €5.4 and €5.8 billion, as compared to the CO_2 costs estimated in the S3-RES70% and S4-RES75% scenarios, respectively.

On average, over the entire period 2022-2030, the scenario maximizing the use of lignite (S2-Lignite) leads to 3.9 million tonnes of CO_2 emissions in addition to those projected in the NECP per year and to more than 7.6 million tonnes in addition to the average annual emissions foreseen in the scenario aiming at a 70% RES share (S3-RES70%), the latter being consistent with the announcements of the Minister of Environment and Energy. This difference is reduced to 2.7 million tonnes in 2030 (8.5 million tonnes in S2-Lignite compared to 5.8 million tonnes in S3-RES70%), corresponding to 2.7 percentage points of the whole country's net emissions in 1990.

In summary, the scenario shifting the country's energy path back to lignite would burden the climate budget of the power sector in the period 2022-2030 by an additional 68 and 73 million tonnes compared to the S3-RES70% and S4-RES75% scenarios, respectively. Thus, in order to meet the sectoral carbon budgets provided for by draft the climate law until 2030, large cuts will be required in other, more "challenging" sectors, such as industry or transport; whereas, in electricity production, there already exist mature and more cost-effective clean renewable energy alternatives to fossil fuels. At the same time, Greece's prospects for meeting the climate target set by the government (with cross-party consensus) to reduce net greenhouse gas emissions by at least 55% in 2030 compared to 1990 levels will fade.

Conclusions

The aim of this analysis was to quantitatively assess the potential that is inherent in different energy policy options for reducing Greece's dependence on Russian fossil gas. Its focus was electricity production, as more than 2/3 of the fossil gas covering domestic consumption is channeled into this sector. This share is higher than the European average; therefore, compared to other European countries, it is essential for Greece to examine the substitution of fossil gas in electricity production by other technologies.

Four scenarios regarding the evolution of the electricity production mix were developed and their potential to substitute Russian fossil gas in the period 2022-2030 was analyzed. The first scenario represents Greece's current planning, exactly as described in the National Energy and Climate Plan (NECP). The second scenario is based on an extension of lignite plant operation and the maximum utilization of lignite. The third and fourth scenarios maintain the lignite plant retirement time-line exactly as described in the existing NECP, but substitute fossil gas in electricity production with a forward-bearing development of wind and photovoltaics, with the ultimate goal of attaining, respectively, a 70% and 75% share of renewables in gross final electricity consumption by 2030. The degree of reduction of dependence on Russian fossil gas, which covered 47.8% of domestic consumption in 2021 in all uses, was calculated for each scenario, along with the corresponding carbon footprint of the four electricity production mixes for the period 2022-2030. The main conclusions drawn from the comparative analysis of the 4 scenarios can be summarized as follows:

- The scenario maximizing the use of lignite -up to legally allowed levels- reduces the dependence on Russian fossil gas more than the existing NECP but much less than the two scenarios aiming at a 70% and 75% RES share in the gross final electricity consumption. Taking the quantity of Russian gas that covered domestic consumption in 2021 as a reference point, the average annual reduction in dependence on Russian gas for the period 2022-2030 is 29.8% in the case of the lignite-based scenario, compared to 61% and 68.2%, respectively, for the two RES-based scenarios.

- Even in the short term, i.e. within 2022, the installation of 1 GW of wind and 1 GW of photovoltaics reduces dependence on Russian gas more than the scenario favoring lignite use (28.4% vs 23.4%). These levels of new wind and photovoltaic capacity are also in line with the latest available DAPEEP planning for 2022.

- Cumulatively, over the four-year period 2022-2025, the lignite-based scenario reduces dependence on Russian gas by 40.7%, while the RES-based scenarios achieve savings of 54.3% (S3-RES70%) and 55.1% (S4-RES75%), assuming the installation of 1 GW of new wind and 1 GW of new PV capacity per year over the three-year period 2022-2024.

- The lignite scenario leads to CO_2 emissions in 2022-2030 that exceed the respective amounts of both the existing NECP (by 34 million tonnes) and the 70% and 75% RES penetration scenarios by 68 million and 73 million tonnes of CO_2, respectively; therefore, maximizing lignite use also means derailing the country's climate budget for the power sector.

- By maintaining current CO_2 price levels on the emissions exchange until 2030 (a possibly conservative estimate), the scenario favoring lignite would burden the operating costs of the country's electricity production system by approximately €5.4 billion and €5.8 billion more than, the scenarios aiming at a 70% and 75% RES share in 2030, respectively.

It is therefore evident that a shift towards lignite is neither climatically nor economically advantageous, while it does not sufficiently reduce dependence on Russian fossil gas. On the contrary, a commitment to accelerating the penetration of properly sited RES, especially during the three-year period 2022-2024, constitutes by far the best energy strategy in order to drastically reduce the reliance of the Greek economy to Russian fossil gas. Moreover, this path will lead to much lower CO_2 emission costs for Greece's electricity production mix; meanwhile, Greece will keep the carbon budget for the power sector under control and remain on track to meet the national climate target for reducing net GHG emissions in 2030 by at least 55%, compared to 1990 levels.

In addition, shifting back to lignite at this juncture will constitute a blow to the country's credibility at the level of international climate diplomacy. The lignite phase-out timetable has been announced and reiterated by the Prime Minister himself and other representatives of Greece in international and European *fora* and constitutes the most important climate commitment of the country. A change in this timeline, contrary to the demands of climate science, the conclusions of the Intergovernmental Panel on Climate Change, as well as the convictions of the UN Secretary General, will alienate Greece and deprive it from its seat at the table of European and international climate politics.

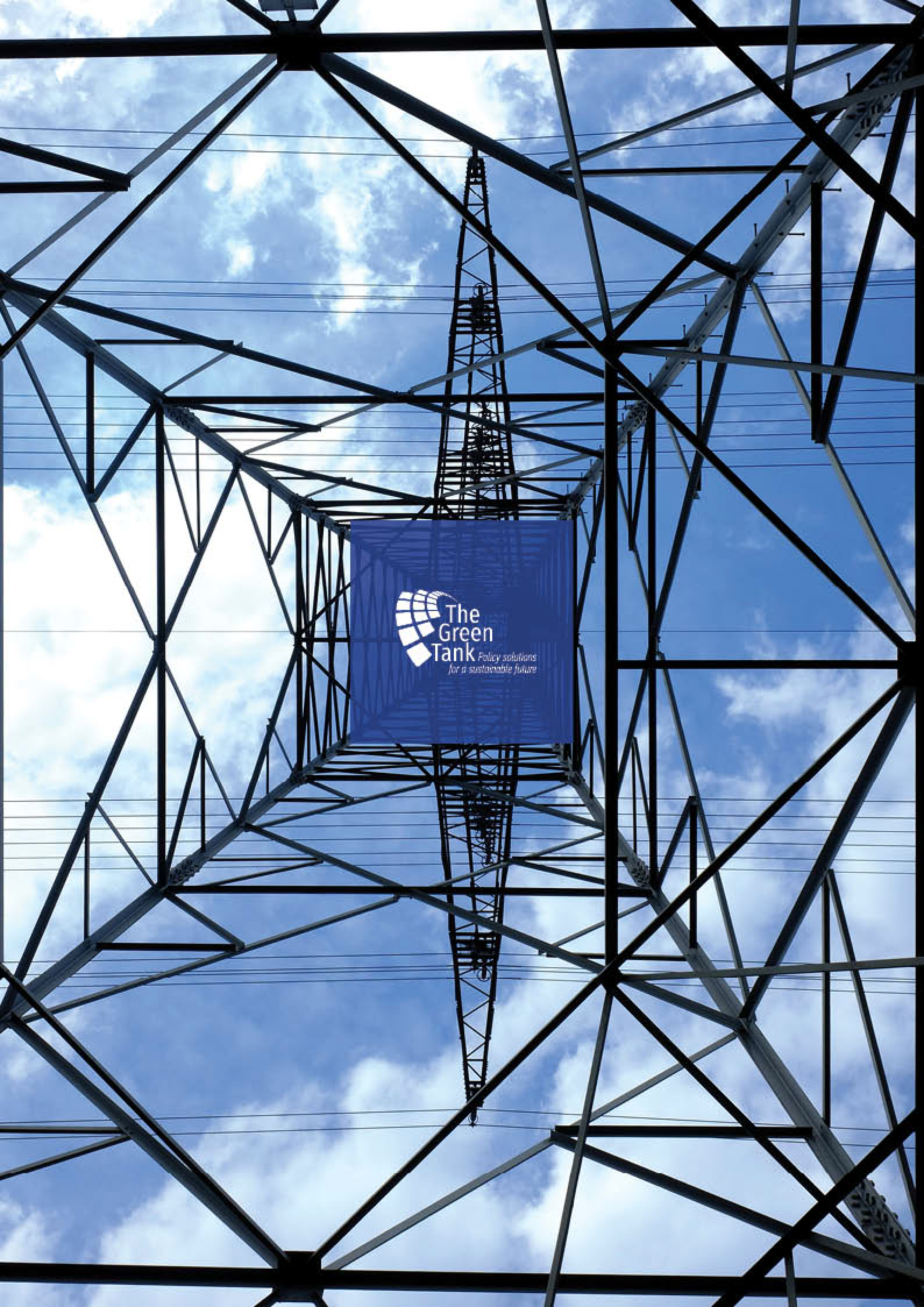
Recommendations

The economy's large reliance on fossil gas proved to be a major threat to Greece. Reversing the sharply increasing trend of using fossil gas, especially in electricity production, should constitute a key objective of policy makers.

The results of this analysis demonstrate that, even with the short-term perspective of 2022, the government should prioritize accelerating the penetration of renewables, rather than bolstering lignite-fueled electricity production. This solution shields the Greek economy much more effectively from the threat of its large exposure to Russian gas. Emphasis should be placed not only on large-scale renewables, but also on providing incentives for the installation of small-scale RES, which shall meet own electricity needs through the development of energy communities using the net metering and virtual net metering schemes. In addition, the acceleration of the deployment of renewables must be accompanied by grid development; furthermore, it is imperative to fast-track the establishment of an institutional framework on energy storage, which is absolutely necessary to support the integration of increased shares of stochastic renewables.

Besides the electricity production sector, emphasis should also be placed on limiting the use of fossil gas in homes and businesses. First and foremost, the planning with regard to district heating and the heating of individual residences in Western Macedonia and Megalopolis should be immediately revised, as it is now entirely based on fossil gas. Regardless of the duration of the current energy crisis, due to the revision of the Directive for the EU Emissions Trading System, and in accordance with the European Commission's proposal, fossil fuel-based heating will be financially burdened from 2026 onwards. In this context, it is necessary to focus nationwide on the development of heating systems based on renewables, as well as on the substitution of existing fossil gas and heating oil boilers by heat pumps. In terms of climate policy, changing the article of the draft climate law on heating is imperative. Instead of targets for replacing oil boilers with fossil gas-based heating systems, it should include targets regarding the penetration of RES in heating, similar to those adopted by other countries.

Finally, the government should take steps to decouple industrial production from fossil gas by promoting the electrification of industrial processes, where feasible, and green hydrogen production. After all, the decarbonization of industry guarantees the strengthening of its competitiveness in the long term.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