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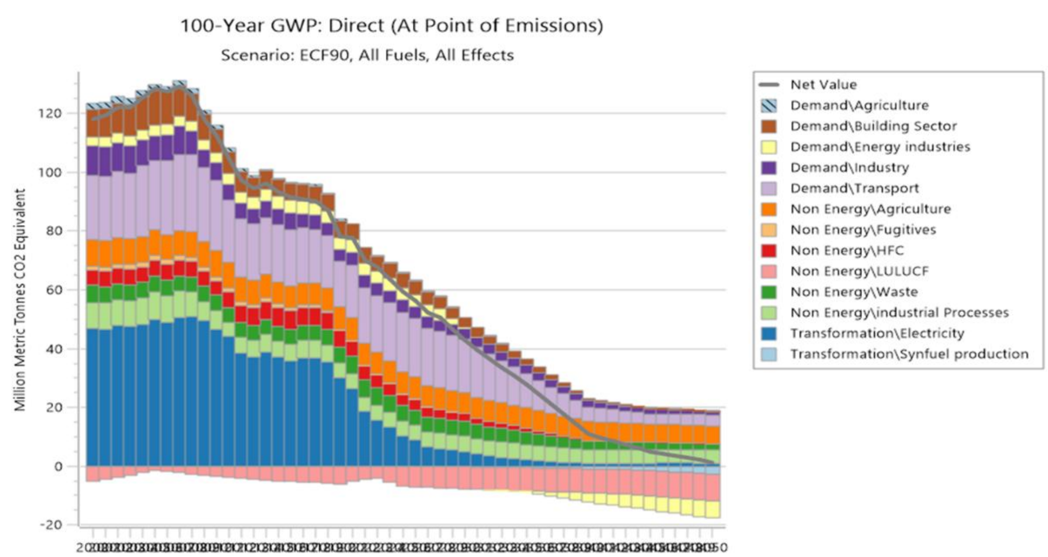
Scenarios for 90% and 95% of Greek GHG emissions reduction by 2040



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Summary

In this work, pathways for Greece to achieve 90% and 95% reductions in greenhouse gas emissions by 2040 relative to 1990 levels, building upon the existing National Energy and Climate Plan (NECP24).

Using the LEAP energy model, two enhanced scenarios (ECF90 and ECF95) were developed. These scenarios primarily rely on accelerating and strengthening existing policies rather than introducing entirely new measures.

Key aspects of the two scenarios structure include:

- The transport sector and non-CO_2 emissions provide the largest opportunities for additional reductions.
- Increased electrification, particularly in transport and heating, is to play a central role.
- Some additional expansion of PV significantly reduces reliance on natural gas.
- Improvements in waste management and elimination of F-gases can deliver substantial emissions reductions.
- Carbon capture technologies provide additional support, particularly in industry, to reach 95% reduction.

To achieve 95% reduction both an increased electrification of the residential and transport sector together with additional CCS would be required.

1. Introduction

The Greek National Energy and Climate Plan (henceforth NECP24) as published in the Greek Official Journal on 19 December 2024 (ΦΕΚ Β6983/19Δεκ2024)[1] provides a bird's eye breakdown of the contributions of the various sectors to the national Greenhouse Gases (GHG) emissions amounts, in 5-year steps (see Table 1 below) leading to overall emissions of 21.1 MtCO2eq in 2040 and 11.8 and 2.6 MtCO2eq respectively in 2045 and 2050. In view of the 103.7 $MtCO_2eq$ national emissions in 1990, these national NECP24 amounts correspond to 79.7%, 88.6% and 97.5% GHG reductions wrt 1990.

Following recommendations on 2 June 2025 from the independent European Scientific Advisory Board on Climate Change (ESABCC) set up under the EU Climate Law the European Commission (EC) proposed on 2 July 2025 amending the European Climate Law to adopt a 90% reduction target for 2040. The EC did not break down this target by Member State (MS) although it provided mechanisms for trading between MSs as well as a possible limited role for high-quality international carbon credits in the second part of the 2030-2040 decade.

In the initial discussions at European Council, Greece indicated that it is not in favor of the proposed 90% target nor has it initiated a process to improve its 80% reduction as per its NECP24. It is then important to develop scenarios that realistically lead to 90% reduction and even to an inspirational 95% reduction to present in the public debate that hopefully will take place soon.

This report describes two such plausible scenarios for a 90% and 95% reduction by 2040 implemented in the LEAP energy model[2]. The basic avenue of approach chosen in designing these scenarios is to examine in detail the Policies and Measures (PaMs) of the NECP24 scenario which leads to only an 80% reduction by 2040 as shown in Table 1 and adopt as many of those as possible. These PaMs may be enhanced in scope and timetable of implementation but are to keep their target and approach.

Note that Subtotal #1 is to be stored presumably underground in the South Kavala storage facility, which might not be able to accommodate all this amount and clearly not for many years to come.

This approach has the advantage that the PaMs are already included in NECP24 and can therefore be deemed already appropriate and realistic and should be considered beyond doubt. In this respect, the acceleration of the application of PaMs might be considered to reach scheduled reduction amounts originally expected in say 2045 earlier and conceivably by 2040

[1] Φ.Ε.Κ. - Εθνικό Τυπογραφείο
[2] https://leap.sei.org

Table 1: NECP Emissions ($MtCO_2eq$)								
		2022	2025	2030	2035	2040	2045	2050
A	Electricity production	18.8	10.2	4	1.5	1.4	1	1.2
B	Energy industries	5.9	5.6	4.7	4.2	2.3	2	1.7
C	Industry (with process emissions)	9.2	8.4	7.1	6	4.8	4.5	4.3
D	Residential	5	3.8	2.1	1.3	0.5	0.2	0.2
E	Tertiary	0.6	0.7	0.5	0.3	0.1	0	0
F	Agriculture	0.6	0.2	0.2	0.1	0.1	0.1	0.1
G	Transport with all air transport	21.3	21.9	19.8	15.1	10.3	5.6	1.4
H	Non-CO2 emissions	20.6	17.6	15.4	14.1	13	10	8.6
1	Subtotal; A to H	82	68.4	53.8	42.6	32.5	23.4	17.5
I	CC from Industry	0	0	-3.3	-3.4	-4.2	-4.1	-3.9
J	DAC	0	0	0	0	0	0	-4.5
K	CO2 for synfuels	0	0	0.2	0.4	0.8	1.2	2.7
2	Subtotal : (I + J + K)	0	0	-3.1	-3	-3.4	-2.9	-5.7
3	LULUCF	-5.5	-6.2	-6.6	-7.2	-8.1	-8.6	-9.1
4	Total excluding LULUCF (#1 + #2)	82	68.4	50.7	39.6	29.1	20.5	11.8
	Total including LULUCF (#4 + #3)	**76.5**	**62.2**	**44.1**	**32.4**	**21**	**11.9**	**2.7**
	% reduction wrt 1990 (103.5MtCO2)	**26.2%**	**40.0%**	**57.5%**	**68.8%**	**79.7%**	**88.5%**	**97.4%**

To reach 90% and 95% reduction (i.e. to reach 10 to 5 MtCO2 net emissions from the 21 MtCO2 inscribed in 2040) a reduction by ca 10 to 15 MtCO2 is needed. The analysis indicates that emission reductions should focus primarily on those sectors that contribute the most in 2040 and beyond namely the transport sector and the non-CO2 emissions sources (rows G and H respectively).

A second sector, candidate for reduction, is the industrial sector (row C in Table 1) with its process emissions which should be seen in conjunction with the possibility of carbon capture (i.e row I). Emission reductions in this sector could be accomplished by either increasing efficiency, switching fuel or increasing carbon capture. The latter though, would require that sites for storage can be found as the possible use of captured CO_2 for additional synfuel production to meet domestic use is limited.

Finally, another means for reducing emissions is to increase LULUCF sinks but this in the NECP24 is already almost double the current amount (4677 $ktCO_2eq$ in 2023 to 8100 $ktCO_2eq$ in 2040) and additional land areas required to expand further are difficult to find.

Of the remaining sectors, Electricity, Energy industries, Residential, Tertiary and Agriculture (energy use) some limited margin for reduction is present in the energy sector which basically refers to the Refineries and the Electricity Generation sectors. To reduce emissions from the former might mean to reduce production, possibly driven naturally by falling demand as vehicle fleets become increasingly electrified while in the electricity sector the small remaining amount is due to NG consumption associated with covering low Renewable Energy Production (RES) production and ensuring grid stability.

It should be noted that the Residential and Tertiary sectors do not provide potential for further meaningful reductions as they have already been brought to near zero emissions and Agriculture (energy) has already a very small contribution.

The Policies and Measures (PaMs) that comprise the two scenarios compiled in this work have been implemented in the LEAP energy model (https://www.sei.org/tools/leap-low-emissions-analysis-platform/). The PaMs of the NECP24, which was modelled utilizing the TIMES-MARKAL model by the CRES, the Greek National Center for Renewable and Energy Conservation for the Ministry for Environment and Energy, has also been implemented in LEAP to facilitate direct comparison. To do so, all sectors have been disaggregated down to the lower possible level that can be supported by available data and incorporated in the LEAP tree.

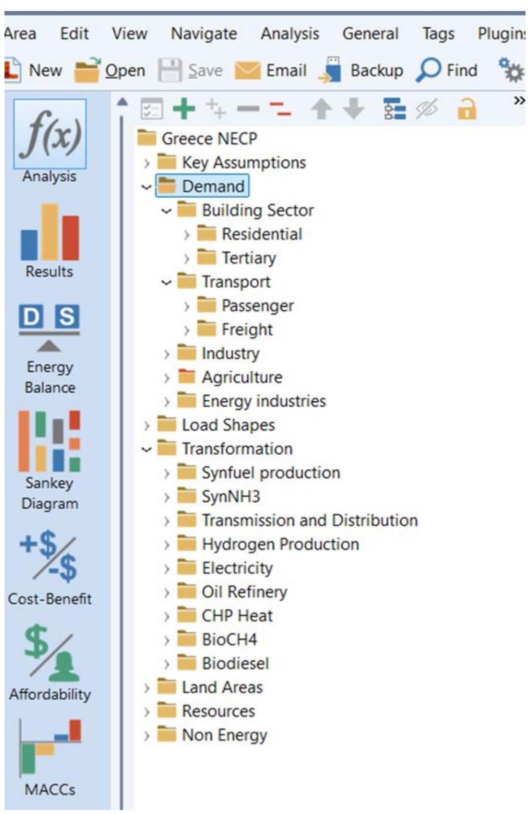
This report is structured as follows: The next Section 2 provided a concise presentation of the LEAP model. In Section 3, the detailed structure of the LEAP model developed is introduced and in Section 4 the comparison of the three scenarios, the NECP24 and the two scenarios to reduce by 2040 GHG emissions by 90% and 95% wrt to 1990, are presented. The comparison is carried out sector (and subsector) by sector by describing the changes and assumptions in PaMs in the three scenarios. Finally, in Section 5 some concluding remarks on the approach utilized and possibilities to make use of the results and the LEAP model structure to inform possible campaigns to improve the Greek NECP either now or in its next update are offered.

2. The Structure of the LEAP model employed

The LEAP (Long-range Energy Alternatives Planning) energy model[3] is a model that is widely used to investigate energy planning scenarios and GHG emissions at national and regional scales. It has been used for reviews of the NECPs of a number of MSs as well as for providing input to national authorities in charge of compiling the NECPs but also for energy planning for various countries of the developing world. Currently there are more than 85 licensees only in Greece. It has been the software used for thousands of scientific papers on energy policy. Its wide use is due to its availability (free for academic and NGO use), affordability (limited computational requirements) and straightforward and ease of use. It also allows for disaggregated representation of the energy demand and supply structure in as much technological detail and end-use analysis as chosen.

The basic structure of the modeling framework is in the form of a tree whose branches include demand sectors (residentiary, tertiary, industry, transport, energy industry and agriculture), the energy needs for which are to be satisfied by transformation sectors (electricity generation plants, refineries, synfuel and H2 generating plants) for the production of various energy modes from primary energy sources and imports. Non-energy effects that contribute to emissions such as F-gases use, waste, agricultural cultivations and livestock and LULUCF are also included to ensure full emission inventories.

Figure 1: General Tree



The tree utilized for the mimicking of the Greek NECP24 and the 2 new scenarios is shown in aggregated form in Fig. 1 that follows. Detailed breakdowns of various sub-branches of the tree per sector will be given further down as the structure and content for each sector is presented.

In building the tree and the structure of the model, three major data bases, namely the Greek energy balance up to 2024, the CRF tables of the GHG inventory and the latest version of the Intergraded Database of the European Energy System (IDEES) of the Joint

[3] Heaps, C.G., 2022. *LEAP: The Low Emissions Analysis Platform.* [Software version: 2026.4.0.4] Stockholm Environment Institute. Somerville, MA, USA

Research Center of the European Union (covering up to and including all years to 2021)[4] have been used and provided guidance as well as a plethora of data. These databases have provided the input for the Current Scenario i.e. the energy sector up to and including 2021 which is not modelled and which all the other three NECP24, reduction scenarios 90% and 95% use as a starting point. The modelled values for the NECP24 start in 2022 and continue till 2050, a depth of time horizon applied to all scenarios. These data have been augmented by data from other Greek State Agencies such as ELSTAT, the Greek Statistical Service, the Greek Ministry of Environment and Energy which also includes data from the energy audits of the Greek building stock and finally, EUROSTAT. The contents of these databases also dictated the limits of disaggregation for each sector to be presented below.

A sector-by-sector presentation of the modelling structure is given next.

[4] https://publications.jrc.ec.europa.eu/repository/handle/JRC137809

3. Sectorial Analysis

3.1 The residential sector

The building stock has been divided into 3 main branches, unrenovated, renovated and new builds. Each of these branches is subdivided by climatic zone. Greece is divided as regards energy use for energy audits into 4 climatic zones. Taking into account the building stock and population distribution, these have been merged into two (North and South). Furthermore, again because of different thermal behavior and heating/cooling requirements of building types, each of these subdivisions were further subdivided into single and apartment dwellings. Finally, each of these 12 categories were again sub-subdivided according to the Greek energy building audit system classification[5]. The full classification has 9 classes (A+, A, B+, B, C to G). All nine classes were taken to be populated by unrenovated buildings of all 4 categories, whereas the renovated buildings were considered to only populate 4 classes (all A, all B, C, D) and the new builds again to be of 4 classes (A+, A, B+, B).

This structure as implemented in the LEAP tree is shown in Fig. 2 below.

For all these building classes, energy use has been apportioned into 7 activities, namely heating, cooling, lighting, domestic water heating, cooking and other electrical equipment use. The energy carriers for these uses include all fuels including synfuels after 2035 and electricity. In choosing the relative use of the energy carrier, the IDEES data were used as a guide but extensions in the future to 2050 are to be decided as a matter of policies and measures to be implemented. These are seen in Fig. 3

Furthermore, energy use intensity for all classes per m2 were derived from an analysis of the data for over 2 million dwellings that have been recorded in the scope of the Greek energy use audits to obtain energy efficiency certificates. Energy efficiency certificates are legally required for any sale or rental of a dwelling as well as for issuance of permits for the construction or renovation of any kind. These data are available by climatic zone and class. Yet, because of a number of methodological issues of the audits, they differ from those of IDEES which made it necessary to spend considerable effort to reconcile the values. This was accomplished by adjustments so as to bring the energy consumption values in line with the fuel use by carrier, inscribed in the national energy balances until 2022. For the next time period, from 2022 till 2050 for the NECP24 scenario, the adjustment is applied to bring energy use by carrier in line with NECP24. For the other 2 new scenarios ECF90 and ECF95, value choices were part of the scenario narrative.

[5] doi:10.2760/522233

Figure 2: The Residential Sector

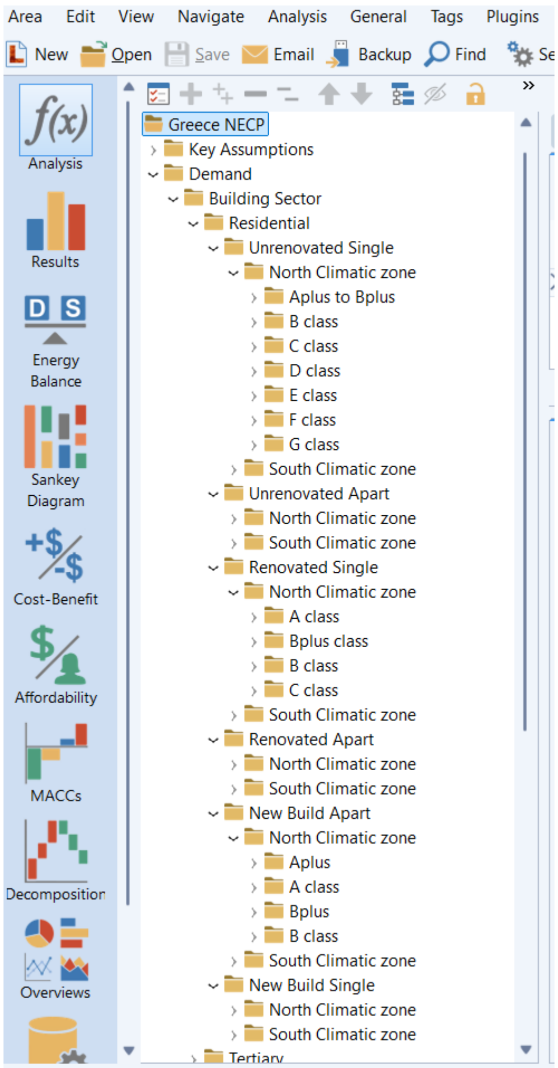
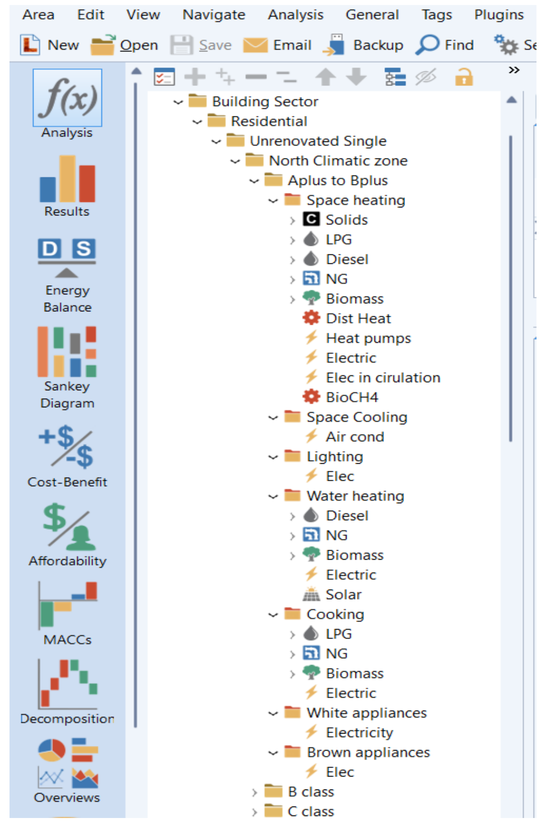


Figure 3: Details of the Building Sector



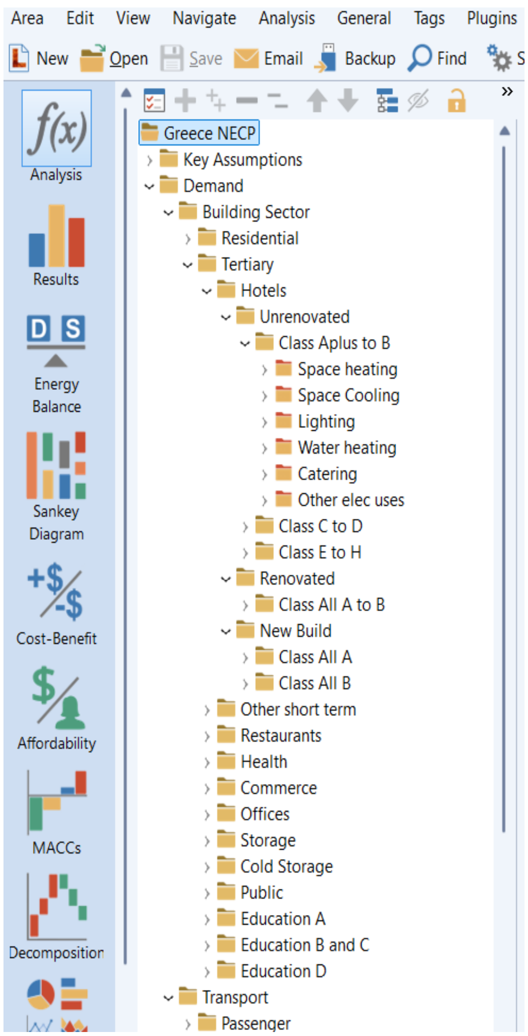
3.2 The tertiary sector

This sector has been divided into 12 subsectors, namely hotels, other short-term rentals, restaurants, health, commerce, offices, storage (regular and cold), public and education (in 3 zones: north, central and south). Each of these subsectors, as in the building sector, has been divided into 3 categories, unrenovated, renovated and new builds. In the unrenovated category, 4 energy groups of classes (out of 9 in total) of buildings are assumed, i.e. A+ to B, C & D, and E to G. In the renovated category, only one group is assumed, which includes classes A+ to B, and finally, in the new builds, the two groups considered included classes A+ & A and B+ & B.

The tree structure for the Tertiary Sector is displayed in Fig. 4 below.

As with the residential sector (see Fig. 2), six uses have been again assigned with cooking replaced by catering in some subsectors as appropriate. Each use, as in the Residential Sector (see Fig. 3), is covered by all applicable energy carriers.

Figure 4: Tertiary Tree Structure

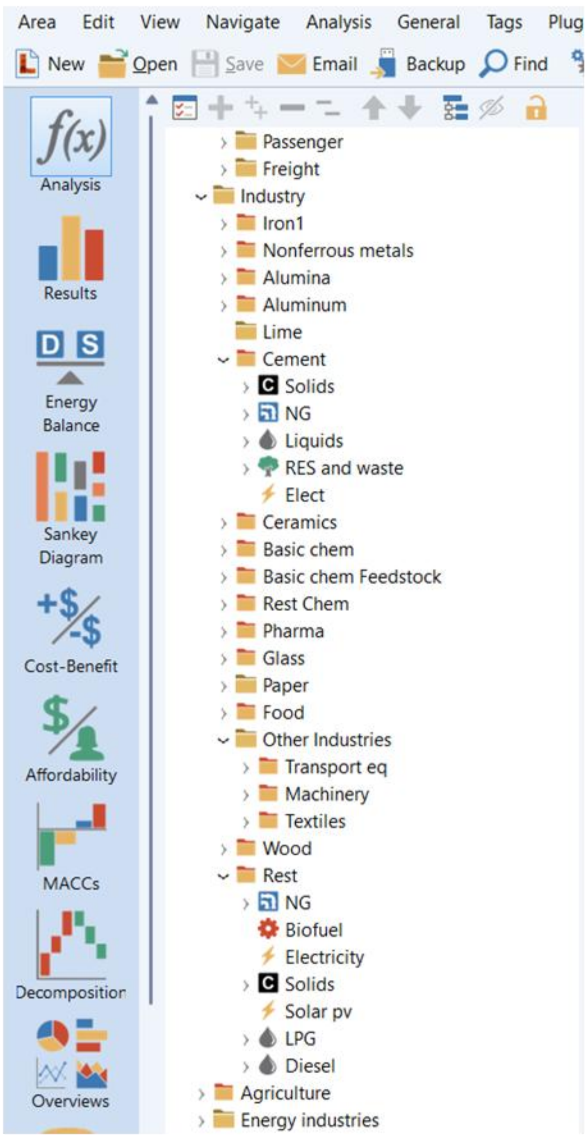


Here again, energy use intensities for all classes per m2 were derived from an analysis of the data that have been recorded in the scope of the Greek energy use audits to obtain energy efficiency certificates. These data are available by climatic zone and class. For the tertiary sector, differences between climatic zones were not significant as energy consumption is driven by activity rather than by heating and cooling demand. IDEES again has provided coefficients for the 2000-2021 period, albeit without the disaggregation of this model. The energy consumption per m2 was again adjusted so as to bring its values in line with the IDEES aggregated values and the fuel use inscribed per carrier in the national energy balances until 2022. For the next time period from 2022 till 2050 for the NECP24 scenario the adjustment is carried out to bring energy use per carrier in line with its proscribed values. For the other 2 new scenarios ECF90 and ECF95, value choices were part of the scenario narrative.

3.3 The industrial sector.

For the industrial sector, the IDEES taxonomy has been implemented. This includes 13 subsectors which cover the Greek industrial sector in sufficient detail (refineries, electrolyzes and synfuel production units are treated elsewhere separately).

Figure 5: The Industrial Sector



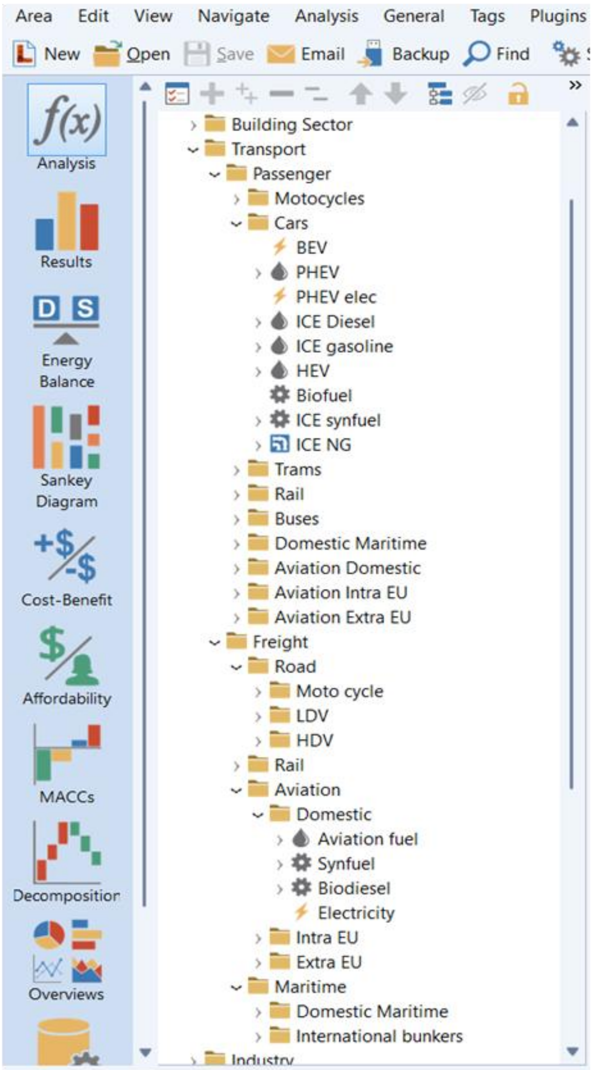
The subsector with the largest energy use and emissions is that of cement. Greece has only 4 installations that produce fairly constant amounts (from 8384kt in 2014 to a minimum of 6712kt in 2020 and to 7278kt in 2023 more than 50% of which is exported) so no further disaggregation is needed. Similarly, there is only one active steel industrial enterprise in Greece utilizing scrap iron as a feedstock, one aluminum mine with its connected alumina producing facility and one aluminum smelting facility.

The production quantities and the energy intensities for the 2000-2021 period have been derived from IDEES data as well as from national sources. For the next time period from 2022 till 2050, for the NECP24 scenario the adjustment is carried out to bring energy use, by carrier, in line with its future energy consumption values. For the other 2 new scenarios ECF90 and ECF95, value choices were part of the scenario narrative and in particular output predictions.

3.4 The Transport sector.

The transport sector is divided into passenger and freight. The passenger transport demand is met by 7 modes of transportation including domestic navigation and aviation plus international flights separated into intra- and extra EU routes. Similarly, the freight transport demand includes 5 modes (LDV, HDV, rail, aviation and maritime) with the international bunkers treated separately in the maritime mode. For each mode all appropriate energy carriers are included (see Fig. 6)

Figure 6: Details of the Transport Sector



The passenger (pkm) and freight (tkm) kilometers travelled have been taken from both IDEES and the earlier 2023 version of the NECP (the NECP24 does not provide specific breakdown data for pkm and tkm) for the 2000-2021 period. For the next time period from 2022 till 2050, for the NECP24 scenario the adjustment is carried out to bring energy use, by carrier, in line with its future NECP24 energy consumption values. For the other 2 new scenarios ECF90 and ECF95, value choices were part of the scenario narrative and in particular output predictions.

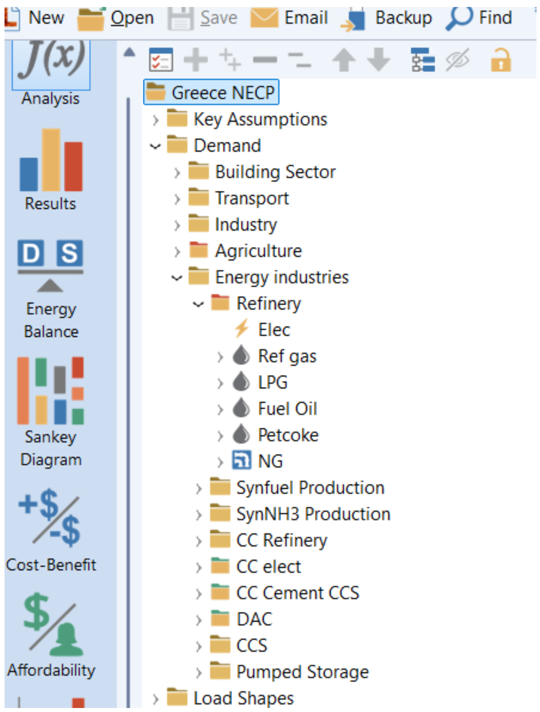
3.5 The Agricultural sector (energy use).

This sector is not a large consumption of energy (only 0.8% of total national energy demand) but not as regards non-energy emissions which are accounted for in the non-energy branch of the model. Thus, it has been considered as a unit without any breakdown to various uses although again all energy carriers are included.

3.6 Other energy industries sector.

Following the national energy balances, this sector includes the refineries and synfuel production (as regards energy consumption only – fuel production is addressed in the Transformation branch of the model), Direct Atmospheric Capture (DAC) and Carbon Capture and Storage (CCS).

Figure 7: The Energy Sector

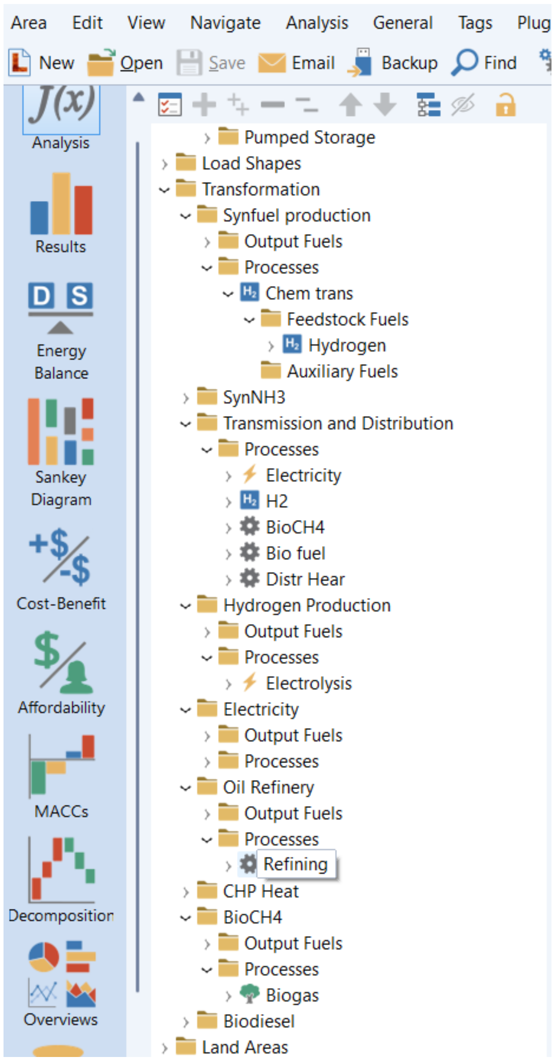


These sectors, also present in the Transformation branch, have not been further disaggregated up to now because of the difficulty in getting better input energy data as to the activity level in the next 25 years (refineries) or the cost and efficiency evolution for DAC and CCS, and the requirements for synfuels and SAFs, especially approaching 2040, all of which are still not in commercial production phase. Current values for the electricity needs for all these processes have been included in the modelling as these are part of the Demand.

3.7 Transformation sector.

In this sector, also following the discussion in the February 2025 Budapest ECF workshop, the electricity production subsector, the main transformation technology, has been disaggregated down to each individual non-RES unit. Wind energy is also broken down to land-based and off-shore. As almost half of the existing NG units will still be operational until 2040 and in view of an additional anticipated capacity of 2500MW to be added in the next 3 years plus at least 4 hydro plants of 1200MW of which 680MW pumped storage already planned, it is important to provide flexibility (and competition) which will affect the relative share of the generation mode to meet demand. This disaggregation has now introduced 72 distinct entries, instead of the original 7 which grouped units according to the input energy carrier used.

Figure 8: Transformation Sector

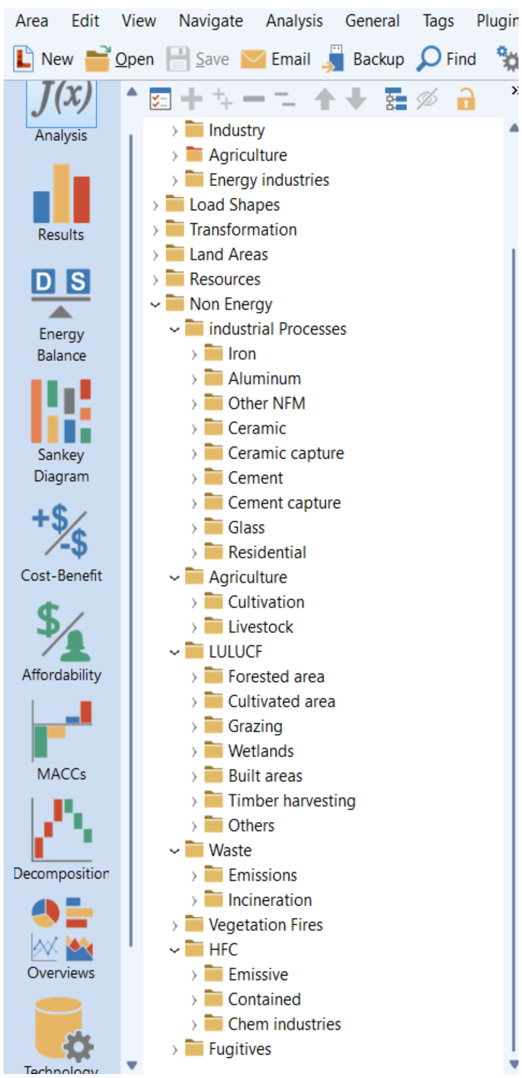


The capacity values, efficiency and other operating conditions of the units and the retirement schedule of lignite plants past 2021, have been chosen taking into account the age of each unit, its known specifications and official announcements, and match the NEPC2024 trajectories for the NECP24 scenario. For the ECF scenarios, deviations have been chosen in the timing of decommissioning of thermal units and more realistic assumptions (especially for offshore wind) have been made regarding renewable deployment.

The Transformation sector also includes entries for H_2 and synfuel production, the latter subdivided into synthetic methane and the rest of synfuels, as well as refineries. Greece has 3 refineries of ca 620kbbls/day, of which one (280kbbls/day) is a little over 10 years old and the largest one (285kbbls/day) has been refurbished recently (2021). In view of the complexity of refining and the difficulty of modelling a very diverse stream of products and specific capabilities, it was judged that the present aggregated approach is sufficient. A separate entry is included in this sector to account for the production of H^2, synfuel (both liquid and gaseous) and ammonia.

3.8 Non-energy emissions.

Figure 9: non-CO2 Emissions Tree



A full branch covers emissions of non-energy GHG. This branch includes 7 categories, namely: Industry (with 9 subsectors), LULUCF (with 7 subsectors), Waste (with 3 subsectors), Fires, HFC (with 3 subsectors), Fugitive emissions, and Agriculture (with 2 subsectors, one with 4 sub-subsectors and the other with 5). In the scope of this contract, this amount of disaggregation (see Fig. 9) covers the needs of most scenarios put forward and no additional entries have been added.

The values for the emissions for all these entries in the 2000-2021 period have been abstracted from the IDEES data base and the Greek GHG inventories submitted to the UNFCCC and augmented by data from the Greek Statistical Service (ELSTAT). For the period 2022 to 2050, the trajectories were derived so as to match more aggregated values included in the NECP24, while for the ECF scenarios different parameter evolution has been chosen to reflect proposed policies.

These enhancements of the model provide a large amount of flexibility to cover a wide variety of policies and measures to be introduced in the two new ECF scenarios as well as the ones inscribed in the NECP24.

The economic data for all 72 power units, namely CAPEX and OPEX, broken down to fuel costs and O&M, have been added. This includes projections to 2050 and have been based on various data bases but also on input from Greek operators of power units. In addition, costs have been added for electrolyzer units, synfuel production units, batteries and CC installations although all these cost estimates carry an increased uncertainty as they are projected to be implemented at a much later date, by which time technological improvements are expected to bring down costs.

4. The three scenarios implemented

Utilizing the fully disaggregated tree of the energy sector demand and supply, the first scenario that has been modelled in LEAP was the Greek official NECP24. Values before 2021 and starting in 2000 (i.e. what is referred to as the Current Scenario in LEAP) are the ones provided by IDEES, National Energy Balances, CRFs, official Energy Audits et al.

In Table 2, an indication of the accuracy of the mimicking of the NECP24 for 2040 the year of interest is provided. In Table 2, the values for 2022 are also provided. It should be noted that these values, both those from NECP24 (Table 30 on page 74565 of the Official Government Journal) and LEAP modelled results (column LEAP24 in Table 2) to be compared with the 2022 Inventory results, are also shown.

As becomes clear from Table 2, the major contributors to the total GHG emissions in 2040 are the Transport and the non-CO_2 sectors and those are the ones that would need to be reduced substantially to achieve the 90% and 95% reduction called for. This is not to say that smaller contributions from the other sectors are to be ignored but clearly reductions additional to those already included in the NECP24 would be more difficult to institute.

To present the PaMs for the two new scenarios, first an overview of the reductions achieved is presented In Table 3 where the sectoral emissions in 2040 for the NECP24 (already shown in Table 2) are juxtaposed with those of the two new scenarios (ECF90 and ECF95) together with the emissions in NECP24 for the years 2045 and 2050. These two last columns are provided to show that the PaMs included in the 2 new scenarios ECF90 and ECF95 are actually almost equivalent to accelerating the NECP24 PaMs by about 5 to 7 years, providing thus further grounds for their applicability.

As already mentioned, the two new scenarios are based on intensifications/variations of PaMs of the NECP24 rather than on the introduction of new or additional ones. In some sectors or subsectors, the choice was made to take them as they are and make no changes at all. This approach was adopted to reduce possible criticism of the scenarios content and doubts about their applicability and efficacy.

Table 2: Emissions ($MtCO_2eq$)					
1990 =103.7 (101.7) MtCO2eq	2022			2040	
	NECP24	LEAP24	Inventory	NECP24	LEAP24
Electricity	18.8	16.2	18.8	1.4	1.5
Energy Industry (Refinery)	5.9	4.3	5.84	2.3	2.4
Industry	9.5	8.81	9.18	4.8	4.6
Energy	4.1	3.86	4.58	1.19	1.2
Process	5.4	4.95	4.6	3.61	3.4
Residential	5	4.6	5.08	0.5	0.6
Tertiary	0.6	0.7	0.6	0.1	0.15
Agri	0.6	0.2	0.6	0.1	0.1
Transport	21.6	19.2	17.9	10.3	10.53
2W		0.8			0.2
Cars		7.1			2.7
Trams		0			0
Rail		0			0
Buses		1			0.2
Maritime Domestic		1.9			1.7
Domestic		0.7			0.9
Intra EU		1.9		3.3	1.6
Extra EU		0.7			0.6
LDV		2.1			1.23
HDV		3			1.4
nonCO2	20.6	20.03	19.49	13	12.78
Energy		0.74	0.74		0
Agri		7.4	7.97		6.8
F-gas		4.69	4.58		1.38
Waste		7.2	6.2		4.6
Total	**76.4**	**68.54**	**71.21**	**32.5**	**32.66**
LULUCF	-5.5	-4.7	-5.18	-8.1	-8.1
Total incl. LULUCF	70.9	63.84	66.03	24.4	24.56
CC				-4.2	-4.1
CO2 use				0.8	0.8
CCS				-3.5	-3.7
DAC				0	0
Total incl. CCS	**70.9**	**63.84**	**66.03**	**20.9**	**20.86**
% Reduction wrt 1990	**31.6%**	**38.4%**	**36.3%**	**79.8%**	**79.9%**

Taking Table 3 as a guide, let us discuss for each sector the reductions to be secured in all three scenarios NECP24, ECF90 and ECF95 and point out the differences between them to reach the 2040 emission reduction targets.

Table 3: Emissions ($MtCO_2eq$)

1990 =103.7 (101.7) $MtCO_2eq$	2040				2045	2050
	NECP24	**LEAP24**	**ECF90**	**ECF95**	**NECP24**	**NECP24**
Electricity	1.4	1.5	0.8	0.8	1	1.2
Energy Industry (Refinery)	2.3	2.15	1.6	1.6	2	1.7
Industry	4.8	4.6	4.5	3.95	4.5	4.3
Energy	1.19	1.2	1.2	0.95	0.96	0.6
Process	3.61	3.4	3.3	3	3.5	3.7
Residential	0.5	0.6	0.6	0.4	0.2	0.2
Tertiary	0.1	0.15	0.15	0.15	0	0
Agri	0.1	0.1	0.1	0.1	0.1	0.1
Transport	10.3	10.53	4.75	3.65	5.6	1.4
2W		0.2	0.1	0		
Cars		2.7	1.4	0.8		
Trams		0	0	0		
Rail		0	0	0		
Buses		0.2	0	0		
Maritime Domestic		1.7	0.3	0.3	1.37	0.23
Domestic Aviation		0.9	0.5	0.5		
Intra EU Aviation	3.3	1.6	1	1	2.26	0.89
Extra EU Aviation		0.6	0.3	0.3		
LDV		1.23	0.48	0.25		
HDV		1.4	0.67	0.5		
nonCO2	13	12.88	9.6	7.77	10	8.6
Energy		0.1	0.1	0.1		
Agri		6.8	6.5	6		
F-gas		1.38	0	0		
Waste		4.6	3	1.67		
Total	**32.5**	**32.51**	**22.1**	**18.42**	**23.4**	**17.5**
LULUCF	-8.1	-8.1	-8.1	-8.1	-8.6	-9.1
Total incl. LULUCF	**24.4**	**24.41**	**14**	**10.32**	**14.8**	**8.4**
CC	-4.2	-4.1				
CO2 use	0.8	0.8	0.81	0.8	1.2	2.7
CCS	-3.5	-3.7	-3.5	-5	-2.9	-5.7
DAC	0	0	0	0	0	4.5
Total incl. CCS	**20.9**	**20.71**	**10.5**	**5.32**	**11.9**	**2.7**
% Reduction wrt 1990	**79.8%**	**80.0%**	**89.9%**	**94.9%**	**88.5%**	**97.4%**

4.1 Electricity Sector

In the Electricity Sector, the main differences are in the capacity of the Photovoltaic (PV) and wind onshore plants (see Table 4). In particular, the PV capacity in the ECF scenarios is increased gradually reaching 30GW by 2040 (vs 26GW in the NECP24) and finally, 40GW by 2050 (vs. 35GW in the NECP24).

Table 4: Electricity Power Plant Capacity (GWnet)								
Fuels		2022	2025	2030	2035	2040	2045	2050
Lignite	**Actual**	2.20	1.52					
	NECP	1.60	1.30					
	LEAP24	2.10	1.20	-	-	-	-	-
	ECF90	2.10	1.20					
	ECF95	2.10	1.20					
NG	**Actual**	5.30						
	NECP24	6.30	7.00	7.90	6.30	5.90	5.90	5.90
	LEAP24	4.91	6.54	8.34	6.90	5.91	5.48	5.48
	ECF90	4.91	6.58	7.67	5.96	3.74	2.49	2.49
	ECF95	4.91	6.58	7.67	5.96	3.74	2.49	2.49
Oil	**Actual**	0.86	0.81					
	NECP24	0.85	0.82	0.10	0.10	0.10	0.10	0.10
	LEAP24	0.89	0.86	0.20	0.17	0.10	0.08	0.05
	ECF90	0.89	0.86	0.20	0.17	0.10	0.08	0.05
	ECF95	0.89	0.86	0.20	0.17	0.10	0.08	0.05
Biomass/Biogas	**Actual**	0.20	0.20					
	NECP	0.20	0.10	0.10	0.10	0.10	-	-
	LEAP24	0.18	0.18	0.18	0.18	0.16	0.15	0.14
	ECF90	0.18	0.18	0.18	0.18	0.16	0.15	0.14
	ECF95	0.18	0.18	0.18	0.18	0.16	0.15	0.14
PV	**Actual**	5.90	12.20					
	NECP24	5.40	8.50	13.50	18.50	26.00	30.60	35.10
	LEAP24	6.32	8.50	13.50	18.50	26.00	30.60	35.10
	ECF90	5.89	9.69	14.00	20.00	30.00	35.00	40.00
	ECF95	5.89	9.69	14.00	20.00	30.00	35.00	40.00
Wind Onshore	**Actual**	4.70	5.70					
	NECP24	4.70	7.00	8.90	9.50	11.00	13.00	13.00
	LEAP24	4.70	7.00	8.90	9.50	11.00	13.00	13.00
	ECF90	4.70	7.00	8.90	9.50	13.00	13.00	13.00
	ECF95	4.70	7.00	8.90	9.50	13.00	13.00	13.00
Wind Offshorw	**Actual**	-	-					
	NECP	-	-	1.90	3.90	5.80	8.20	11.80
	LEAP24	0.00	0.00	0.19	3.90	5.80	8.20	11.80
	ECF90	0.00	0.00	0.19	3.90	5.80	8.20	11.80
	ECF95	0.00	0.00	0.19	3.90	5.80	8.20	11.80
Hydro	**Actual**	3.30	3.30					
	NECP	3.40	2.80	3.10	3.60	3.80	4.20	4.50
	LEAP24	3.17	3.17	3.96	4.46	4.61	4.71	4.81
	ECF90	3.17	3.17	3.96	4.46	4.61	4.71	4.81
	ECF95	3.17	3.17	3.96	4.46	4.61	4.71	4.81
Total	**Actual**	47.20	54.38					
	NECP24	52.00	53.90	60.40	78.80	101.50	122.90	145.50
	LEAP24	51.05	55.08	62.44	81.34	103.65	126.74	149.43
	ECF90	50.97	55.60	64.49	85.40	114.58	132.83	155.32
	ECF95	50.97	55.60	64.49	85.40	114.58	132.83	155.32

Table 5: Electricity Generation (TWh)								
By Fuel		2022	2025	2030	2035	2040	2045	2050
Lignite	Actual	2.2	1.5					
	NECP	1.6	1.3					
	LEAP24	2.1	1.2	-	-	-	-	-
	ECF90	2.1	1.2					
	ECF95	2.1	1.2					
NG	Actual	5.3						
	NECP24	6.3	7.0	7.9	6.3	5.9	5.9	5.9
	LEAP24	4.9	6.5	8.3	6.9	5.9	5.5	5.5
	ECF90	4.9	6.6	7.7	6.0	3.7	2.5	2.5
	ECF95	4.9	6.6	7.7	6.0	3.7	2.5	2.5
Oil	Actual							
	NECP24	0.8	0.8	0.1	0.1	0.1	0.1	0.1
	LEAP24	0.9	0.9	0.2	0.2	0.1	0.1	0.1
	ECF90	0.9	0.9	0.2	0.2	0.1	0.1	0.1
	ECF95	0.9	0.9	0.2	0.2	0.1	0.1	0.1
Biomass/Biogas	Actual	0.2	0.2					
	NECP	0.2	0.1	0.10	0.10	0.10	-	-
	LEAP24	0.2	0.2	0.2	0.2	0.2	0.1	0.1
	ECF90	0.2	0.2	0.2	0.2	0.2	0.1	0.1
	ECF95	0.2	0.2	0.2	0.2	0.2	0.1	0.1
PV	Actual	5.9	12.2					
	NECP24	5.4	8.5	13.5	18.5	26.0	30.6	35.1
	LEAP24	6.3	8.5	13.5	18.5	26.0	30.6	35.1
	ECF90	5.9	9.7	14.0	20.0	30.0	35.0	40.0
	ECF95	5.9	9.7	14.0	20.0	30.0	35.0	40.0
Wind Onshore	Actual	4.7	5.7					
	NECP24	4.7	7.0	8.9	9.5	11.0	13.0	13.0
	LEAP24	4.7	7.0	8.9	9.5	11.0	13.0	13.0
	ECF90	4.7	7.0	8.9	9.5	13.0	13.0	13.0
	ECF95	4.7	7.0	8.9	9.5	13.0	13.0	13.0
Wind Offshorw	Actual	0.00	0.00					
	NECP	-	-	1.9	3.9	5.8	8.2	11.8
	LEAP24	0.0	0.0	0.2	3.9	5.8	8.2	11.8
	ECF90	0.0	0.0	0.2	3.9	5.8	8.2	11.8
	ECF95	0.0	0.0	0.2	3.9	5.8	8.2	11.8
Hydro	Actual	3.3	3.3					
	NECP	3.4	2.8	3.1	3.6	3.8	4.2	4.5
	LEAP24	3.2	3.2	4.0	4.5	4.6	4.7	4.8
	ECF90	3.2	3.2	4.0	4.5	4.6	4.7	4.8
	ECF95	3.2	3.2	4.0	4.5	4.6	4.7	4.8
Total	Actual	47.2	54.4					
	NECP24	52.0	53.9	60.4	78.8	101.5	122.9	145.5
	LEAP24	51.1	55.1	62.4	81.3	103.6	126.7	149.4
	ECF90	51.0	55.6	64.5	85.4	114.6	132.8	155.3
	ECF95	51.0	55.6	64.5	85.4	114.6	132.8	155.3

This is chosen because of the latest PV installation rates that far exceed those of NECP24 without any special incentives provided. In particular, in 2023 PV installations in Greece reached 5.9GW, in 2024 9.6GW and in 2025 an extraordinary 12.2GW more than 40% above the 8.7GW inscribed in the NECP.

Similarly, for onshore wind the installed capacity is increased in 2040 to 13GW (from 11GW) which actually, is the amount in the NECP24 for 2050. This represents an acceleration of the installation of onshore wind rather than an overall increase, and would only require moving forward whichever PaMs are inscribed in NECP24.

As a result, the utilization of NG power plants decreases (see Table 5) and the GHG emissions are further reduced to 0.8MtCO_2eq by 2040 (from 1.4MtCO_2eq in NECP24).

These changes in PV and wind capacity are the same in both ECF scenarios.

4.2 Refineries

The emissions from the operations of the refineries depend on their production output as their consumption, and can be estimated by the percentage of the own energy use to input which over the last 20 years has varied between 4.7% and 5.2%. Their output covers internal consumption, bunkering, international aviation and exports. The NECP24 provides information for all three of those but not for exports. The consumption of petroleum products for bunkering and international aviation drops to 86% and 74% respectively by 2040 compared with 2022 and then remains almost the same in 2050 in NECP24. On the other hand, internal consumption decreases substantially to match the emissions reported for refineries in the NECP24 and, assuming that the refinery structure remains basically unchanged, the implied export amount also decreases to 58% by 2040 and down to 6% in 2050. This conforms with the expected overall demand for petroleum products in view of the net zero targets of the EU and hopefully of other countries which import refinery products.

In the ECF scenarios, the internal consumption decreases more reaching 29% (from 24%) by 2040 wrt 2022 in line with the differences in the demand of the other sectors between the NECP24 and ECF scenarios, international aviation decreases to 60% (from 76%), and exports are assumed to decrease to 39% (from 58%) but bunkering is taken to decrease by the same amount (to 86% wrt 2022) as NECP24.

No difference is assumed between the two ECF scenarios.

4.3 Energy Sector (other than Refineries)

The energy requirements of the rest of the activities in this sector (carbon capture, DAC and CCS, pumped storage) are taken to be covered by green electricity and consequently no GHG emissions are produced.

4.4 Residential Sector

In the Residential sector, NECP24 has already included PaMs (energy upgrades through renovation and fuel switching) that reduce the emissions from 5.0 $MtCO_2eq$ in 2022 to 0.5 $MtCO_2eq$ by 2040 and 0.2 $MtCO_2eq$ by 2050. These PaMs are taken to be also included in ECF90. For ECF95, an accelerated switching from diesel and NG to heat pumps is incorporated via incentives to be offered to owners of unrenovated dwellings of the lower classes (E, F and G)so that fossil fuel use for heating in 2040 is almost half of that in NECP24.

4.5 Tertiary Sector

As in the Residential Sector, in the Tertiary sector, NECP24 has already included PaMs that reduce the emissions from 0.6MtCO2eq in 2022 to 0.1 MtCO2eq by 2040 and almost zero by 2050. These PaMs are taken to be also included in ECF90 and ECF95.

4.6 Agriculture (energy)

The emissions from energy use in the Agricultural sector are small reaching 0.2 $MtCO_2eq$ already by 2030 and 0.1 $MtCO_2eq$ by 2035 and remain at that level till 2050. Note that the Greek Agriculture Sector basically uses electricity (68%) rather than diesel for energy. The PaMs and resulting emissions are taken to be the same as those in NECP24 for both ECF scenarios for the whole period to 2050.

4.7 Transport Sector

In this sector, the broad means available for emission reduction include (i) increase in the rate of conversion of the vehicle fleet to electricity use, (ii) improvement in engine efficiency either of vehicles or of the fleet as a whole through fleet renewal, (iii) increased use of mass transit, (iv) reduction of travel (passenger kms) either by actual reduction of km travelled or by increasing occupancy, (v) increasing the use of green synfuels and biofuels and (vi) promotion of mild means i.e. walking and bicycling. A number of these were taken on board in NECP24 but their implementation still leaves a lot of room for improvement. A notable approach that is incorporated in the new scenarios is the increased utilization of rail travel both for passengers and freight, which is currently among the lowest in the EU.

A crucial parameter is the amount of travel (in vkm) for which no information is provided in NECP24 although some information can be found in its earlier version of January 2023 and in the 2019 Greek Roadmap to 2050. In both, the pkm especially for air travel domestic and international, are seen to increase substantially without any discernable rationale given but most likely to be attributed to expectations of an increase in tourist volumes. This seems unlikely as tourism has already reached in 2025 the carrying capacity limits of most destinations.

In the following five tables (Tables 6a to 6e), detailed information is provided for the fleet (numbers and composition), vehicle-km traveled and specific fuel consumption for all these scenarios to highlight the differences between them and the nature of PaMs needed to reduce emissions.

Table 6a: 2Wheeled, Rail and Buses, Assumptions and Measures			
	NECP24	**ECF90**	**ECF95**
2 Wheeled vehicles			
	NECP2024	ECF90	ECF95
No of Vehicles	The number of 2W has gone from 1.12mil in 2005 to 1.60 in 2025 to 1.64 in 2020 and 1.85 in 2025. It is assumed that the total will peak and flat out at 1.9mil	Unchanged	Unchanged
Vehicle-km	Following IDEES data average km/vehicle/yr remains constant over 20 years at ca 4500	Unchanged	Unchanged
Fuel consumption	Fuel efficiency has improved from ca 45goe/km in 2000 to 32goe/km in 2022 with the trend to continue reaching 27goe.km in 2050. Electricity effiency to remain constant	Unchanged	Unchanged
Fleet composition	From 100% fossil in 2020 to 75% in 2030 and 35% in 2040 to 5% in 2050	Down to 20% in 2040 with enhanced purchase bonus	Down to 5% in 2040 with enhanced purchase bonus
Rail	Assumptions and Measures		
Fleet composition	All electric by 2030	Unchanged	Unchanged
Buses	Assumptions and Measures		
	NECP2024	ECF90	ECF95
No of Vehicles	The number of buses according to ELSTAT has remained unchanged from 2000 to now at ca 26500. It is assumed that it will remian the same	Unchanged	Unchanged
Vehicle-km	Following IDEES data average Vkm remained constant at about 480MVkm from 2000 to 2022. It is assumed that it will remain there until after 2040 with an increase to ca 600Mvkm by 2050	Unchanged	Unchanged
Fuel consumption	Variable with ca 0.4kgoe/km to 0.65kgoe/km for diesel city and ca 0.1-0.2kgoe/km for electric	Unchanged	Unchanged
Fleet composition	From 97% fossil and 3%NG in 2020 to 82% fossil, 4%NG and 13% electricin 2030 to 23% fossil, 4%NG, 60% electric and 13%H2 in 2040 and 65%elenctic and 35% H2 in 2050	Down to 82% electric and a4% H2 in 2040	Down to 82% electric and a4% H2 in 2041

Table 6b: Passenger Cars Assumptions and Measures			
Passenger Cars	**NECP24**	**ECF90**	**ECF95**
No of Vehicles	The number of cars in Greece has increased substantially in the last 10 years going from ca 5Mil to 6Mil (this for a country with 10.5Mil inhabitants). Never-the-less there is ample room for renewal in view of the fact that the average vehicle age is 17 years.	Unchanged	Unchanged
Vehicle-km	Following IDEES data average Vkm reached 53Gvkm in 2010 and then dropped due to the economic collapse to ca 40Gvkm by 2020. Since then, it has increased and it is assumed that it will reach ca 55Gvkm and remain close to that until 2050. Occcupancy rate is not expected to improve	A concerted effort is envisioned to encourage mode switch assisted by both conjestion and the openning of new metro lines in both Athens and Salonika, so that vkm drop to ca 42GVkm by 2050	As in ECF90 with a small additional switch to bring vkm down to 40Gvkm by 2050
Fuel consumption	Fuel efficiency of all types of vehicles is assumed to keep improving as per the long time trend. ICE Gasoline is assumed to improve by ca 20% between 2021 and 2050 and ICE diesel by 15%. BEV efficiency is also assumed to increase by ca 25%. Overall energy consumption is expected to decrease substancially as the fleet transits to much more efficient electric vehicles	Unchanged	Unchanged
Fleet composition	From ca 80% gasoline, 10% diesel, 2.5% PHEV and 1.5 electric in 2021, the fleet changes, via incentives and market conditions to ca 62% gasoline, 17% diesel , 9% HEV and 6% electric in 2030, to 14% gasoline, 12& diesel, 16% HEV, 5% PHEV and 40% electric in 2040 and finally in 2050 to 1.5% gasoline, 0% diesel, 14% PHEV, 10% HEV and 74% electric bearing in mind the tendency to keep cars longer In all this period, actual vkm allocation is further adjusted to give a 15-20% premium in vkm to electric vehicles in view of reduced running costs so that in 2040 electric vkm are up to 49% (from 40%) and in 2050 to 87% (from 73%) with these vkm subtracted from gasoline mainly and diesel.	No change till 2030 but by 2040, electricity use increases to 64% while gasoline and HEV reduce together to ca 15%, PHEV remains at ca 13% and diesel falls to 1% as does NG. By 2050, electricity reaches 87%, PHEV goes down to ca 8% and gasoline and diesel are near zero.	From the ECF90 values the main difference comes between 2035 and 2040 so that at 2040 the sum of gasoline and HEV is down to 6% (from 15%) and BEV are up to 72% (from 64%) which would require additional incentives to replace older ICE with BEV. In 2050 all three scenarios are the same.

Table 6c: Domestic Maritime Assumptions and Measures			
	NECP24	**ECF90**	**ECF95**
No of ships	No information provided in NECP. Coastal navigation ships in 2025 numbered 155. It is assumed that the total number would remain approximately constant as the tourist levels have reached carrying capacity of the islands	Unchanged	Same as ECF90
Vehicle-km	No information in NECP. In IDEES it vaires from ca 6Mvkm in the 2000s down to ca 3.5Mvkm in the mid 2010's. It is assumed to increase to pre-crisis levels in the 2020s and continue to ca 6Mvkm by 2050	Unchanged	Same as ECF90
Fuel consumption	Fuel efficiency has decresed to ca 155kgoe/km in the 2020s from ca 125kgoe/km as hi-speed Gas turbine ferries have taken a large share of passengers. It is assumed to improve to ca 135kgoe/km by 2050 as technical advances are implemented.	Unchanged	Same as ECF90
Fuel mix	NECP calls for the introduction of NG and Biodiesel by 2030 reducing marine fuel to 90% with further increases to 12% and 10% respectively by 2040 with diesel covering 70% of demand and a radical change after leading to the introduction of Synfuel with 44%, Ammonia by 10% and bioLNG by 21% and no diesel in 2050	Major difference is the large increase of biodiesl use to 40%, by 2040, together with Ammonia for 13% and acceleration of bioLNG from 5% to 17% with a commensurate reduction of NG to 5% so that diesel is only 10%	Same as ECF90

Table 6d: Aviation Assumptions and Measures			
	NECP24	ECF90	ECF95
Domestic Aviation			
vkm	No specific information in NECP. An earlier version of NECP (2023) did provide estimates calling for more than doubling by 2050 wrt 2015 preCOVID levels due to tourism increases and this was followed.	As tourism is reaching saturation levels, the increases in NECP are judged to be excessive. More moderate increase (to less than doubling) is assumed.	As tourism is reaching saturation levels, the increases in NECP are judged to be excessive. More moderate increase (to less than doubling) is assumed.
Fuel consumption	Despite the almost doubling of vkm, fuel consumption increased moderately (ca 12%) due to continuous improvements of fuel efficiency (from 11.9kgoe/km in 2000 to 5.5kgoe/km in 2021 for domestic flights). This improvement is assumed to continue to 4.0kgoe/km in 2040 and 3.7kgoe/km in 2050.	Unchanged	Unchanged
Fuel mix	NECP calls for a transition from kerosene to biofuel and synfuel so that by 2040 they represent 66%, 25% and 8% respectively with kerosene going down to 17% by 2050.	In the ECF90 scenario, the transition is accelerated so that by 2040 kerosene is down to 50% with biofuel to 30% and synfuel to 20%. The 2050 values are near those of the NECP	Same as ECF90
Intra EU Aviation			
vkm	No specific information in NECP. An earlier version of NECP (2023) did provide estimates calling for more than doubling by 2050 wrt 2015 preCOVID levels due to tourism increases and this was followed.	As tourism is reaching saturation levels, the increases in NECP are judged to be excessive. More moderate increase (to less than doubling) is assumed.	As tourism is reaching saturation levels, the increases in NECP are judged to be excessive. More moderate increase (to less than doubling) is assumed.
Fuel consumption	Despite the almost doubling of vkm, fuel consumption increased moderately (ca 12%) due to continuous improvements of fuel efficiency (from 3.9kgoe/km in 2000 to 3.0kgoe/km in 2021 for Intra EU flights). This improvement is assumed to continue to 2.7kgoe/km in 2040 and 2.3kgoe/km in 2050.	Unchanged	Unchanged
Fuel mix	NECP calls for a transition from kerosene to biofuel and synfuel so that by 2040 they represent 66%, 25% and 8% respectively with kerosene going down to 17% by 2050.	In the ECF90 scenario, the transition is accelerated so that by 2040 kerosene is down to 50% with biofuel to 30% and synfuel to 20%. The 2050 values are near those of the NECP	Same as ECF90
ExtraEU Aviation			
vkm	No specific information in NECP. An earlier version of NECP (2023) did provide estimates calling for more than doubling by 2050 wrt 2015 preCOVID levels due to tourism increases and this was followed.	As tourism is reaching saturation levels, the increases in NECP are judged to be excessive. More moderate increase (to less than doubling) is assumed.	As tourism is reaching saturation levels, the increases in NECP are judged to be excessive. More moderate increase (to less than doubling) is assumed.
Fuel consumption	Despite the almost doubling of vkm, fuel consumption increased moderately (ca 12%) due to continuous improvements of fuel efficiency (from 5.1kgoe/km in 2000 to 3.2kgoe/km in 2021 for Extra EU flights). This improvement is assumed to continue to 2.8kgoe/km in 2040 and 2.6kgoe/km in 2050.	Unchanged	Unchanged
Fuel mix	NECP calls for a transition from kerosene to biofuel and synfuel so that by 2040 they represent 66%, 25% and 8% respectively with kerosene going down to 17% by 2050.	In the ECF90 scenario, the transition is accelerated so that by 2040 kerosene is down to 50% with biofuel to 30% and synfuel to 20%. The 2050 values are near those of the NECP	Same as ECF90

Table 6e: Freight Assumptions and Measures			
Road Freight	**NECP24**	**ECF90**	**ECF95**
Light Duty Vehicles (LDV)			
No of Vehicles	The number of trucks (sum of HDV and LDV) has remained (ELSTAT data) almost constant in the last 25 years (increasing by ca 15%). This total number is not expected to increase further. IDEES states a decrease for the number of LDV from ca 700-750k in 2010-2015 to ca 600k by 2021. No further significant change in this number is envisioned.	Unchanged	Unchanged
vkm	Following IDEES data average Vkm increased up to ca 8800Mvkm by 2015 and then dropped to alow of ca7500Mvkm in 2020 to recover to 2015 in the next 2-3 years. It is assumed that it will increase further reaching ca 9500Mvkm by mid 2030s and drop slightly to 9300Mvkm by 2050.	Unchanged	Further reduction of vkm by 25% by 2050 as part of a drive to switch to rail from HDV transport including utilizing piggyback
Fuel consumption	Fuel efficiency is kept constant assuming that major improvements in heavy trucks have already been ncorporated. Yet overall consumption drops by about 35% between 2022 and 2050 due to fleet composition to more efficient energy sources.	Unchanged	Unchanged
Fleet composition	From 60% diesel and 40% gasoline in 2020 to 78% diesel, 9% gasoline 4% electricity and 2% PHEV in 2030 to 54% diesel, 14% PHEV and 31 electric in 2040 to 77%electic and 20% PHEV in 2050	No change till 2030 but by 2040, electricity use increases to 58% and biofuel to 20% diesel, while diesel falls to 15% and NG to 5%. By 2050, electricity reaches 88% and biofuel falls to 10% with diesel to 0%.	No change till 2030 but by 2040, electricity use increases to 57% and biofuel to 20% diesel, while diesel falls to 15% and NG to 5%. By 2050, electricity reaches 88% and biofuel falls to 10% with diesel to 0%.
Heavy Duty Vehicles (HDV)			
No of Vehicles	The number of trucks (sum of HDV and LDV) has remained (ELSTAT data) almost constant in the last 25 years (increasing by ca 15%). This total number is not expected to increase further. IDEES claims a substantial deecrease in the last 5 years	Unchanged	Unchanged
vkm	Following IDEES data average Vkm dropped from ca 2700Mvkm in 2000s to 2100 in 2019, 1900 in 2020 and up again to 2300 by 2021. It is assumed that they remain about constant tilll 2050 as there do not seem to be economic drivers or product inctease.	Unchanged	Further reduction of vkm by 25% by 2050 as part of a drive to switch to rail from HDV transport including utilizing piggyback
Fuel consumption	Fuel efficiency is kept constant assuming that major improvements in heavy trucks have already been ncorporated. Yet overall consumption drops by about 35% between 2022 and 2050 due to fleet composition to more efficient energy sources.	Unchanged	Unchanged
Fleet composition	From 97% diesel and 3%NG in 2020 to 84% diesel 7% biofuel and 7% NG in 2030 to 37% diesel, 7% biofuel and NG and 46% electricity in 2040 to 91%elect and 9% H2 in 2050	No change till 2030 but by 2040, electricity use increases to 57% and biofuel to 20% diesel, while diesel falls to 15% and NG to 5%. By 2050, electricity reaches 88% and biofuel falls to 10% with diesel to 0%.	No change till 2030 but by 2040, electricity use increases to 57% and biofuel to 20% diesel, while diesel falls to 5% with synfuel taking the difference. and NG to 5%. By 2050, electricity reaches 85% and biofuel falls to 10% with synfuel taking the rest and diesel to 0%.

In view of the importance of the Transport Sector emission reduction in Table 7, the corresponding final energy consumption by fuel of the two ECF scenarios together with those of the NECP24 as reported and modelled is provided.

Table 7: Final Energy Consumption (ktoe) in Transport

By Fuel		2022	2025	2030	2035	2040	2045	2050
Oil	Actual	5820						
	NECP	6684	7011	6251	4721	3156	1709	375
	LEAP24	5869	6418	5827	4599	3178	1550	389
	ECF90	5999	6465	5866	3661	1378	781	201
	ECF95	5937	6073	5529	3445	1079	745	199
NG	Actual	27						
	NECP24	14	32	131	165	172	107	91
	LEAP24	49	73	160	178	189	128	89
	ECF90	59	90	182	147	105	78	32
	ECF95	59	90	173	142	104	77	31
Biofuels (including Bio CH_4 and Bio LNG)	Actual	0						
	NECP	204	267	342	556	703	763	834
	LEAP24	84	318	330	480	646	648	660
	ECF90	102	317	388	671	942	837	813
	ECF95	103	298	351	720	1050	880	813
Electricity	Actual	19						
	NECP24	18	32	138	609	1175	1744	2075
	LEAP24	42	74	221	634	1111	1691	1934
	ECF90	45	80	292	940	1483	1683	1796
	ECF95	45	74	275	894	1470	1605	1735
H_2	Actual	0						
	NECP24	0	0	0	1	48	93	126
	LEAP24	0	0	4	6	58	203	306
	ECF90	0	0	4	27	172	189	211
	ECF95	0	0	4	27	172	189	211
Ammonia	Actual	0						
	NECP	0	0	0	0	4	39	72
	LEAP24	0	0	0	0	4	44	74
	ECF90	0	0	0	21	93	105	122
	ECF95	0	0	0	21	93	105	122
Synfuels	Actual	0						
	NECP	0	0	16	69	39	371	1022
	LEAP24	0	0	4	94	251	513	1003
	ECF90	0	0	14	107	390	478	667
	ECF95	0	0	14	102	460	535	706
Total	Actual	5866						
	NECP24	6920	7342	6878	6121	5297	4826	4595
	LEAP24	6044	6884	6548	5991	5436	4777	4455
	ECF90	6205	6952	6746	5574	4564	4150	3841
	ECF95	6143	6535	6346	5351	4428	4135	3817

In Table 7, the quality of the mimicking quality of the NECP24 in LEAP (LEAP24 in Table 7) by fuel can also be ascertained by comparing the values for NECP24 and LEAP24.

In all Tables 6a to 6e information from IDEES Data base (2021 version) has been utilized. Reasonable estimates of fuel efficiency improvements over the next 25 years based on their evolution in the last 10 years have also been incorporated.

It should also be noted that emissions from bunker fuel for international maritime transport are not included in the inventories or the NECP24 and have also been excluded in the two ECF scenarios. Domestic maritime freight is, whose energy use is small, has been included in Domestic Maritime also in view of the fact that a notable amount of freight is already carried in the coastal shipping fleet reported separately.

Unlike maritime bunkering, international aviation is included in the inventory and in all scenarios where again air freight is incorporated in the overall aviation emission estimates. For these, the increased use of SAF is taken to be in accordance with the ReFuelEU Regulation 2023/2405, for which the European Commission is under pressure to postpone/water down.

4.8non-CO2 Emissions

The other (besides Transport) major potential emission reduction pool is that of the non-CO_2 emissions sector. In Table 8 below the non-CO_2 emissions for 2023 (from the latest 2025 National Inventory submission) are presented. From this amount of 19.9 MtCO_2eq in 2023 and 20.6 MtCO_2eq in NECP24 for 2022 (vs. 20.2 MtCO_2eq in the Inventory), PaMs already inscribed in NECP24 result in a 33.5% reduction by 2040 to reach 13.0MtCO_2eq by 2040 and 8.6MtCO_2eq.

Table 8: non-CO_2 gases 2023 Inventory (ktCO_2eq)	
Energy	**1226**
Fuel combustion	867
Fugitives	359
F-gases: Product use	**4583**
Refrigeration	4171
Aerosols, fire equipment, solvents)	412
Agriculture	**7938**
Enteric fermentation	4119
Agricultural soils	2691
Rest	1128
Waste	**6199**
Solid waste disposal	4470
Wastewater	1602
Rest	123
LULUCF	**555**
Total	**19946**

A examination in the breakdown by sector and subsector, shown in Table 8, provides guidance for approaches for further reduction

The first one is the refrigeration emissions that can be reduced to zero as current equipment reaches their end of life and refrigerants are replaced. A second is the Waste sector, and particularly the solid waste disposal site emissions. Proper solid waste disposal facilities in Greece handle only a small amount of the total waste, a situation that has resulted in a number of fines already imposed by the European Commission. Collecting and using CH_4 for power generation or at least flaring it would reduce emissions substantially. This might entail redesigning the overall waste collection and treatment system both by enhancing recycling and by eliminating uncontrolled disposal sites. Finally, better agricultural soil management, which involves better use of inorganic fertilizers, can also contribute to emissions reduction. Enteric fermentation is more difficult to tackle as it would involve mostly means to capture CH_4 in stables which might not be financially viable and almost impossible for sheep and especially goats, the majority of which are in free range. All these possible reductions are incorporated in the new ECF scenarios.

4.8.1 Energy

The fugitive emissions are to a large part from the lignite mines which, as lignite plants are decommissioned, they would disappear. As total fossil fuel energy use is reduced by more than 80% by 2040 wrt 2022, there will be an equivalent reduction leading to the low 0.1 $MtCO_2eq$ value for 2040 which is assumed to be the same for ECF scenarios.

4.8.2 Agriculture

Detailed information for emissions from this subsector as a whole, let alone in the subdivisions (livestock including enteric and manure, rice, and soils both direct and indirect), are not available in NECP24. As a result, in view of the difficulties in reducing emissions from these activities, a reduction coefficient has been utilized taking into account the time series of the last 10 years (2010 to 2023) which differs by subsector to reflect the estimated difficulty in applying mitigation PaMs. The following Table 9 provides details.

4.8.3 F-gases

NECP24 indicates that in 2040, even taking into account all PaMs in accordance with Regulation 2024/573, there are still 1.38 $MtCO_2eq$ stemming from F-gas use in refrigeration and aerosols. The ECF scenarios call for complete elimination of these emissions by legislating stricter timetables for the replacement of refrigerants by other non-fluoride substitutes by 2040.

Table 9: Agriculture non-CO_2 emissions Assumptions and Measures			
	NECP24	**ECF90**	**ECF95**
Livestock			
Enteric CH_4	Number of animals is assumed to remain nearly constant till 2050 as seems to be the case for the last 10 years with the exemption of number of poulty which has increased by 20% since 2025. Reducing enteric emissions is difficult as it leads to improved stabling conditions and secondarily to fee switching. Taking that inot account, NECP2024 assumes a small improvement of 5% by 2040 and 15% by 2050 wrt 2022.	ECF90 assumes an increased effort to control enteric emissions leading to slightly better reductions of 15% by 2040 and 20% in 2050	Same as ECF90
Manure CH_4	Number of animals is assumed to remain nearly constant till 2050 as seems to be the case for the last 10 years with the exemption of number of poulty which has increased by 20% since 2025. Handling manure is easier to accomplish, so NECP2024 incorporates larger reductions of 25% by 2040 and 35% by 2050 wrt 2022	Unchanged from NECP2024	Improving further the handling of manure to 50% by 2040 and 55% by 2050 wrt 2022
Manure N_2O	Number of animals is assumed to remain nearly constant till 2050 as seems to be the case for the last 10 years with the exemption of number of poulty which has increased by 20% since 2025. Handling manure is easier to accomplish, so NECP2024 incorporates larger reductions of 25% by 2040 and 35% by 2050 wrt 2022	Unchanged from NECP2024	Improving further the handling of manure to 50% by 2040 and 55% by 2050 wrt 2022
Agri soils N_2O			
Synth Fertilizer	The use of synthetic fertilizers exhibits large variability the last 25 years (a spread of +/-20%). It is assumed that efforts to reduce excess fertilization will start to produce results so that by 2040 their use is at the lowest level of the spread (ca -15%) and by 2050 is down by 20% wrt 2023	The trent is accelerated and the reduction reaches 30% by 2040 wrt 2023 and 35% by 2050	Same as ECF90
Manure	The slow trend (1-2%/yr) to reduce emissions of the last 20 years is assumed to continue till 2050	Unchanged from NECP2024	Same as ECF90
Crop residue	The slow trend (1-2%/yr) to reduce emissions of the last 20 years is assumed to continue till 2050	Unchanged from NECP2024	Same as ECF90
Pastures	The slow trend (1-2%/yr) to reduce emissions of the last 20 years is assumed to continue till 2050	Unchanged from NECP2024	Same as ECF90
Sewage	Basically unchanged from current levels. The conribution of this category is very small	Unchanged from NECP2024	Same as ECF90
Soils Indirect N_2O			
Field burning CH4	Basically unchanged from current levels. The conribution of this category is very small	Unchanged from NECP2024	Same as ECF90
Field burning N2O	Basically unchanged from current levels. The conribution of this category is very small	Unchanged from NECP2024	Same as ECF90
Urea CO2	Basically unchanged from current levels. The conribution of this category is very small	Unchanged from NECP2024	Same as ECF90
Rice			
	Cultivated areas are assumed to remain awithin the range of the last 20 years i.e. +/-15%	Area is assumed to decrease by 40% (going back to pre2000 levels) in view of the reduction of water resources	Same as ECF90

4.8.4 Waste Management Sector

Waste can be separated into two broad categories, solid and wastewater. The amount of solid waste produced is from municipal sources (as other waste is mostly inert) which is directly dependent on population. In all projections of population in Greece is seen to decrease reaching 9.7Million by 2040 and 9.3Million by 2050 from 10.5Million currently. If tourist presence is included these numbers increase to 9.97Million and 9.6Million respectively.

The same is true for the part of wastewater that is produced from domestic use. An additional amount of wastewater is produced by the industrial sector. Wastewater is responsible for the emission of both CH_4 and N_2O. The CH_4 domestically produced wastewater emissions are typically 12-15% of the total amount with industrially produced ones responsible for the remaining 85-88%, whereas the N_2O emissions are almost entirely the opposite with the domestic amount reaching 95-97%.

As for other non-CO_2 emissions, the NECP24 also does not include specific amounts. This necessitated the production of estimates utilizing IDEES breakdown and the National Emission Inventories and its CRF tables for 2000-2023 and the generation of reasonable extensions on to 2050, always ensuring that the total of non-CO_2 sector is in line with that reported (see Table 1)

In view of the fact that this is a sector with large contribution to the total emissions in 2040, as with the respective non-CO_2 emissions from the agricultural sector, a more detailed analysis of PaMs is provided in Table 10 following.

Table 10: Waste Assumptions and Measures			
	NECP24	**ECF90**	**ECF95**
Solid Waste Disposal (SWD) CH_4			
Production of Solid Municipal Waste (SMW)	SMW volume is almost constant at ca 4500Mt in the last 15 years. This is assumed to decrease as efforts to reduce material use have some results but only to ca4100Mt by 2040 and 3300Mt by 2050 (25% in total) as kg/cap/day drops from 1.3 currently to 1.0 in 2040 and 0.9 in 2050. Landfilled percentage increases reaching 95% by 2040 and 98% by 2050	ECF90 assumes an increased effort to reduce production succeeding to reduce production to ca 3600Mt by 2040 and 2750Mt by 2050	Same as ECF90
Managed SMW	Emissions in managed landfills is ca 2950Mt CO2eq in 2021-2023 to 2000MtCO2eq in 2040 and ca 1000Mt CO2eq by 2050	In view of the decreased production and landfilled amounts, managed amounts reach ca 1300MtCO2eq in 2040 and ca 550MtCO2eq in 2050	In view of the reduced amounts producted and landfilled and by enhancing substantially recovery to flare or electricity generation emissions reach ca 800MtCO2eq by 2040 and near zero (ca 50MtCO2eq) in 2050
Unmanaged SMW	Unmanaged landfill volumes compared to managed one keep decreasing to ca 30% in the last 5 years and are expected to remain at at that percentage albeit at smaller absolute numbers to 2050. Implied emission factors though are much larger by a factor of almost 100 as there is no recovery. Thus emissions decrease from ca 1400Mt CO2eq in 2020-2025 to 950MtCO2eq in 2040 and ca 800Mt CO2eq by 2050 almost as much as the managed landfill ones with only 30% of volume.	Unchanged from NECP2024	Improving further the handling of manure to 50% by 2040 and 55% by 2050 wrt 2022
Sludge (from wastewater treatment plants)	As wasterwater treatment increases, the volume of sludge increases resulting	Unchanged from NECP2025	Improving further the handling of manure to 50% by 2040 and 55% by 2050 wrt 2023
Anaerobic (from biogas installations)	This is a small amount of the order of 100ktCO_2eq	Unchanged from NECP2026	Same as ECF90
Wastewater CH_4 and N_2O			
Domestic CH_4	The use of synthetic fertilizers exhibits large variability the last 25 years (a spread of +/-20%). It is assumed that efforts to reduce excess fertilization will start to produce results so that by 2040 their use is at the lowest level of the spread (ca -15%) and by 2050 is down by 20% wrt 2023	The trent is accelerated and the reduction reaches 30% by 2040 wrt 2023 and 35% by 2050	Same as ECF90
Industrial CH_4	The slow trend (1-2%/yr) to reduce emissions of the last 20 years is assumed to continue till 2050	Unchanged from NECP2024	Same as ECF90
Domestic N_2O	The slow trend (1-2%/yr) to reduce emissions of the last 20 years is assumed to continue till 2050	Unchanged from NECP2024	Same as ECF90
Industrial N_2O	The slow trend (1-2%/yr) to reduce emissions of the last 20 years is assumed to continue till 2050	Unchanged from NECP2024	Same as ECF90

4.9 LULUCF

The LULUCF removals were taken to be the same as those in NECP24 for both ECF scenarios for the whole period to 2050. This is because the amounts of removal already included in the NECP24 are difficult to achieve and a further increase has been considered unrealistic.

4.10 Carbon Capture, Utilization and Storage Sector

There are a number of activities such as process emissions in industry that are directly proportional to production and cannot be mitigated by technical means or substitution. In these cases, when not enough sinks are available for covering them, carbon capture may need to be employed. The captured CO_2 can then be used as feedstock for example in producing synfuels (Carbon Capture and Utilization – CCU) or it can be permanently stored mostly in underground storage facilities, most likely depleted oil or NG deposit formations.

In NECP24, carbon capture is included from the energy and industry sectors starting as early as 2030 with 3.3 $MtCO_2$ annually and increasing to 4.2 $MtCO_2$ in 2040 and declining to 3.9 $MtCO_2$ by 2050 as both fossil fuels' use decreases.

At the same time, to meet the near zero overall emissions target by 2050, additional removals are needed. To this end, the NECP24 includes the use of direct capture of CO_2 from the atmosphere (DAC) after 2045 and its storage together with the remaining amounts of captured CO_2 from energy and industry, after the amounts used as feedstock are subtracted. The values for all these are shown in Table 1.

As shown in Table 3, the ECF90 scenario includes the same amounts of CC, CCU, CCS and DAC as NECP24 (4.1$MtCO_2$, 0.8$MtCO_2$, 3.5$MtCO_2$ and zero respectively in 2040). ECF95 also includes the same amounts of CC and CCU but increases the amount stored (CCS) to 5$MtCO_2$, an amount still smaller than that stored by 2050 (5.7$MtCO_2$).

It should be mentioned that all processes of capture, utilization and storage are to be carried out using electricity produced by RES which is accounted for in the demand of the Energy Sector (see Section 4.3).

5. SOME CONCLUDING REMARKS

As the Greek NECP as published in the Official Government Journal in December 2024 and submitted to EC in January 2025, calls for an 80% reduction of GHG emissions by 2040 wrt 1990. This clearly is not in line with the target of 90% proposed by EC albeit with some flexibilities. The Greek Government has indicated that it considers the 90% difficult to meet and expressed reservations in consenting with a Council decision in this respect.

Lately (March 2026), the Greek Prime Minister also announced, in a reversal of the Greek position for over 50 years, that the Government is considering seriously the introduction of small modular nuclear reactors to the electricity production mix. These developments enhance the need for a new national debate on the energy mix toward the national and the EU decarbonization targets and for the necessary modifications of the NECP to achieve more ambitious reduction targets. It is hoped that this will become an issue in the upcoming elections that have to take place in the Spring of 2027 but may come sooner as the current Government is involved in a number of financial and legal scandals.

In view of the above, the two scenarios have been constructed to adhere as much as possible to the approaches in the NECP and its proposed PaMs as for example the rates of energy renovations in the residential sector. For some sectors this meant simply accelerating the application of PaMs by 5 years. In particular, as almost all of the industry sector CO2 emissions are already captured and used for synfuel production, additional carbon capture may be utilized in the energy sector and even by DAC with the captured CO_2 going to increase synfuel production as adequate land storage LULUCF may be more difficult to find. This option is added to the 95% reduction scenario (ECF95). In others, emission reductions have been included that can be accomplished by administrative measures that are realistic even taking into consideration political considerations, such as PV installation rates and waste management.

This principle was also followed in the architecture of the LEAP model tree and its implementation. To provide evidence of the modelling reliability a lot of effort was expended in making sure that the mimicking of the NECP in the LEAP (LEAP24) matched the values inscribed in the NECP (NECP24) as is evident both for the emissions (see Tables 2 and 3 for a comparison) and also for the crucial electricity sector (see Tables 4 and 5 for a comparison). It should be noted that this was accomplished despite the contradictory information included in the NECP as published, as for example the hydro installed capacity which is given as 4678MW of large hydro by 2050 in one place (p74149), 4100 in another (i.e. 4500MW total minus 490MW small in p74584) while in p74149 the pumped storage facilities are given as 5453MW! Similarly, the offshore capacity in 2030 is given as 1900MW but their production is 600GWh (p74584) which implies a capacity factor of CF=4% which is off by a factor of ten!

As in every modelling effort, there is always room for improvement either in the scope or in the processes modelled. Thus, future work in improving this version of the model of the Greek energy and emissions status in LEAP can follow two directions. The first is the acquisition of more and better disaggregated data imputed in LEAP exogenously, especially as regards energy efficiency evolution of a number of technologies including road vehicles, airplanes and ships, but also electrolysis and synfuel production. This would also include the collection of data to input more detailed load slices in LEAP especially taking advantage of the recent improvements in the LEAP capacity that extended the load shapes to individual fuels. The second is a more detailed bottom-up representation of sectors such as industry and the refineries, and possibly the tertiary sector. As regards the industry sector and refineries, this would need to secure data both technical and activity for each of the very few units (there are only three refineries, only one steel and one alumina/aluminium production facility as well as four cement factories) which may be confidential. Similarly, more disaggregated information would help in analyzing the waste disposal facilities and their management.

Finally, it would be interesting to carry out sensitivity analyses in a number of the exogenously specified parameters that may include NG planned installations with full permitting but no FID as well as limitations or conditions that might stem from physical constraints or financial considerations on import and export of electricity, synfuels and biofuels.

The two scenarios ECF90 and ECF95 are made available to the Greek Center for Renewables and Energy Conservation and selected NGOs including Greenpeace and WWF as well as to students of the University of Athens and the National Technical University of Athens upon request.