Recommendations for policies and measures to mitigate ETS2 implementation impacts in Greece

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Executive Summary

This study assesses the impacts of the new Emissions Trading System for buildings and road transport (ETS2) on Greek households, and puts forth well-documented recommendations for the mitigation of energy and transport vulnerability. The proposed interventions could be included in the National Social Climate Plan and financed by the available resources of the Social Climate Fund (SCF); the remaining revenues of the ETS2; and part of the public revenues from the existing Emission Trading System for electricity production, heavy industry, and aviation (ETS1).

Using the Household Budget Survey (HBS) data, kindly provided by the Hellenic Statistical Authority (ELSTAT), both energy and transport vulnerability were quantified by calculating specific indicators. The latter were formulated so as to combine household income level with the percentage of income used to meet fossil fuel-based residential energy and transport needs.

The analysis indicated that -well in advance of the ETS2 launch (2027)- Greece is facing an acute problem: indeed, currently, 26.5% and 13.9% of the population is energy-vulnerable and transport-vulnerable, respectively.

The direct socio-economic impact of the ETS2 on vulnerable populations was estimated to range from EUR 833 million to EUR 1.6 billion over the period 2027-2032, for average carbon prices of 45 EUR/t CO_2 to 84 EUR/t CO_2; this additional burden will increase the number of energy- and transport-vulnerable households by approximately 0.9-1.5% and 1.1-2.1%, respectively.

In order to relieve the energy- and transport-vulnerable populations from these direct impacts resulting from ETS2 implementation, it is recommended that direct income support be provided to all energy-vulnerable households (1.15-1.17 million households), as well as to the transport-vulnerable population not residing in Attica or Thessaloniki (a sub-group of 448-475 thousand households). The implementation cost of this measure ranges between EUR 742 million (based on an allowance price of 45 EUR/t CO_2) and EUR 1.42 billion (based on 84 EUR/t CO_2). This expenditure corresponds to 15.5%-29.7% of the SCF resources for Greece, thus, remaining significantly below the 37.5% limit set by the SCF Regulation regarding funds dedicated to direct income support.

Moreover, in order to radically combat energy vulnerability, a number of structural measures are recommended; these include expanding social housing; replacing oil-based heating systems with heat pumps; deep or shallow renovations; and the installation of photovoltaic systems to meet own electricity needs either by individual households or collectively through energy communities. These packages of measures shall be implemented to specific priority sub-populations, thus, eliminating energy vulnerability in 276-348 thousand households, for an estimated total cost of EUR 6.8-8.4 billion over the period 2026-2032.

With regard to alleviating transport vulnerability, the measures recommended include the provision of a discount on unlimited travel cards for all adult members of transport-vulnerable households in Attica and Thessaloniki; the provision of free tickets for these households' minors;

and the subsidization of electric vehicle leasing for particularly transport-vulnerable households not residing in Athens or Thessaloniki. Estimated to cost EUR 1.18-1.28 billion (depending on carbon price levels), the implementation of these measures will support 262-282 thousand transport-vulnerable households. Moreover, given the possibility of mobilizing funds from other sources beyond the SCF, it is recommended that an additional EUR 3.2 - 4.3 billion be committed to upgrade transport infrastructure by promoting public transport; improving railways; and streamlining bus transportation. In total, these resources represent 54-73% of the NECP budget for actions aimed at upgrading transport infrastructure by 2030.

All the above investments, including direct income support, amount to a total of EUR 11.9-15.5 billion. The implementation of these measures has a twofold significance: on the one hand, it can substantially contribute to reducing emissions in the buildings and transport sectors; on the other hand, it can mitigate the — already acute — issue of energy and transport vulnerability.

Nevertheless, in order to cover these costs, employing all available financial resources -and not only those extended by the Social Climate Fund (SCF)- is vital. There are three sources of available funds: (a) the Social Climate Fund, budgeted at EUR 4.78 billion; (b) the remaining revenues to be collected from ETS2 carbon auctions, which will range between EUR 2.75 billion and EUR 6.34 billion (for an allowance price of 45 EUR/t and 84 EUR/t, respectively); and (c) half of the public revenues from the auctioning of allowances under the existing ETS1, estimated at EUR 4.33 billion (based on an allowance price of 75 EUR/t).

The implementation of the ETS2 represents a major turning point on the path towards achieving the climate targets. The resources available should, therefore, decisively contribute to bringing household energy and transport vulnerability to an end, through a definitive decoupling from fossil fuels. It is imperative that the revenues generated by the new system be channeled transparently and equitably back to society, primarily supporting the most vulnerable households that are disproportionately affected. Thus, carbon pricing can represent a strategic tool for the transition, rather than an additional burden, ensuring broad social acceptance. To that end, the design of an effective Social Climate Plan is key; this plan should clearly identify vulnerable populations, as well as the socio-economic impacts of the ETS2 and the targeted measures to mitigate them.

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1 Introduction

1.1 ETS2 Overview

Successive economic and climate crises in recent years have dictated the acceleration of fossil fuel decoupling in the sectors of the national economy. Particularly with regard to electricity production, the implementation of the Emissions Trading System (EU-ETS, hereafter referred to as ETS1) has played a key role in reducing the sector's emissions (-71% in 2023 compared to 2005). Nonetheless, with regard to the sectors under the Effort Sharing Regulation (ESR), which includes buildings, transport, agriculture, and waste management, progress has been slow.

The uncertainty over achieving emission reduction targets and, ultimately, climate neutrality in 2050 has led to a plethora of legislative developments in the EU, the most important being the "fit for 55" package, under which the ETS Directive was revised in 2023. This revision introduced a new scheme, the ETS2, aimed at decarbonizing the buildings and road transport sectors. The carbon price under the new system is expected to incentivize the implementation of long-term measures with a positive social and climate impact (for instance, investments in building renovation and low-emission mobility).

Thus, the ETS2 will cover CO_2 emissions from fuel consumption (diesel; fossil gas; petrol; and other non-zero emission fuels) in buildings, road transport, and additional sectors (mainly small-scale industry (SSI) not covered by the existing ETS).

Similar to the existing ETS, ETS2 is a cap and trade system; this scheme, however, will require from fuel suppliers, rather final consumers, to monitor and report their emissions, and surrender sufficient carbons each year to cover the latter. All emission allowances will be auctioned. The cap will be set so as to reduce emissions by 42% by 2030 compared to 2005 (-43% for the building and road transport sectors).

The ETS2 will become fully operational in 2027; nonetheless, it has been foreseen that, in the event of exceptionally high fossil gas or oil prices in 2026, its launch be postponed to 2028 so as to prevent additional burdens on households, SSIs and third sector companies, as well as to ensure a smooth implementation. In order to guarantee the latter, namely, by preventing abrupt carbon price changes, the following rules have been adopted:

- Emissions monitoring and reporting will start in 2025.
- During 2027, a 30% higher volume of allowances than required (as determined to meet the reduction target mentioned above) will be auctioned, so as to ensure market liquidity.
- During the first three years of ETS2 operation, if the price of allowances exceeds 45 EUR/t (2020 prices), additional allowances may be released to address excessive price increases.
- Additional allowances may also be released if the price of allowances increases too quickly.

ETS2 success, with regard to the emission reduction that will be achieved, will largely depend on Member States' ability to effectively address and mitigate the impacts of the scheme's

implementation in a socially equitable manner. To this end, Regulation (EU) 2023/955 has established the Social Climate Fund (SCF) for the period 2026 – 2032 to financially support the measures and investments included in Member States' social climate plans. As stated in Article 1 of the Regulation, "*the measures and investments supported by the Fund shall benefit households, micro-enterprises and transport users, which are vulnerable and particularly affected by the inclusion of greenhouse gas emissions from buildings and road transport within the scope of Directive 2003/87/EC, in particular households in energy poverty or households in transport poverty*".

In order to receive financial support, each Member State must develop (and submit to the European Commission) a Social Climate Plan; the latter shall be consistent with the respective National Energy and Climate Plan (NECP) and include a coherent set of existing or new national measures and investments to address the impacts of the ETS2, while "*accompanying and accelerating necessary measures to meet the climate targets of the Union*" (Article 4). Social Climate Plan content is specified in Article 6 of the Regulation.

According to the Regulation, vulnerable households, vulnerable micro-enterprises, and vulnerable transport users shall be the beneficiaries of the relevant measures and investments. The concept of vulnerability is specified in the Regulation; nonetheless, each Member State will formulate and adopt its own precise approach to determine intervention beneficiaries (vulnerable households, micro-enterprises, and transport users). In any event, the vulnerability indicator is broader compared to the energy poverty indicator or the number of social tariff recipients. For instance, the Regulation defines vulnerable households as "*households in energy poverty or households, including low income and lower middle-income ones, that are significantly affected by the price impacts of the inclusion of greenhouse gas emissions from buildings within the scope of Directive 2003/87/EC and lack the means to renovate the building they occupy*".

The measures to be included in the Social Climate Plan and financed by the SCF will relate to, inter alia:

- Building renovations, particularly for vulnerable households and vulnerable micro-enterprises;
- Providing access to affordable and energy-efficient housing, including social housing;
- Supporting the decarbonization and electrification of final consumption by providing access to affordable and energy efficient systems, while integrating renewable energy production and storage through either individually installed systems or participation in energy communities.
- Promoting zero- and low-emission mobility and transport by providing access to zero- and low-emission vehicles and bicycles and developing charging infrastructure.
- Incentivizing the use of affordable and accessible public transport and supporting both public and private entities in developing and providing sustainable mobility on demand, shared mobility services, and active mobility options.

In addition to the above, the Social Climate Plan may include measures that provide temporary direct income support to vulnerable households, micro-enterprises, and transport users. However, the cost of these measures must not exceed 37.5% of the Plan's estimated total cost.

The Regulation stipulates that the funds available to the SCF shall amount to a maximum of EUR 65 billion (EUR 54.6 billion if the implementation of the ETS2 is postponed to 2028). Moreover, it provides for the distribution of these resources among Member States over the period 2026 – 2032; Greece has been allocated 5.52% of total funds. Finally, the Regulation specifies Member States' minimum contribution to the total cost of the Social Climate Plan at 25%.

1.2 Objectives and structure of the study

This study was carried out to formulate substantiated recommendations for interventions that could be included in the Social Climate Plan and funded by the available resources. These interventions aim at supporting households (where household members are also targeted as transport users), while, simultaneously, reducing both the energy costs and carbon footprint of vulnerable households in Greece. It should be noted that, based on the national energy balance data, the electrification of final consumption in the residential sector is at lower levels (~36% in 2021) compared to both the tertiary sector (~75% in 2021) and the industrial sub-sectors not included in the ETS (~45% in 2021). In addition, based on national GHG emissions inventory data, emissions from transport activities of households account for 75% of road transport emissions (passenger cars and light trucks).

In particular, this project aimed at:

- Identifying vulnerable households and vulnerable transport users in line with the SCF Regulation;
- Assessing the impact of ETS2 implementation on households;
- Specifying measures to mitigate the impacts of ETS2 implementation in line with the SCF Regulation;
- Analyzing the effectiveness of several energy saving and renewable energy promotion measures in mitigating these impacts; and
- Formulating policy recommendations based on both the aforementioned analysis and the resources available for action implementation.

The study's methodological framework -developed in line with the SCF Regulation- is described in Chapter 2. Subsequently, in Chapter 3, vulnerable households and transport users are identified based on different levels of CO_2 prices, and the impacts attributed to the implementation of the ETS2 are calculated. A set of measures to address these impacts is presented in Chapter 4, together with recommendations for a suitable combination of policies and measures, taking into account the available resources. Finally, the study's key findings are summarized in Chapter 5.

2 Methodology

2.1 Identification of vulnerable households

2.1.1 Overview

The Social Climate Fund was introduced to support vulnerable households, micro-enterprises and transport users affected by the inclusion of greenhouse gas emissions from buildings and road transport in the scope of Directive 2003/87/EC (ETS2). Undoubtedly, the implementation of ETS2 will affect to some extent the prices of fossil fuels used in buildings and road transport; therefore, it is vital that the SCF resources be employed to protect vulnerable households and enterprises through temporary direct income support, as well as through structural measures and investments; importantly, the latter will also contribute to the long-term reduction of CO_2 emissions from household activities. This study focuses on the households that will be affected by the implementation of the ETS2, with regard to both residential fuel use (mainly for space heating but also for other uses) and household members' use of fossil fuel-based transport.

Formulating recommendations for specific policies and measures that can successfully mitigate the impacts of ETS2 implementation and, at the same time, contribute to the decarbonization of the economy, constitutes this study's ultimate objective. To this end, the first step is to identify vulnerable households, with regard to both residential fossil fuel consumption (energy-vulnerable households) and fossil-fueled transport use (transport-vulnerable households).

The detailed data of the Household Budget Survey (HBS) conducted annually by the Hellenic Statistical Authority (ELSTAT) serve to identify the number and characteristics of households that fall into the two aforementioned vulnerability groups. These data provide a detailed picture of Greek households' expenditures for goods and services (including energy resources), while capturing additional parameters of interest, such as income; household composition; dwelling characteristics; etc.[1] The methodological framework applied in order to identify energy- and transport-vulnerable households is delineated in the following Sections.

2.1.2 Household energy vulnerability

In European countries and in Greece, households' lack of access to essential energy services that provide basic levels and decent standards of living and health -including adequate heating; hot water; cooling; lighting; and energy for electrical appliances- constitutes a long-standing issue. Often referred to as "energy poverty", this issue is fundamentally linked to three key parameters: low household income; high energy prices; and buildings' low energy efficiency. The various indicators that have been used to define energy poverty fall under the following categories (Thema & Vondung, 2020b):

- *Expenditure-based metrics*, where energy poverty is defined based on information regarding the household's energy expenditure and often compared against its income.

[1] We would like to thank ELSTAT for providing the detailed data required for this analysis.

- *Consensual-based metrics*, where energy poverty is defined based on self-reported assessments regarding both household conditions and the households' ability to access and purchase basic energy services. These indicators often incorporate outcome-based metrics related to energy poverty consequences, such as electricity disconnections; late bill payments; common cold-related mortality; etc.
- *Direct measurement metrics*, where a direct measurement of the household's level of energy services (such as heating) is compared against a predefined standard to determine energy poverty.

There are strengths and weaknesses to each indicator's ability to capture energy poverty (Halkos & Kostakis, 2023; Thema & Vondung, 2020a; Halkos & Gkampoura, 2021; Herrero S.T., 2017); furthermore, different indicators may focus on distinct aspects of the phenomenon. As the latter cannot be holistically addressed by a single indicator, the use of multiple metrics is often preferred, thus, highlighting the diverse facets of energy poverty. The Greek State, in its Action Plan to Combat Energy Poverty (Ministry of the Environment and Energy (YPEN) 2021), has adopted the National Energy Poverty Index (NEPI); this indicator stipulates that a household is classified as energy-poor if the following two conditions apply simultaneously:

(i) the annual cost of the energy consumed by the household is below 80% of the minimum required energy consumption; and
(ii) the equivalized annual net income of the household (based on the OECD relevant scale) is below 60% of the median of the respective income of all households, according to the definition of relative poverty.

The European Parliament Regulation 2023/995, establishing the SCF, defines vulnerable households (with regard to residential energy vulnerability alone) as "*households in energy poverty or households, including low income and lower middle-income ones, that are significantly affected by the price impacts of the inclusion of greenhouse gas emissions from buildings within the scope of Directive 2003/87/EC and lack the means to renovate the building they occupy*" (Article 2). Under this definition, energy-vulnerable households encompass a wider population than energy-poor households.

For the purposes of this study, experience was drawn from the use of various indicators of energy poverty regarding both their advantages and disadvantages. Specifically, expenditure-based indicators that consider energy expenditure and household income were deemed best suited to identify energy-vulnerable households based on different carbon price scenarios in the context of the ETS2. Nonetheless, the use of these indicators gives rise to the following key issues:

- The debate on whether to use actual or required energy costs. On the one hand, using the former data -readily available from the HBS- could conceal energy underconsumption, which, in turn, could lead to certain households being unaccounted for as energy-poor. On the other hand, required energy costs are not readily available and their estimation requires a rather complex computational groundwork. The NEPI takes into account the minimum required energy expenditure, a quantity that is not clearly defined; confidence in the calculation process is, thus, undermined.
- Most expenditure-based metrics take into account household income in a relative way, along the lines of the definition of poverty generally adopted at European level.

Nonetheless, this approach obscures the assessment of the effects produced by specific policies aimed at reducing energy poverty.

Based on the above considerations, in the context of the present study, a new indicator was formulated to identify energy-vulnerable households under the SCF. This indicator requires the concurrence of the following three conditions:

(i) *The household's disposable income is below the income criteria set for receiving the State's heating subsidy*. As these criteria also take into account assets, this analysis uses the total net household income after taxes, which includes non-monetary components (HBS variable HH099). The heating subsidy is adjusted based on household composition, thus, taking into account households' distinct needs.

(ii) *The share of energy expenditure required to ensure adequate thermal comfort conditions at home exceeds 10% of total net household income after taxes, which includes non-monetary components (HBS variable HH099)*. This criterion controls for dwelling energy efficiency, as it is expected that buildings with low energy efficiency will have increased energy needs in order to reach adequate thermal comfort conditions. A 10% threshold was adopted in the context of this analysis, as it has been used extensively as an energy poverty indicator in the UK and elsewhere (DECC 2015; Jones et al. 2016).

(iii) *Fossil fuels are used to meet the household's residential energy needs*. This criterion is introduced into the calculation process in order to focus the analysis on energy-vulnerable or energy-poor households affected by the ETS2; it is controlled by household expenditure on the purchase of fossil gas and/or oil products for residential use, recorded in the HBS through variables HE0452 and HE0453.

The indicator of household energy vulnerability was first calculated based on a reference scenario, using the detailed HBS data combined with additional confidential data provided by ELSTAT for the needs of this study, for the year 2021. This specific year was selected for the following reasons: it is relatively recent; the detailed HBS data are available; and it does not present the particularities of other recent years, namely 2020, where incomes and energy consumption were affected by the Covid-19 pandemic management measures, and 2022 – first half of 2023, where energy prices surged due to Russia's invasion of Ukraine. Thus, it could be argued that 2021 best reflects the current living conditions of Greek households in circumstances of relative normality. Subsequently, the household energy-vulnerability indicator was recalculated for 3 different carbon price scenarios reflecting, respectively, low, moderate and high average carbon prices over the 2027-2032 period (please see Section 2.2 for more detailed information).

In order to test criterion (i) of the indicator, the analysis used the income criteria for receiving the heating subsidy that were in force in 2021, presented in Table 2.1. Based on the composition of each household included in the HBS, the corresponding income threshold of vulnerability was calculated and compared to the total net income of the household.

Table 2.1 Income thresholds for receiving the heating subsidy for the year 2021 (EUR).

Household Composition	Income threshold (EUR)
Single individual	14,000
Married individual	20,000

Additional threshold per child	3,000
Single-parent family with one child	23,000
Additional child in single-parent family	3,000

The required energy expenditure used in criterion (ii) of the energy vulnerability indicator was estimated based on the Greek Regulation on the Energy Performance of Buildings (KENAK); a simplified calculation process was applied, taking into account certain structural characteristics of dwellings, as recorded in the HBS. This calculation process is presented in Annex I.

2.1.3 Household transport vulnerability

The issue of transport poverty has been clearly less studied at the European level; no single definition exists and just a few indicators have been used to capture this phenomenon. The term is largely used to describe individuals' inability to access basic services or their workplace due to a lack of affordable or available transport options.

Based on the literature, the following key factors lead to transport poverty:

- *Lack or low frequency of transport (availability)*
- *Lack of accessibility to transport means or infrastructure (e.g. for persons with disabilities)*
- *Transport affordability (inability to cover transport costs)*
- *Excessive travel time*
- *Unsatisfactory travel conditions (the available transport options are dangerous or unsafe).*

In a broader context, transport poverty may also refer to individuals or households that may have access to affordable options of transport; however, as the latter represents a significant share of their budget (10% or more), they are vulnerable to transport cost increases.

The following have been considered as indicators of transport poverty (Cludius et al., 2024):

- *The proportion of the population characterized by material and social deprivation that owns a car*. Here, it is assumed that these individuals are essentially 'forced' to acquire a car due to a lack of alternatives, and, thus, bear additional financial pressures. Nonetheless, this indicator has been subject to considerable criticism, as car ownership is part of established social living standards.
- *The percentage of the population that has no or very difficult access to public transport infrastructure*. These indicators are often quantified via a relevant question included in the EU-SILC.
- *The percentage of the population with mobility problems that has difficult access to public transport infrastructure*.
- *The percentage of the economically active population that needs more than 30 minutes to travel to work (one-way commute)*.
- *The percentage of the population that cannot afford to own a car*. This indicator is also quantified through EU-SILC.
- *The percentage of the population that considers public transport tickets too expensive*.
- *The percentage of households whose transport expenditure exceeds 6% of their total expenditure*. HBS data can be used to calculate this indicator.

- *The percentage of households whose transport expenditure exceeds twice the national median price*. Again, HBS data can be used to calculate this indicator.

The European Parliament Regulation 2023/995 establishing the SCF provides the following definitions regarding transport vulnerability (Article 2):

- "*Transport poverty*" means "*individuals' and households' inability or difficulty to meet the costs of private or public transport, or their lack of or limited access to transport needed for their access to essential socioeconomic services and activities, taking into account the national and spatial context".*
- "*Vulnerable transport users*" means "*individuals and households in transport poverty, but also individuals and households, including low income and lower middle-income ones, that are significantly affected by the price impacts of the inclusion of greenhouse gas emissions from road transport within the scope of Directive 2003/87/EC and lack the means to purchase zero- and low-emission vehicles or to switch to alternative sustainable modes of transport, including public transport*".

Vulnerable transport users, thus, form a broader population group compared to that characterized by transport poverty. Furthermore, a more direct reference is made to the disposable income of transport-vulnerable households. Based on the above considerations, in the context of the present study, a new indicator was formulated to identify transport-vulnerable households under the SCF. This indicator takes into account the income of households, as well as the level of their transport expenditure. In particular:

- With regard to the income criterion: the first condition applied in the case of energy vulnerability (condition (i)) is adopted, using the same thresholds and assumptions.
- With regard to transport expenditure: for a household to be considered transport-vulnerable, more than 6% of its total income must be dedicated to transport expenditure. The latter includes the purchase of fuel for the household's vehicles (HBS variables H07221; H07222; and H07223) and the purchase of tickets for land transport via bus, metro, and rail (HBS variables H0731 and H0732). As in the case of energy vulnerability, 'income' means the total net income after taxes, which includes non-monetary components (HBS variable HH099).

The formulation of this indicator was essentially dictated by the need for quantitative estimates of the impact of ETS2 implementation, while ensuring relative sensitivity to the effect of carbon prices. Therefore, indicators based on the EU-SILC were deemed unsuitable in this case. Moreover, as in the case of energy vulnerability, relative vulnerability thresholds were avoided, as their use obscures the assessment of the measures applied. Here again, the quantitative analysis of the transport vulnerability indicator was based on the HBS detailed data for the year 2021. As in the case of the energy-vulnerability indicator, the household transport vulnerability indicator was first calculated for a reference scenario, using the detailed HBS data; subsequently, the indicator was recalculated for 3 different carbon price scenarios reflecting, respectively, low, moderate and high average allowance prices over the period 2027-2032.

2.2 Assessment of the economic impacts of the ETS2 on vulnerable households

The results of the HBS (2021), also used to identify vulnerable households and transport users, were employed to assess the economic impacts of the ETS2 on vulnerable households. It should be noted that this assessment related only to direct economic impacts; the extent to which household expenditure will be affected was not examined.

As mentioned in section 2.1, by adopting different carbon price values as a result of the implementation of the ETS2, vulnerable households were re-identified and household energy expenditure (buildings and transport) was recalculated.

- Low allowance price scenario (ETS2-CP45): 45 EUR/t[2].
- Medium allowance price scenario (ETS2-CP57.5): 57.5 EUR/t[3].
- High allowance price scenario (ETS2-CP84): 84 EUR/t[4]

The difference in vulnerable households' energy expenditure before and after the application of each carbon price was taken to represent the additional burden due to the implementation of the ETS2. The average burden (in EUR per household) was then calculated based on the HSB 2021 sample, and used to determine the additional burden at national level, separately for buildings and transport. The change in fuel prices due to the incorporation of carbon prices is presented in Table 2.2.

Table 2.2 Fuel prices (in EUR/kWh) in the reference scenario (prior to the incorporation of carbon prices) and in the three scenarios considered.

	Reference scenario	ETS2-AP45	ETS2-AP57.5	ETS2-AP84
Diesel (heating)	0.102	0.114	0.117	0.124
Fossil gas	0.073	0.082	0.085	0.090
Diesel (transport)	0.139	0.151	0.154	0.161
Petrol	0.185	0.197	0.201	0.208

[2] This is the target value not to be exceeded in the first years of operation of ETS-2, in accordance with the revised ETS Directive.

[3] This is the median of price values for the period 2027-2032 included in the European Commission's Guidelines for Social Climate Plans. https://shorturl.at/1hNEq

[4] Based on the European Commission's 2030 estimate provided in the impact assessment report accompanying its latest proposal for the revision of the ETS Directive revision (2003/87/EC).

2.3 Identification of an adequate mix of policies and measures -in line with decarbonization- to mitigate ETS2 impacts

The selection of measures that could be included in the Social Climate Plan and financed by the SCF was carried out in compliance with the SCF Regulation provisions. The initial selection criteria were as follows:

1. Measures should provide direct support to households to address the additional burden resulting from ETS2 implementation, taking into account that, as stipulated in the Regulation, the cost of these measures may not exceed 37.5% of the estimated total cost of the Plan; and
2. Measures should address the structural issues (for instance, aging buildings with low energy efficiency; under-developed network of public transport), which affect households' energy consumption and their members' transport habits, thus, contributing to household vulnerability even before ETS2 implementation.

Direct support measures target vulnerable households, covering additional costs -for both mobility and residential energy use- that will result from the implementation of the ETS2. Particularly with regard to Attica and Thessaloniki, both of which have a more developed urban transport network, support is provided by granting free tickets to specific population groups (e.g. children; students) or covering half the cost of unlimited travel cards.

Relevant studies published by the European Commission were consulted (Cludius et al., 2024; Ludden et al., 2024) in order to identify appropriate measures to address structural issues and reduce the burden resulting from ETS2 implementation, thus, ultimately decarbonizing household energy consumption. In this context, measures should contribute to energy saving; improve energy efficiency; promote the decarbonization of final energy consumption; and encourage further penetration of renewable energy sources. In addition, the cost-effectiveness of interventions over the duration of their implementation -albeit not a direct focus of this study- constituted one of the selection criteria, particularly with regard to measures targeting dwellings.

In this direction, and taking into account the results of a previous study entitled "Strategies for reducing the carbon footprint and tackling energy poverty in Greek households" (Mirasgedis et al. 2024), the following dwelling-related measures were examined:

- Energy renovations (shallow or deep), in order to reduce energy requirements and energy costs, as well as the impact of ETS2 implementation.
- Replacement of oil-fired heating systems with heat pumps, in order to promote decoupling from fossil fuels and prevent the direct impact of ETS2 implementation. Considering that the available resources would not be able to cover the replacement of both oil-fired and fossil gas-fired boilers, the former heating systems were favored over the latter, as they are more prevalent (oil holds the largest share among heating systems in Greece) and more polluting; in addition, decoupling from oil in the building heating

sector constitutes a key objective of the National Climate Law (Law no. 4936/2022, article 17).

- Installation of photovoltaic systems (PV) -4 kW per household- on roofs or participation in energy communities, in order to promote citizens' active participation in the transition through self-consumption of renewable energy. Over the past years, Greece has seen a lot of progress in this field; nonetheless, a stagnation in relevant connection requests has been observed recently, mainly due to the shift from (virtual) net metering to (virtual) net billing.
- Access to affordable and energy-efficient housing (social housing). A proportion of the provided aid, which will cover the total renovation cost, shall be paid to landlords of residences to be rented to energy-vulnerable households, while the remainder shall be dispensed to households renting these dwellings.

With regard to measures addressing transport vulnerability, the study examined the promotion of electromobility through subsidized leasing schemes, as well as the implementation of horizontal actions aimed at developing/improving infrastructure to foster the use of public transport, ultimately benefiting all users and not just those who are vulnerable.

The following are noted regarding the penetration and implementation of the measures:

- Housing-related measures are not alternate and shall be implemented as a single package of measures to address vulnerability more permanently.
- Observing optimal spatial availability, photovoltaic systems shall be installed directly on roofs of single-family houses in non-urban areas (with the exception of such areas in Attica); households residing in urban dwellings (both single-family houses and apartment buildings) will benefit from photovoltaic systems through their participation in energy communities.
- Deep energy renovations concern areas with high heating requirements (northern Greece); in contrast, shallow energy renovations relate to households in southern Greece, where heating requirements are comparatively low.
- The measure regarding access to affordable and energy-efficient housing relates to energy-vulnerable single-parent or large families that rent their dwelling.
- The promotion of electromobility concerns households with high transport vulnerability (transport costs exceed 15% of income) not residing in Attica and Thessaloniki, namely, residing in areas with lower access to public transport and greater difficulties in commuting.

The cost values presented in Table 2.3 were used in order to calculate the capital requirements for the implementation of the aforementioned measures. These figures represent the total investment cost required for each intervention, disregarding any existing or planned subsidy schemes or other support policies.

Table 2.3 Investment cost of considered interventions aimed at mitigating ETS2 implementation impacts.

Intervention	Cost	Comments
Shallow renovations	100 EUR / m^2	As reflected in the NECP
Deep renovations	332 EUR / m^2	BPIE (2020)
Heat pumps	400 EUR / kW	"Exikonomo – Anakenizo for Youth" (Saving-Renovating program) Program Guide
Roof Photovoltaics	1,800 EUR / kW	"Roof Photovoltaics" Program Guide
Photovoltaics through energy communities	900 EUR / kW	Assumption
Social housing	38,984 EUR / dwelling	Includes the cost of deep renovation, heat pump, and photovoltaics on roof
Urban transport discounts	150 EUR / cap	A 50% discount based on current Athens Urban Transport Organization (OASA) pricing policy
Electromobility (EV)	10,000 EUR per household	Covering the cost of a 3-year lease

3 ETS2; energy and transport vulnerability

3.1 Energy vulnerability

Applying the methodological framework presented in Section 2.1.2, energy-vulnerable households were identified based on both the reference scenario and the three ETS2 implementation scenarios using different average carbon prices. The results are summarized in Table 3.1.

The results of the analysis show that approximately one in four Greek households (26.5%) is energy-vulnerable already under current conditions (reference scenario). This high rate can be attributed to Greece's structural causes of energy poverty, namely, relatively low incomes, high energy prices, and buildings' low energy efficiency. The implementation of the ETS2 is expected to raise the energy vulnerability indicator by 0.9-1.5%, depending on the average price of carbons over the period under consideration, based on this study's assumptions. In fact, the scenario founded on the highest allowance price broadens the margins of energy vulnerability by approximately 64,000 households. The change in energy vulnerability levels is only affected by the increases in energy product prices (oil products and fossil gas) that will ensue from the implementation of the ETS2; depending on the scenario, these increases are estimated at 12-22% and 12-23% for oil products and fossil gas, respectively. The entire additional burden is assumed to be passed on to households.

Overall, the implementation of the ETS2 is estimated to inflate household energy expenditure by EUR 231-437 million per year, depending on carbon prices (the lower and upper margin of this additional burden was calculated based on carbon prices at 45 EUR/t CO_2 and 84 EUR/t CO_2, respectively). Of these costs, approximately EUR 85-162 million per year correspond to energy vulnerable households, further aggravating their circumstances.

Table 3.1 Impact of the ETS2 on residential energy expenditure and on Greek households' energy vulnerability levels.

	Reference scenario	ETS2-AP45	ETS2-CP57.5	ETS2-CP84
Percentage of energy-vulnerable households	26.5%	27.4%	27.6%	28.0%
Number of energy-vulnerable households	1,111,581	1,151,826	1,160,846	1,175,417
Additional household energy expenditure (mEUR/y)		231.0	298.2	436.8
Additional energy expenditure of energy-vulnerable households (mEUR/y)		85.2	110.3	162.2

Figures 3.1-3.4 illustrate the distribution of energy-vulnerable households by Region; income class; building construction year; and type of dwelling. Given that the implementation of the ETS2 does not significantly affect the number of energy vulnerable households, the distributions

presented in these figures are based on the ETS2-CP84 scenario, which generates the largest population of energy-vulnerable households.

The distribution of energy vulnerable households by Region (Figure 3.1) is related primarily to the climatic conditions and population of each region, and secondarily to the available heating means. Thus, Central Macedonia is the Region with the highest concentration of energy-vulnerable households due to Thessaloniki's larger population, combined with the unfavorable climatic conditions in Northern Greece. Eastern Macedonia and Thrace also host a significant number of energy-vulnerable households, while fewer are recorded in Western Macedonia (EL53), where it is possible for households to meet their energy needs via alternative means (district heating). The number of energy-vulnerable households in Attica amounts to approximately 240,000, mainly due to its high population concentration. In fact, as illustrated in the same figure, energy vulnerability levels in Attica are the lowest nationwide, due to both the relatively mild climatic conditions and the relatively higher household incomes.

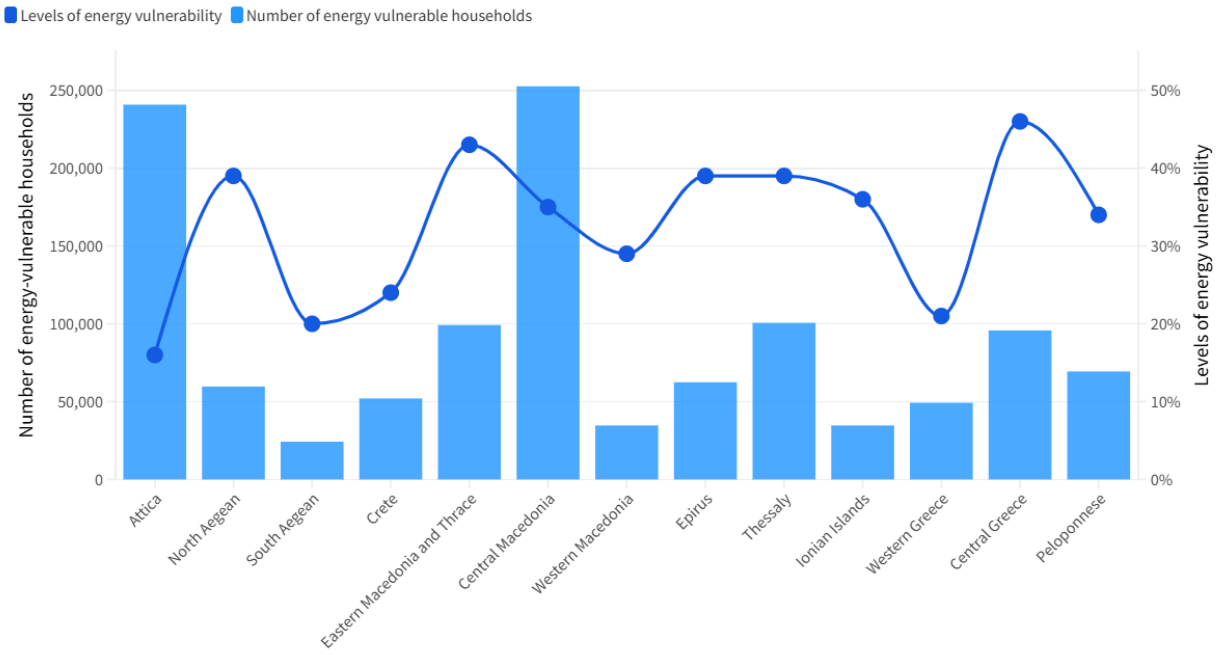

Figure 3.1 Number of energy-vulnerable households and levels of energy vulnerability by region.

Nearly 70% of energy-vulnerable households reside in dwellings built before 1980, namely, prior to the adoption of any regulation on thermal insulation in Greece; an additional 19% reside in dwellings constructed between 1981-1995, namely, during the first period of implementation of the Regulation on thermal insulation (Figure 3.2). Therefore, improving building envelope energy efficiency seems to decisively reduce household energy vulnerability.

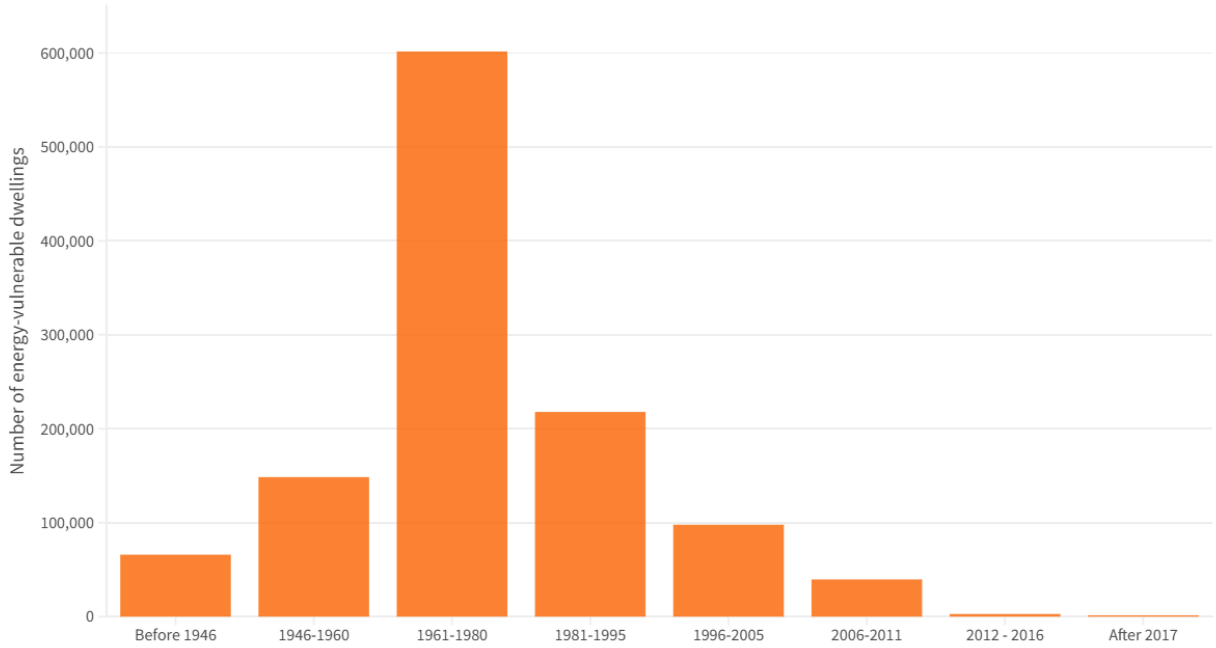

Figure 3.2 Distribution of energy-vulnerable households by year of dwelling construction.

Moreover, Figure 3.3 illustrates that households residing in single-family houses show a relatively higher vulnerability, mainly due to the higher energy losses recorded in this type of dwellings.

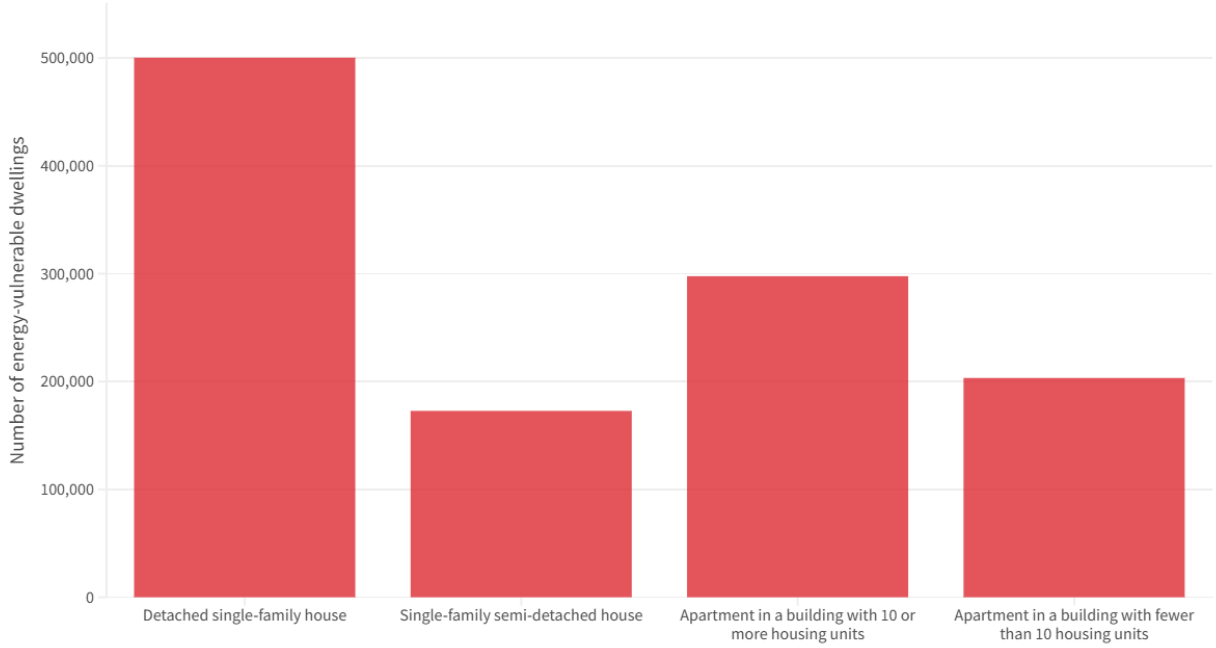

Figure 3.3 Distribution of energy-vulnerable households by dwelling type.

Finally, income constitutes a key determinant of energy vulnerability, as 59% of energy-vulnerable households have a total annual income below EUR 10,000; furthermore, an additional 30% are detected in the EUR 10,000-15,000 annual income bracket.

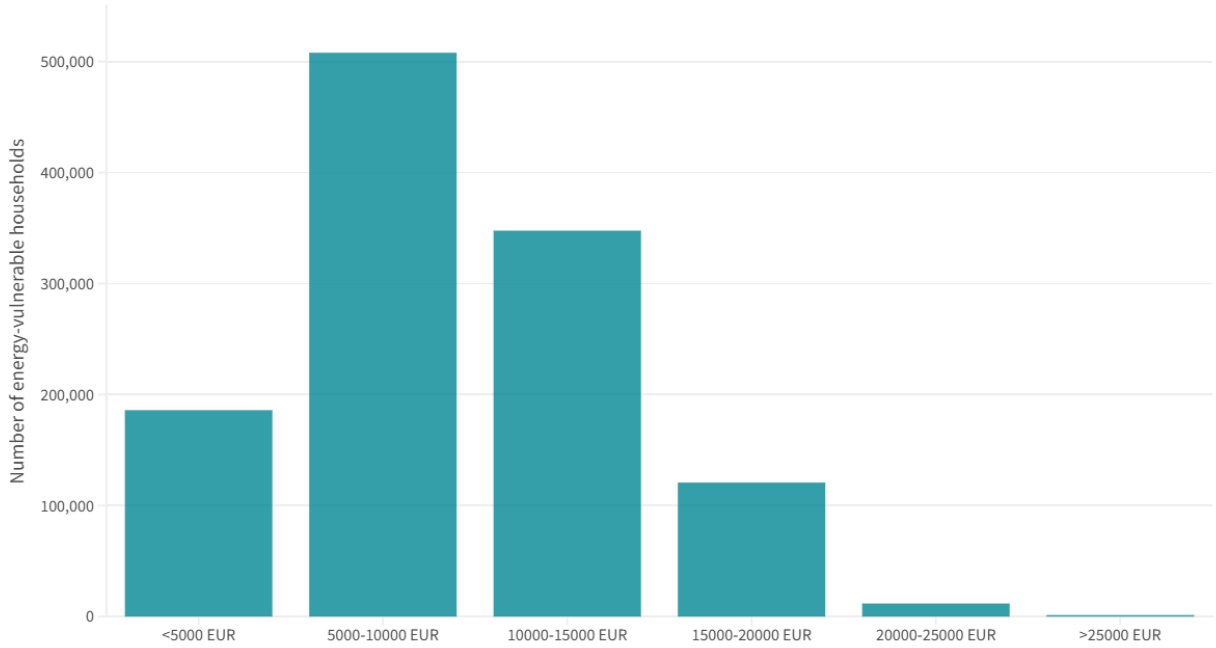

Figure 3.4 Distribution of energy-vulnerable households by total annual net income.

3.2 Transport vulnerability

By applying the methodological framework presented in Section 2.1.3, household transport vulnerability was identified, based on both the reference scenario and the three ETS2 implementation scenarios using different average carbon prices. The results are summarized in Table 3.2. The analysis found that the implementation of the ETS2 will lead to a 1.1-2.1% increase in transport vulnerability, depending on the price of carbons. In the reference scenario reflecting the current situation, the number of transport-vulnerable households approximates 585,000; this number increases by 46,000-87,000, depending on the examined scenario (low-high allowance price levels). The additional travel costs incurred by Greek households due to ETS2 implementation are expected to amount to EUR 223-412 million per year, of which EUR 54-104 million per year correspond to transport-vulnerable households.

Focusing again on the ETS2-CP84 scenario, Figure 3.5 shows the distribution of transport-vulnerable households by region. The highest number of vulnerable households is recorded in the regions hosting the largest urban centers nationwide, namely, Attica and Central Macedonia. Nonetheless, the levels of regional transport vulnerability paint a different picture. Attica records the lowest levels of transport vulnerability, mainly due to its residents having the option to use public transport. Overall, approximately 33% of transport-vulnerable households live in urban areas as opposed to 67% residing in non-urban areas. These observations highlight the potential of public transport -and transport infrastructure overall- in addressing transport vulnerability.

Table 3.2 Impact of the ETS2 on Greek households' transport expenditure and vulnerability levels.

	Reference Scenario	ETS2-CP45	ETS2-CP57.5	ETS2-CP84
Percentage of transport-vulnerable households	13.9%	15.0%	15.4%	16.0%
Number of transport-vulnerable households	584,933	630,729	645,300	671,667

Additional household travel expenditure (mEUR/y)		222.6	281.4	411.6
Additional travel expenditure corresponding to transport-vulnerable households (mEUR/y)		53.6	69.0	104.1

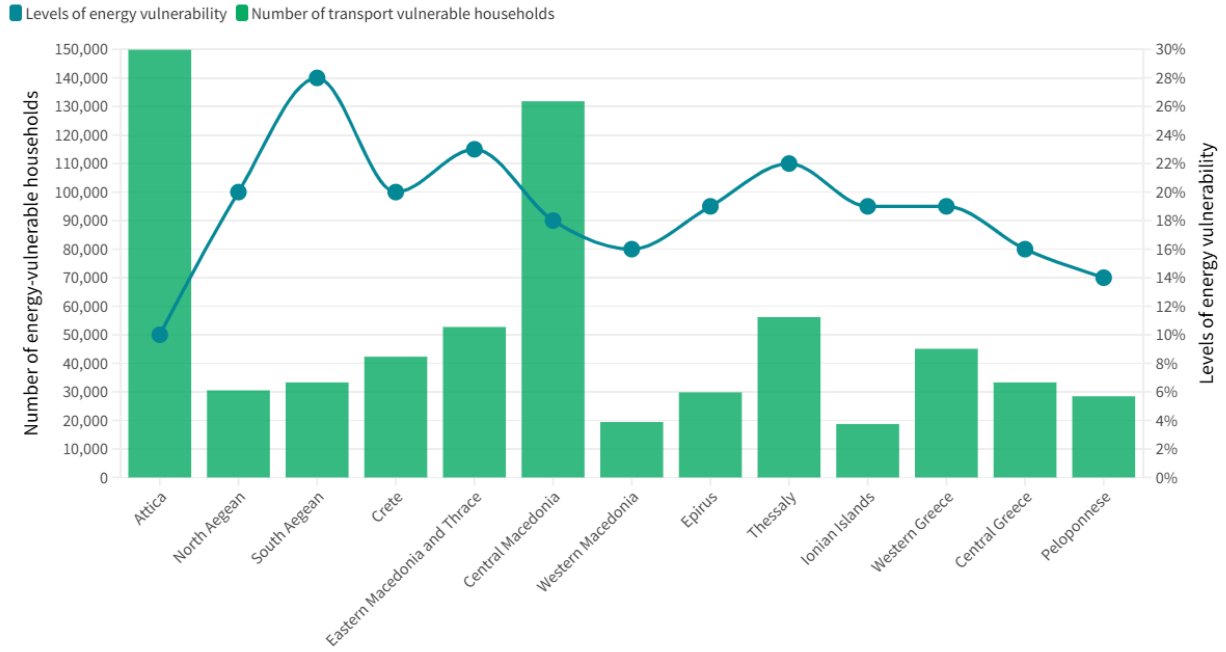

Figure 3.5 Number of transport-vulnerable households and transport vulnerability by Region.

Household income constitutes an important determinant of transport vulnerability; nevertheless, as illustrated by Figure 3.6, transport-vulnerable households are spread across a wider income range compared to those affected by energy vulnerability (see Figure 3.4). In particular, 45% of transport-vulnerable households have an income below EUR 10,000, while 36% fall under the EUR 10,000-15,000 annual income bracket. Moreover, 20% of transport-vulnerable households have an even higher income.

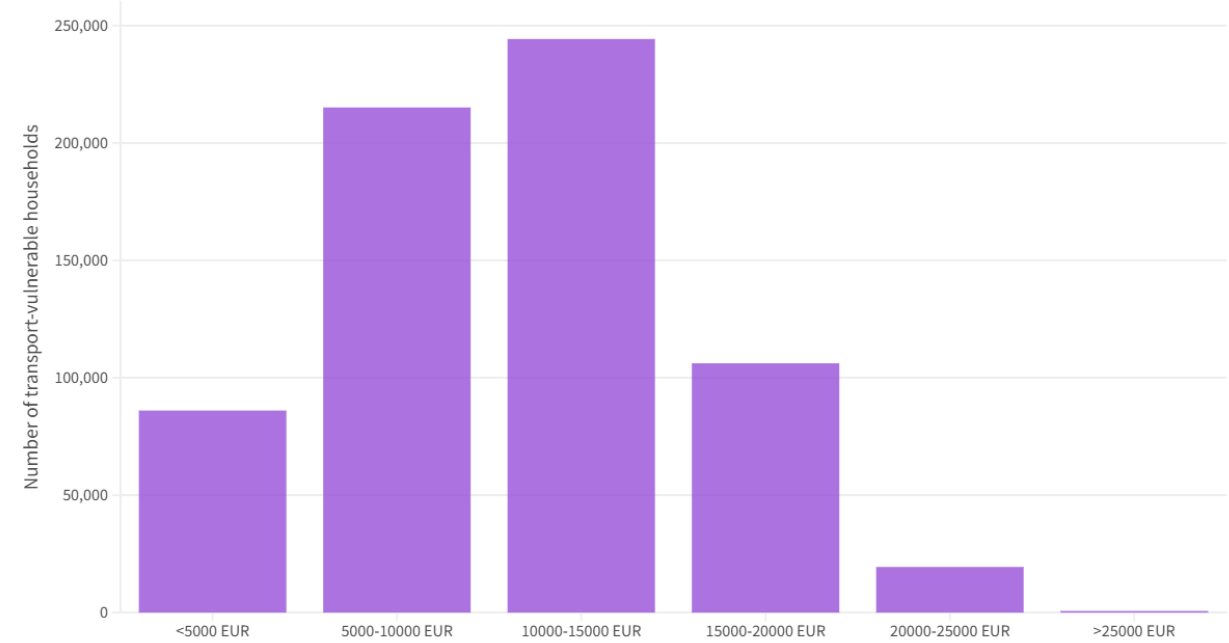

Figure 3.6 Distribution of transport-vulnerable households by total annual net income.

3.3 Concluding remarks

The analysis carried out in this chapter indicates that, even in the current circumstances, a significant percentage of Greek households is affected by energy (approximately 26.5%) and transport (13.9%) vulnerability. The implementation of the ETS2 will impose additional burdens on households, adjusted by the allowance prices that will be set, by:

- Expanding the number of energy-vulnerable and transport-vulnerable households by, respectively, approximately 0.9-1.5% and 1.1-2.1%.
- Increasing all households' expenditure on both residential energy needs (by 231-437 million EUR/year) and transport needs (by 223-412 million EUR/year). Therefore, the total annual burden incurred by households as a result of ETS2 implementation could range from EUR 454 million -in a scenario assuming an average allowance price of 45 EUR/t CO_2- to EUR 848 million -if the average allowance price climbs to 84 EUR/t CO_2.

The lowest rates of both energy and transport vulnerability are recorded in the Region of Attica. The higher income of residents; the relatively mild climate conditions; the more modern building stock; and the existence of transport infrastructure constitute the most important factors driving this finding. On the other hand, the absolute number of energy- or transport- vulnerable households in Attica is elevated due to the high population concentration in the wider capital region.

Household income and dwelling energy efficiency -which is highly correlated with building age- are both important determinants of energy vulnerability, along with dwelling construction type, with single-family houses showing higher energy losses. Household income is also a significant determinant of transport vulnerability.

It should be noted that energy and transport vulnerability have been considered separately in this analysis. Overall, in the ETS2-CP45 scenario, 35% of households are affected by either energy or transport vulnerability, while 7.5% of households are affected by both. The respective percentages in the ETS2-CP84 scenario are similar, at 35.9% and 8.1%.

4 Policies and measures addressing ETS2 impacts

4.1 Overview of policies and measures

Following the methodology described in Section 2.3, the beneficiary households of each intervention category are presented below, together with the corresponding capital requirements for the implementation of these interventions. It should be noted that these figures express the maximum number of beneficiaries before taking into account the available resources.

In the first intervention category, direct income support is provided to vulnerable households so as to mitigate the additional burden resulting from ETS2 implementation. Specifically, these measures entail the subsidization of the entire additional financial burden resulting from ETS2, with regard to both residential energy expenditure and mobility -with the exception of Attica and Thessaloniki regarding transport vulnerability. Taking into account the results presented in sections 3.1 and 3.2, the cost of direct income support measures over the entire period 2027 – 2032 is estimated at EUR 742 million based on an allowance price of 45 EUR/t; EUR 961 million (57.5 EUR/t); and EUR 1,421 million (84 EUR/t) (Table 4.1). Depending on the scenario, the cost of direct income support ranges between 15.5% and 29.7% of the SCF resources allocated to Greece, thus, being significantly below the 37.5% limit stipulated in the SCF Regulation.

Table 4.1 Direct income support provided to vulnerable households (number of households and costs) to alleviate the additional burden due to ETS2 implementation.

	ETS2-AP45	ETS2-AP57.5	ETS2-AP84
Number of energy-vulnerable households	1,151,826	1,160,846	1,175,417
Direct income support for energy-vulnerable households 2027-2032 (mEUR)	511.410	661.682	973.245
Number of transport-vulnerable households	630,729	645,300	671,667
Number of transport-vulnerable households in Attica and Thessaloniki	183,182	188,039	196,365
Number of transport-vulnerable households outside Attica and Thessaloniki	447,547	457,261	475,302
Direct income support for transport-vulnerable households outside Attica and Thessaloniki 2027-2032 (mEUR)	230.934	299.048	447.734
Total cost for direct income support provided to vulnerable households 2027-2032 (mEUR)	742.345	960.731	1,420.979
Total size of Social Climate Fund (mEUR)	4,782.5		
Direct income support to total size of Social Fund for Climate	15.5%	20.1%	29.7%

In Attica and Thessaloniki, where the urban transport network is more developed than in the rest of the country, the study examined a measure promoting the regular use of public transport by transport-vulnerable households through discounts; specifically, the latter entail the provision

of free tickets to specific population groups (e.g. children; students) and covering half the cost of unlimited travel cards. This intervention reduces the financial burden resulting from ETS2 implementation, while encouraging households to increase their use of urban transport.

Table 4.2 Promotion of urban transport use to transport-vulnerable households in Attica and Thessaloniki (number of households and costs).

	ETS2-AP45	ETS2-AP57.5	ETS2-AP84
Number of transport-vulnerable households in Attica and Thessaloniki	183,182	188,039	196,365
Provision of discounts for the use of urban transport, 2027-2032 (mEUR)	400.7	411.3	429.5

In addition, this study explored measures addressing structural issues affecting residential energy consumption and related energy expenditure. Importantly, these interventions can have lasting effects in mitigating vulnerability. As discussed in section 2.3, the selected measures target households using oil-based heating systems (approximately 64% of energy-vulnerable households) and include dwelling renovations (shallow or deep); replacement of oil boilers with heat pumps; and installation of photovoltaic systems on roofs or through energy communities. As noted in section 2.3, the above measures are not alternate and shall be implemented as a single package of measures, with their implementation adapted to the population concerned. The number of households potentially benefiting from these measures is presented in Table 4.3.

Table 4.3 Scope of beneficiaries (maximum number of households) per considered measure to address energy vulnerability. All measures relate to households using oil-based heating.

Scope of Beneficiaries	Intervention	ETS2-AP45	ETS2-AP57.5	ETS2-AP84
		(number of households)		
Apartment buildings nationwide	Shallow energy renovations & heat pumps & PV through energy communities	287,263	290,732	298,364
Single-family houses in Attica		45,795	45,795	47,183
Single-family houses in southern Greece except Attica	Shallow energy renovations & heat pumps & PV on roof	195,672	197,753	201,916
Single-family houses in urban areas in northern Greece	Deep energy renovations & heat pumps & PV through energy communities	14,571	14,571	14,571
Single-family houses in non-urban areas in northern Greece	Deep energy renovations & heat pumps & PV on roof	190,121	190,121	190,121

The investment costs for the implementation of the above interventions are presented in Table 4.4. The capital requirements range from EUR 17.4 to EUR 17.7 billion, based on an allowance price of EUR 45/t and EUR 84/t, respectively.

Table 4.4 Investment costs (in EUR million) for the implementation of the considered interventions to the total number of potential beneficiary households (the maximum number of households presented in Table 4.3) over the period 2027–2032.

Scope of Beneficiaries	Intervention	ETS2-AP45	ETS2-AP57.5	ETS2-AP84
		(mil. EUR)		
Apartment buildings nationwide	Shallow energy renovations & heat pumps & PV through energy communities	4,768.6	4,826.1	4,952.8
Single-family houses in Attica		760.2	760.2	783.2
Single-family houses in southern Greece except Attica	Shallow energy renovations & heat pumps & PV on roof	3,952.6	3,994.6	4,078.7
Single-family houses in urban areas in northern Greece	Deep energy renovations & heat pumps & PV through energy communities	515.6	515.6	515.6
Single-family houses in non-urban areas in northern Greece	Deep energy renovations & heat pumps & PV on roof	7,411.7	7,411.7	7,411.7
Total investment cost		17,408.6	17,508.2	17,742.1

Furthermore, in order to address vulnerability in the most vulnerable households, the study considered the measure of social housing (targeting energy vulnerability), as well as electric car leasing schemes (targeting transport vulnerability). The potential beneficiary households of these interventions and the related costs are presented in Table 4.5.

Table 4.5 Social housing and subsidized electric car leasing program (number of households and costs).

	ETS2-AP45	ETS2-AP57.5	ETS2-AP84
Social housing			
Number of households	14,571	14,571	15,265
Capital requirements, 2027–2032 (mEUR)	568.0	568.0	595.1
Electric car leasing program			
Number of households	78,407	79,795	85,346
Capital requirements, 2027–2032 (mEUR)	784.1	798.0	853.5

The total investment costs for the implementation of the above measures (Tables 4.2 – 4.5) and direct income support were estimated at EUR 19.9 billion for a carbon price of EUR 45/t; EUR 20.2 billion for an allowance price of EUR 57.5/t; and EUR 21.0 billion for an allowance price of EUR 84/t.

In addition to the above interventions, the implementation of horizontal actions aimed at developing/improving infrastructure to promote the use of public transport is vital. These actions' positive effects extend beyond vulnerable individuals to all transport users (households and enterprises). Furthermore, they serve Greece's objectives to decarbonize its economy, as evidenced by relevant such actions being comprised in the NECP. In particular, the latter includes measures relating to:

- Track-based forms of transport (railway; metro; tramway). Measures include, inter alia, the installation of signaling-telecommand systems; the further electrification of railways; and the extension/modernization of metro or suburban lines. According to the NECP, the implementation of interventions aimed at improving track-based forms of transport over the period 2025- 2030 will cost EUR 2.3 billion.
- Urban / intercity road transport and sustainable urban mobility. Actions mainly refer to the renewal of the bus fleet and its electrification, as well as to the exploration of alternative fuels such as green hydrogen. At the same time, local authorities in municipalities with a population exceeding 30,000 inhabitants will be required to draw up sustainable urban mobility plans. Unfortunately, the NECP does not provide detailed information on the costs of the planned measures regarding road transport. The relevant estimates regarding both buses and trucks amount to a total of EUR 11.0 billion regarding the period 2025-2030. Assuming that 1/3 of this cost will be allocated to the modernization of urban buses, the corresponding costs are projected at EUR 3.6 billion.

In total, the infrastructure costs related to addressing the impacts of ETS2 implementation are estimated at EUR 5.9 billion.

4.2 Available Resources

The implementation of the aforementioned measures aimed at mitigating ETS2 impacts (Section 4.1) will require significant funds. Determining the resources that will be made available to the SCF is necessary in order to establish the penetration of these measures. In addition to the funds specified in the SCF Regulation (Article 10), resources to address energy and transport vulnerability may also be accumulated from ETS1 and the ETS2 revenues.

- *Social Climate Fund (SCF)*: according to the Regulation, Greece has been allocated 5.52% of total resources. If ETS2 starts running in 2027 as planned (baseline scenario), the SCF budget shall amount to EUR 65 billion; however, if ETS2 implementation is delayed by one year, this budget will be reduced to EUR 54.6 billion. Given that only the baseline scenario has been considered in this study, Greece's share of the SCF for the seven-year period 2026-2032 amounts to EUR 3.59 billion. Adding to this figure the minimum mandatory national contribution (namely, 25% of the final amount, as stipulated in Article 15 of Regulation 2023/955), the funds at Greece's disposal will total EUR 4.78 billion.

- *Remaining ETS2 revenues*: under the revised ETS Directive, the allocation of the allowances to be auctioned under the new Emissions Trading Scheme for Buildings and Road Transport (ETS2) among Member States will be based on the average of their emissions from sectors under the ETS2 over the period 2016-2018. As stated in the impact assessment report[5] accompanying the European Commission's proposal for the revision of the ETS Directive, based on this criterion, Greece has been allocated 1.6% of ETS2 allowances to be auctioned.

[5] Table 77, part4/4, COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT REPORT Accompanying the document DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 2003/87/EC establishing a system for greenhouse gas emission trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757. https://bit.ly/3ToAW6M

Furthermore, according to an analysis by the Oeko Institut (Braungardt et al., 2022), based on the evolution of the annual cap presented in the Commission's aforementioned impact assessment report, a total of 5,746 billion allowances will be auctioned by the ETS2 over the period 2026–2032. The amount that Greece is expected to receive from the ETS2 –in addition to its share from the Social Climate Fund– can be estimated based on these figures and for a given allowance price in the ETS2, according to the following process: the amount allocated to the Social Climate Fund (€ 86,667 billion) –including the national contributions set at 25%– is subtracted from the total auctioning revenues; the difference is then multiplied by Greece's share. Therefore, based on the three different ETS2 allowance price scenarios considered in this study, Greece's ETS2 revenues will amount to EUR 2.75 billion for an average carbon price of 45 EUR/t; EUR 3.9 billion (for 57.5 EUR/t); and EUR 6.34 billion (for 84 EUR/t).

- *ETS1 revenues*: in addition to ETS2-related revenues, Greece will also have access to revenues generated from the auctioning of allowances under the existing ETS (which covers the sectors of electricity and heat production; energy-intensive industry; and aviation within the European Economic Area). According to the projections of the Climact[6] model, simulating the rules of the revised ETS2 Directive, by the end of the 4th phase of the ETS (period 2025–2030[7]) Greece will receive 115.46 million allowances from the ETS1, including the 20 million allowances allocated to the country by the new Modernization Fund over the period 2024–2030. Assuming EUR 75/ton as an average allowance price for this period, Greece is estimated to collect a total of EUR 8.66 billion. According to Article 10 of the ETS Directive, these resources can be channeled to, inter alia, renewable energy self-production projects (implemented either by individual households and enterprises or collectively through the institution of energy communities); the decarbonization of the transport sector; energy efficiency measures; deep and shallow renovations; and renewable energy projects for building heating. All the aforementioned uses can mitigate ETS2 impacts on the country's energy- and transport-vulnerable populations. If it is assumed that 50% of the total amount received over the period 2025–2030[7] will be dedicated to the aforementioned purposes, then the resources available to address energy and transport vulnerability in Greece could be complemented by EUR 4.33 billion.

Based on the above, the resources at Greece's disposal to address the impacts of ETS2 implementation could amount to EUR 11.86 billion for an ETS2 allowance price of EUR 45/t; EUR 13.01 billion for a price of EUR 57.5/t; and EUR 15.45 billion for a price of EUR 84/t.

4.3 Allocation of available resources

The available resources per examined scenario were calculated in the previous section; clearly, these resources are insufficient to address the needs of energy- and transport-vulnerable households, considering the intervention costs presented in Section 4.1. Therefore, the degree

[6] https://climact.com/en/

[7] The current year is the first in which the recommended policy of channeling 50% of ETS1 resources to mitigate ETS2 impacts on those affected by energy and transport vulnerability can be applied; the distribution of allowances to Member States after 2030 has not been specified.

of implementation of the recommended measures had to be adjusted to reflect the availability of financial resources. In summary, the approach taken is described below.

A top-down allocation of available resources to be channeled to address energy and transport vulnerability was initially carried out. This process was based on the ratio of energy-vulnerable households' additional expenditure to that of transport-vulnerable households. Thus, approximately 61% of the resources available in all scenarios were allocated to address energy vulnerability and 39% to address transport vulnerability. Next, specific recommendations were formulated regarding the degree of implementation of each proposed intervention category, as follows:

With regard to addressing energy vulnerability (Table 4.6 and Figure 4.1):

- In all scenarios, 100% of the additional expenditure incurred by energy-vulnerable households are covered. Depending on the scenario, the cost of this measure ranges between EUR 85 and 162 million/year, namely, between EUR 510 and 972 million for the entire period.
- Social housing is prioritized. The cost of this measure amounts to EUR 568-595 million for the entire period and concerns 14,500-15,200 households.
- The extent of implementation of all other interventions targeting energy vulnerability is determined per scenario, based on the remaining available resources and the total budget of the measures considered. Specifically, the degree of implementation is estimated at 36%, 39%, and 44%, respectively, for the ETS2-CP45, ETS2-CP57.5, and ETS2-CP84 scenarios.

Table 4.6 Number of households targeted by the proposed measures to address energy vulnerability

Household category	ETS2-CP45	ETS2-CP57.5	ETS2-CP84
Provision of direct financial support	1,151,826	1,160,846	1,175,417
Social housing	14,571	14,571	15,265
Package of interventions for dwellings using oil-boilers in apartment buildings	102,326	112,442	131,874
Package of interventions for single-family houses using oil-boilers in Attica	16,313	17,712	20,855
Package of interventions for single-family houses using oil-boilers in southern Greece except Attica	69,700	76,482	89,245
Package of interventions for single-family houses using oil-boilers in northern Greece, in urban areas	5,190	5,636	6,440
Package of interventions for single-family houses using oil-boilers in northern Greece, in non-urban areas	67,723	73,530	84,031

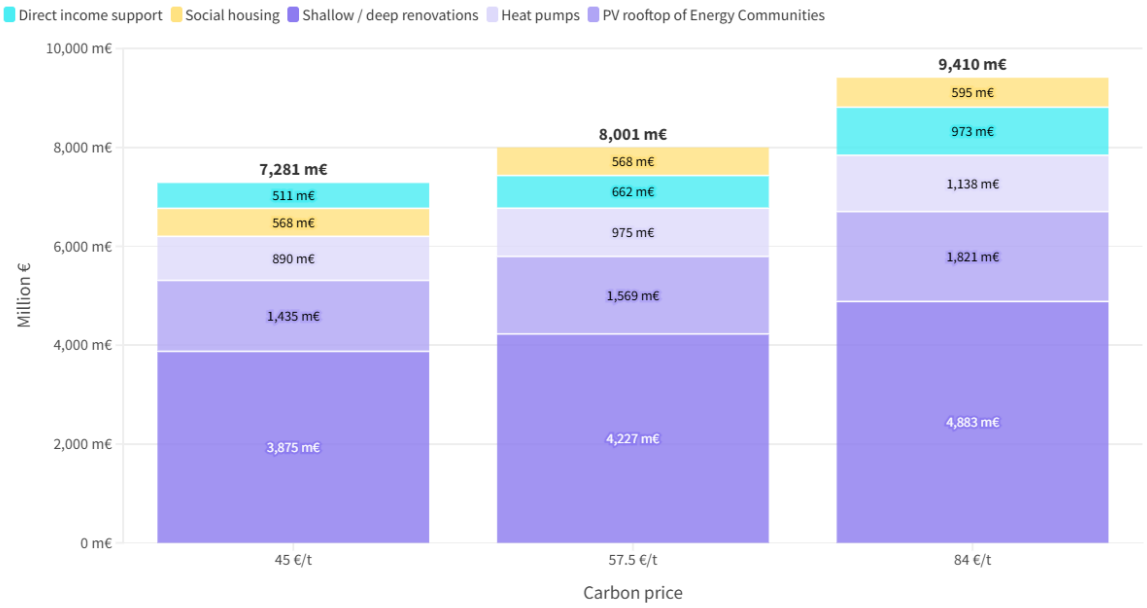

Figure 4.1 Distribution of available resources by measure to address energy vulnerability.

With regard to mitigating transport vulnerability (Table 4.7 and Figure 4.2):

- In all scenarios, 100% of the additional expenditure incurred by transport-vulnerable households not residing in Athens or Thessaloniki (both of which are assumed to provide better transport infrastructure to its residents) are covered. Depending on the scenario, the cost of this measure amounts to EUR 38-75 million per year.
- In all scenarios, transport-vulnerable households residing in Athens and Thessaloniki are provided with a 50% discount on annual unlimited travel cards for all their adult members, and with free tickets for all household minors. The cost of this measure amounts to EUR 401-430 million for the entire period under consideration.
- With regard to households that are particularly transport-vulnerable (namely, whose transport costs exceed 15% of their income), not residing in Athens or Thessaloniki, a subsidy of EUR 10,000 over a three-year period is provided for the lease of an electric vehicle. This expenditure amounts to EUR 784-853 million for the entire period under consideration.
- The remaining available resources, ranging from EUR 3.2 to 4.3 billion depending on the scenario, are allocated to upgrading rail, metro and bus transport infrastructure. This investment covers a significant part -namely, 54%, 59%, and 73%, respectively, for the ETS2-CP45, ETS2-CP57.5, and ETS2-CP84 scenarios- of the expenditure foreseen in the NECP for transport infrastructure upgrades by 2030.

Table 4.7 Number of households targeted to address transport vulnerability

Household category	ETS2-CP45	ETS2-CP57.5	ETS2-CP84
Provision of direct financial support	447,547	457,261	475,302
Ticket discounts	183,182	188,039	196,365
Electric vehicles leasing program	78,407	79,795	85,346
Transport infrastructure	Horizontal implementation - 54% of the NECP cost	Horizontal implementation - 59% of the NECP cost	Horizontal implementation - 73% of the NECP cost

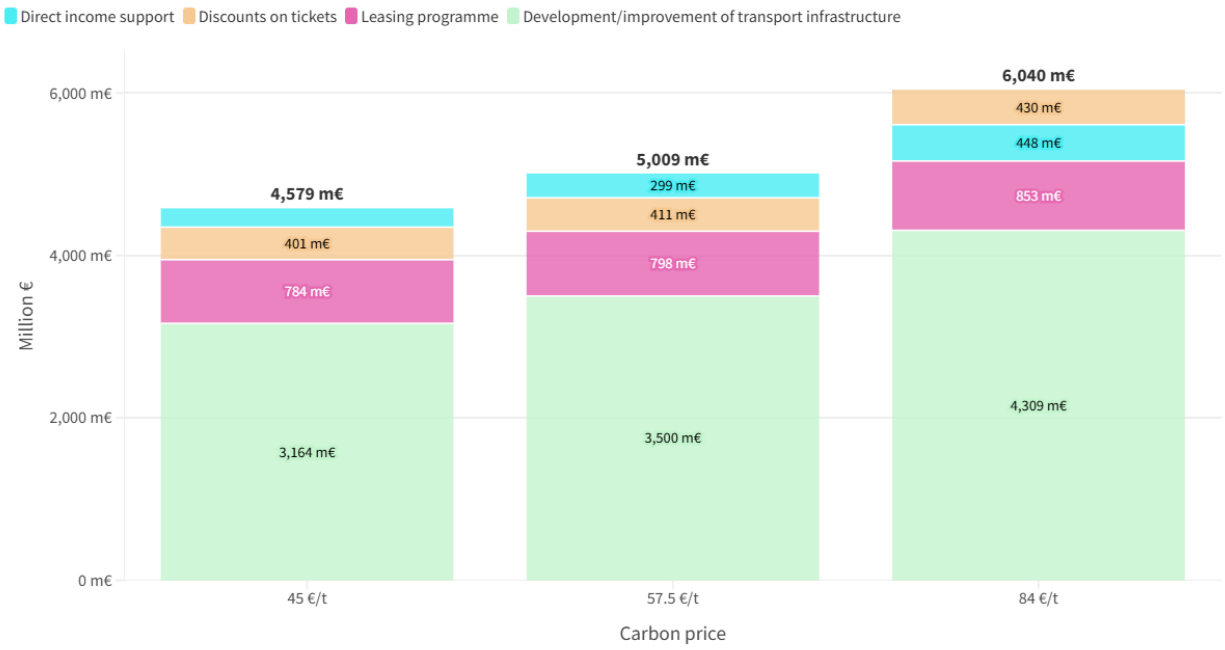

Figure 4.2 Distribution of available resources by measure aimed at addressing transport vulnerability.

5 Conclusions – Policy recommendations

This study explored the impact of the ETS2 on Greek households, in order to formulate well-documented recommendations for interventions that could be included in the Social Climate Plan and financed by SCF resources and ETS2 & ETS1 revenues. In particular, this project sought to:

(i) identify vulnerable households and vulnerable transport users under the SCF Regulation;
(ii) assess the impact of ETS2 implementation on households;
(iii) identify measures that can mitigate the impact of ETS2 implementation, in line with the SCF Regulation;
(iv) assess the effectiveness of these interventions on different household categories; and
(v) formulate policy recommendations based on this analysis, while taking into account the available resources.

The first step in carrying out this analysis was to identify energy- and transport-vulnerable households, largely based on the guidelines provided in EU Regulation 2023/995, which introduced the SCF. In this context, households meeting the following conditions were defined as energy-vulnerable:

(i) *The household's' disposable income is below the income criteria set for receiving the State's heating subsidy*.
(ii) *The share of energy expenditure required to ensure adequate thermal comfort conditions at home exceeds 10% of total net household income after taxes, which includes non-monetary components.*
(iii) *Fossil fuels are used to meet residential energy needs*.

Similarly, households meeting the following conditions were defined as transport-vulnerable:

(i) *The household's disposable income is below the income criteria set for receiving the State's heating subsidy*.
(ii) The household's transport expenditure exceeds 6% of its total income.

The assessment of household energy and transport vulnerability was carried out for three distinct scenarios, founded on different levels of allowance prices (namely, 45 EUR/t CO_2; 57.5 EUR/t CO_2; and 84 EUR/t CO_2), based on European Commission estimates. The quantitative analysis indicated that, even in the current circumstances, a significant percentage of Greek households is affected by energy (approximately 26.5%) and transport (13.9%) vulnerability. The implementation of the ETS2 will impose additional burdens on households -adjusted by the allowance prices that will be set- by:

- Expanding the number of energy-vulnerable and transport-vulnerable households by, respectively, approximately 0.9-1.5% and 1.1-2.1%.

- Increasing all households' expenditure on residential energy needs (by EUR 231-437 million/year) and transport needs (by EUR 223-412 million/year). Therefore, the total annual burden incurred by households as a result of ETS2 implementation could range from EUR 454 million -in a scenario assuming an average allowance price of 45 EUR/t CO_2- to EUR 848 million -in a scenario based on an average allowance price of 84 EUR/t CO_2. Particularly with regard to energy- and transport-vulnerable households, and depending on the allowance price, the additional expenditure ranges from EUR 139 million to EUR 266 million per year, for allowance prices of 45 EUR/t CO_2 and 84 EUR/t CO_2, respectively. Thus, the total direct economic impact of the ETS2 on all energy- and transport-vulnerable households -for the entire period considered (2027-2032)- is estimated to range from EUR 833 million to EUR 1.6 billion.

The Region of Attica records the lowest rates of energy and transport vulnerability. The higher income of residents; the relatively mild climate conditions; the more modern building stock; and the existence of transport infrastructure constitute the most important factors driving this finding. On the other hand, the absolute number of energy- or transport-vulnerable households in Attica is elevated due to the high population concentration in the wider capital region.

Household income and dwelling energy efficiency, which is largely correlated with the age of the buildings, are both important determinants of energy vulnerability, along with dwelling construction type, with single-family houses showing higher energy losses. Household income is also a significant determinant of transport vulnerability.

Finally, in the ETS2-CP45 scenario, 35% of households are affected by either energy or transport vulnerability, while 7.5% of households are affected by both. The respective percentages in the ETS2-CP84 scenario stand at 35.9% and 8.1%.

This study considered a number of interventions aimed at mitigating energy and transport vulnerability, ascertaining that they comply with SCF Regulation provisions on resource allocation. Given the severity of this phenomenon in Greece, it is recommended that -in addition to the SCF resources- all ETS2 public revenues and 50% of the resources from the auctioning of ETS1 allowances be dedicated to alleviate energy and transport vulnerability. Based on the three scenarios considered regarding the evolution of carbon prices, the total resources at the country's disposal to address energy and transport vulnerability are estimated at EUR 11.9 - 15.5 billion.

With regard to policy measures, it is recommended that the additional burden on energy- and transport-vulnerable households due to ETS2 implementation be covered through direct payments (however, excluding transport-vulnerable households in Attica and Thessaloniki which will be supported through subsidies for the use of public transport). The cost of implementing this direct income support measure -depending on the price of carbons- corresponds to 15.5%-29.7% of the SCF resources, thus, being significantly below the 37.5% threshold set by the relevant Regulation.

With regard to structural policy measures (other than direct income support) addressing energy vulnerability, the study considered several energy-saving and renewable energy promotion measures targeting distinct vulnerable sub-groups; these measures include deep and shallow

renovations; replacement of oil heating systems with heat pumps; and meeting electricity needs via photovoltaic systems installed either by individual households or by energy communities. The packages of measures and the sub-populations to which they shall apply vary based on geographical location (which influences heating/cooling needs); dwelling type (single-family house; apartment); heating medium; urbanity; and household characteristics. The total investment required to implement all the above structural measures alleviating energy vulnerability in all the selected sub-populations costs EUR 18 - 18.3 billion. Nonetheless, given that the available resources are finite, it is unrealistic to expect that the funds channeled to address energy vulnerability alone can match the aforementioned amount. Therefore, it was assumed that the proportion of resources dedicated to this purpose out of the total available will correspond to the proportion of the burden incurred by energy-vulnerable households out of the total burden incurred by energy- and transport-vulnerable households, namely, 61%. Under this assumption, the resources available to mitigate energy vulnerability range between EUR 6.8 - 8.4 billion (depending on allowance price levels), including the cost of the social housing measure (EUR 568 - 595 million). It has been estimated that earmarking the entirety of these resources for the implementation of the proposed measures could eliminate energy vulnerability in 276,000 – 348,000 households.

With regard to alleviating transport vulnerability, the measures considered included the provision of a discount on unlimited travel cards for all adult members of transport-vulnerable households in Attica and Thessaloniki; the provision of free tickets for these households' minors; and the subsidization of electric vehicle leasing for particularly transport-vulnerable households not residing in Athens or Thessaloniki. Estimated to cost EUR 1.18-1.28 billion (depending on allowance price levels), the implementation of these measures will support 262,000-282,000 transport-vulnerable households. Moreover, if all financial sources considered are indeed utilized, an additional EUR 3.2 - 4.3 billion will remain accessible; these funds can be used to upgrade transport infrastructure by promoting public transport; improving railways; streamlining bus transportation; etc. In total, these resources represent 54-73% of the NECP budget for actions aimed at upgrading transport infrastructure by 2030.

The implementation of the ETS2 represents a major turning point on the path towards achieving the climate targets. The resources available should, therefore, decisively contribute to bringing household energy and transport vulnerability to an end, through a definitive decoupling from fossil fuels. It is imperative that the revenues generated by the new system be channeled transparently and equitably back to society, primarily supporting the most vulnerable households that are disproportionately affected. Thus, carbon pricing can represent a strategic tool for the transition, rather than an additional burden, ensuring broad social acceptance. To that end, the formulation of an effective Social Climate Plan is key; this plan should clearly identify the vulnerable populations, as well as the socio-economic impacts of the ETS2 and the targeted measures to mitigate them.

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Annex I: Estimation of required residential energy expenditure

The required energy needs of household dwellings taken into account in the energy vulnerability indicator are calculated based on a simplified version of the method applied by the Building Energy Performance Regulation (KENAK), using dwelling characteristics and data recorded by the HBS.

First, the required capacity of heating systems is estimated based on the equation (Technical Guideline by the Technical Chamber of Greece (TCG), (TOTEE), 2017):

$$Pgen = \left(A * Um * 1{,}5 * \frac{V}{3}\right) * \Delta T$$

Where:

Pgen: The calculated maximum required thermal capacity of the building's heating unit (in W)

A: The external surface area of the building envelope (walls; ceilings; veranda/outdoor lobby; openings) exposed to outdoor air; and/or in contact with adjacent buildings; and/or in contact with unheated spaces; and/or in contact with the ground; as taken into account in the building's energy performance certificate (in m^2).

The total building envelope area is calculated based on the dwelling characteristics, according to:

$$A = 2 * \frac{Ah}{7} * 3 + 2 * \frac{Ah}{\frac{Ah}{7}} * 3 + 2 * Ah$$

where A is the total envelope area (m^2) and A_h is the area of the dwelling (m^2).

Um: The calculated average thermal transmittance for the total area A (in W/m^2K).

In order to calculate a representative thermal transmittance of the dwelling, the total surface area of the building envelope (walls; ceilings; veranda/outdoor lobby; openings) exposed to outdoor air; and/or in contact with unheated spaces; and/or in contact with the ground; is first estimated. For this reason, a distinction is made between two main categories of dwellings:

- Single-family dwellings
- Dwellings in apartment buildings

The following assumptions are adopted for each type of dwelling to calculate the surface area that is exposed to air, where heat losses occur. An opening factor of 15% of the surface area is assumed for all dwellings. With regard to single-family houses, the roof and floor surface areas are assumed to be equal to the surface area of the dwelling. The surface area of the external masonry is defined as the remaining percentage of the total surface area of the building envelope. The TCG Technical Guideline TOTEE 20701-1/2017 of the KENAK provides the thermal transmittance coefficients used for each of these surfaces; these coefficients depend on the building's construction period and the climatic zone in which it is located.

1.5: scaling coefficient due to intermittent operation, distribution network losses, etc.

V: the total fresh air input to the heated space (15 m^3/h/person)

ΔT: the temperature difference for system sizing, which is taken as 18°C for climate zone A; 20°C for climate zone B; 23°C for climate zone C; and 28°C for climate zone D.

Dwelling energy requirements are estimated on the basis of heating system installed capacity and operating hours, which are determined according to the following assumptions:

- The heating season is set at 166 days for climate zones A and B, and 186 days for climate zones C and D.
- The maximum number of the heating system's operating hours at full capacity is set at 18 hours per day.
- The actual operating hours of the heating systems during the year is calculated by multiplying the maximum number of hours by the fraction of the total heating degree days corresponding the dwelling's location to the theoretical maximum number of heating degree days that the heating system can sustain based on the ΔT parameter.
- The heating degree days are differentiated by climate zone; moreover, different reference temperatures are selected depending on the type of dwelling. In particular, in the case of a family consisting solely of adults, an average temperature of 17°C is considered sufficient in meeting heating needs; in the case of a family with children and elderly individuals, the home temperature is set at 18°C, as both children and elderly people are considered vulnerable, with greater needs than other age groups.

At the last stage of the calculation, the energy efficiency of the dwelling's heating systems is taken into account, based on the values listed in Table I.1 below.

Using the energy values of the corresponding energy resources, the household energy expenditure required for space heating is calculated. Added to this figure is the energy expenditure for other energy uses, mainly related to electricity consumption, which are calculated uniformly for all households based on energy balance data. The sum of these costs constitutes the energy expenditure required for households to ensure satisfactory conditions of thermal comfort.

Table I.1 Heating system efficiency rates (National Action Plan to Combat Energy Poverty).

System	Efficiency Rate (%)
Central oil heating system (with or without autonomy)	85%
Central fossil gas heating system	90%
Oil stove	35%
Liquid-gas stove	35%
Firewood stove	35%
Water heaters	99%
Electric devices (stove, fan heater, radiator)	99%
Split-type air conditioning units (air-condition units)	220%
Other device	70%


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