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Decarbonisation Policies in the Residential Sector and Energy Poverty: Mitigation Strategies and Impacts in Central and Southern Eastern Europe

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Abstract: The decarbonisation policies for the EU building stock can improve living conditions, including thermal comfort and lower energy bills. However, these measures may impose financial burdens on low-income households, reducing their disposable income and exacerbating their vulnerability. The current study investigates the impact of decarbonisation policies on the EU's building stock, with a specific focus on Minimum Energy Performance Standards (MEPS), the new Emissions Trading System (ETS2) for buildings, and the phase-out of fossil heating systems. By employing a linear, static latest version of Microsoft Excel (Microsoft 365)-based model and analyzing Eurostat data, this study quantifies the effects of these policies on energy consumption, costs, and necessary investments. Moreover, the study emphasizes their implications for low-income groups using vulnerability indicators. The findings demonstrate that a combination of MEPs, ETS2, and phasing out fossil heating systems effectively reduces energy consumption and costs across most countries. However, implementing ETS2 alone may lead to energy reduction and discomfort for low-income groups without addressing underlying demand-side issues. To address this, this study recommends the implementation of more ambitious MEPs or the provision of additional funding alongside ETS2. The phase-out of fossil fuel boilers emerges as the most cost-effective measure in the medium to long term. While MEPS and the phase-out of fossil fuel boilers improve living conditions, they also impose upfront cost burdens and reduce disposable income for low-income households. Therefore, high subsidy rates and supportive policies are necessary to ensure equitable access to investments. The main recommendations include (a) shifting financing to renewable heating systems for low-income households by 2025, addressing cost issues and policies favouring gas boilers; (b) implementing high-funding rate subsidies for energy efficiency in low-income households before 2025, with technical guidance; (c) prioritising the Energy Efficiency First principle in planning to avoid additional emissions or higher costs for low-income households; and (d) considering the energy behaviour of low-income groups in regulations, employing a combination of policies to achieve desired outcomes and ensure thermal comfort.

Keywords: energy policy; EU Emissions Trading System; fossil fuel boiler phase-out; minimum energy performance standards; energy poverty; residential sector; energy efficiency; decarbonisation policy; low-income households; Eastern Europe

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1. Introduction

Europe's most important and threatening crisis is climate change affecting different sectors in different ways, posing uncertainties regarding the continent's future. The reduction in greenhouse gas (GHG) emissions simultaneously requires higher implementation of renewable energy sources (RES) and an improvement in energy efficiency. Buildings account for more than 40% of final energy consumption and at least 36% of energy-related GHG emissions [1]. Therefore, there is a need for renewable and less polluting energy systems for domestic and public buildings. This will result not only in the reduction in GHG emissions but also in the promotion of energy saving, tackling energy poverty, improving health and well-being, as well as creating new opportunities for growth and work. Most EU countries present low levels of energy efficiency in the residential sector due to the ageing of the buildings and the lack of renovation strategies in the last years. Hence, measures promoting the energy efficiency of dwellings in the residential sector must be advanced. This is also illustrated by the Energy Efficiency First (EE1st) principle, part of Article 3 of the new Energy Efficiency Directive (EED) recast proposal, and it "means taking utmost account of cost-efficient energy efficiency measures in shaping energy policy and making relevant investment decisions" [2]. In practice, the EE1st principle balances demand and supply options in order to prioritise the least expensive investments for the energy system from a societal perspective.

This paper aims to understand which policy measures proposed by the European Commission, aimed at decarbonising the residential sector, would have the greatest impact in reducing energy poverty among low-income households and contemporarily improving household energy efficiency in central and southern Eastern European countries.

The following paper will start with a literature review providing theoretical background on the concepts of household energy efficiency, energy poverty, and the relation of these with low-income groups; but also an explanation as to why a focus on central and southern Eastern Europe was chosen and the European energy policy framework (Section 2). This will be followed by a section illustrating the methodology chosen (Section 3), followed by an explanation of the general results obtained (Section 4). Thereafter, these will be discussed (Section 5), followed by an explanation of the entailed policy implications (Section 6), and the final general conclusions (Section 7).

2. Literature Review

2.1. Household Energy Efficiency, Energy Poverty and the Relation of These to Low-Income Groups

As recognised in the European Green Deal, 50 million citizens across the European Union (EU) do not have access to indoor thermal comfort [3]. Bouzarovski (2018) [4] (p. 1) defines energy poverty as a situation which "occurs when a household is unable to secure a level and quality of domestic energy services–space cooling and heating, cooking, appliances, information technology–sufficient for its social and material needs". Nonetheless, various definitions of energy poverty can be found throughout the literature. This can be traced back to its multifaceted nature, as energy poverty is a socioeconomic issue that presents many ramifications. For this reason, definitions vary also across countries, dictated by national socioeconomic conditions which play an important role in defining energy poverty. Within the EU, not all nations present an official, legally recognised definition. Additionally, energy poverty is unevenly distributed across Europe, with eastern and southern regions presenting higher prominence of the latter [5]. This is also due to the environmental and geographical factors of one location which will inevitably affect its vulnerability to energy poverty [4]. Nonetheless, it is agreed within the literature that this intricate phenomenon will always include both economic components, such as the fuel prices, and energy components, such as the energy performance of the dwelling where one household lives, and all the socioeconomic interactions that can result, such as the inability to keep the home adequately warm. The importance of energy performance is enhanced trough regulation and existing building codes [6]. However, this phenomenon does not have only socioeconomic ramifications but, for example, also environmental ones. Indeed, households in a situation of energy poverty will utilise more outdated forms of technology for energy consumption, resulting in more environmental harm.

Energy poverty is closely related to household energy efficiency [7], with the latter being defined as the needed energy to power one household to generate a certain energy output [8]. Improving energy efficiency in general is one of the main objectives of the European Green Deal, with a set target of achieving at least 36% in energy efficiency by 2030 [9]. Energy refurbishments of buildings could reduce energy poverty and concurrently increase household energy efficiency [10]. In fact, measures aimed at tackling energy poverty from the demand side have the potential to alleviate energy poverty while providing direct and tangible benefits to the residents [11]. In addition, greenhouse gas emissions, total energy consumption, and consequently energy expenditures could be lessened [10]. Nations that present a higher range of low-quality and energy-inefficient dwellings tend to present higher levels of energy poverty (and vice versa) [12]. In fact, higher expenditures will result from more inefficient buildings (e.g., low thermal insulation). Another correlation that is found is that residents living in energy inefficient households present below-average disposable incomes [12]. In a similar way, low-income groups are more probable to become energy poor [13] to the extent that the gravity of one household's energy burden is often considered as a solid predictor of which groups will be affected by energy poverty [11]. For this reason, this particular segment of society was the focus of the present study.

An extensive array of studies has been undertaken to thoroughly examine the multifaceted factors that contribute to the pervasive issue of energy poverty. These meticulous investigations delve into crucial aspects such as financial market participation, energy efficiency, and the significance of human capital. By delving into these critical dimensions, these studies provide invaluable policy insights that not only shed light on the root causes of energy poverty but also offer practical recommendations to address and overcome this pressing challenge.

Among these studies, Cheng et al. [14] conducted an insightful investigation on the impact of financial market participation on household energy poverty. Using data from the 2015 Chinese General Social Survey, their findings suggest that engaging in financial markets significantly reduces energy poverty, primarily through the mediation of future expectations. However, the study also reveals that higher financial risk weakens the effect of future expectations on energy poverty by destabilising household finances. Consequently, promoting financial market participation emerges as a potential avenue for alleviating household energy poverty.

Another noteworthy study by Moteng et al. [15] explores the mechanisms through which sanctions affect energy poverty, highlighting the significance of factors such as human capital, energy efficiency, income inequality, and economic growth. By identifying these interconnected mechanisms, the study offers valuable policy insights that can inform policymakers in designing effective strategies and interventions to tackle energy poverty.

Collectively, these studies contribute to a robust foundation of knowledge for policymakers, enabling them to devise and implement targeted strategies, programs, and interventions that can effectively alleviate energy poverty and improve the overall well-being of affected communities.

2.2. Delineation, Explanation, and Selection of the Case Studies

The present research analyses seven countries from central and southern Eastern Europe, as these two regions were found to be particularly characterised by energy poverty. Eastern European states are additionally affected by a late liberalisation of the energy market, a historically unstable energy supply mix, and inefficient thermal insulation of buildings [5]. The countries analysed include Bulgaria, Czechia, Greece, Hungary, Poland, Romania, and Slovakia. As most EU member states, they opted to alleviate the higher burden of energy costs with price regulations, energy bill assistance, as well as tax reductions on the energy bills. Nevertheless, these are not considered as structural measures for the low-income groups and thus should be combined with energy efficiency upgrades and measures for decarbonising the space heating facilities. Moreover, the higher upfront costs of energy efficiency investments combined with the well-known and documented structural barriers do not make energy efficiency a key priority of low- and middle-income groups, notwithstanding the shortened payback period of these investments due to the higher energy prices. The households' reduced disposable income (due to the higher energy prices) is hampering the possibility of investment in refurbishments and clean heating solutions, while the incumbent fossil fuel subsidies further delay such investments. Therefore, if the available funding, such as subsidies on energy efficiency and heat pumps, is not increased for the low-income households, the energy crisis and inflation may even delay energy efficiency investments to remove fossil-fuel-heating in such households. Hence, to counter such trend, a complementary package of supporting measures which includes financial, informational, and technical measures from the national and local authorities is needed to help accelerate energy efficiency investments and finally switch to clean and sustainable space heating.

An interesting aspect to consider is the country's dependence on imported gas and the share it has in its final energy consumption and other energy end-uses. The dependence on imported gas influences the energy price, and with it, the member states' new expenditures to cover the energy costs of households via bill aid. Various figures related to gas utilisation in the considered countries are presented in Table 1. In addition to the analysed countries, France and Germany, Europe's richest countries, are also presented in this table. This is done to see the extent to which economic and geographic indicators play a role. It can be seen how Romania presents the lowest dependency on Russian gas (even lower than France and Germany). Interestingly, Bulgaria is the only country presenting a lower gas share when considering only household energy consumption rather than the total final energy consumption. This table shows how every country's data in relation to natural gas is unique and how data cannot be easily generalised. With regards to electricity generation, Greece stands out with almost 40% of gas share in its electricity production. Stemming from this data, various scatterplots relating to general gas import dependency and the different gas shares per end-use were delineated for the analysed countries (Figure 1).

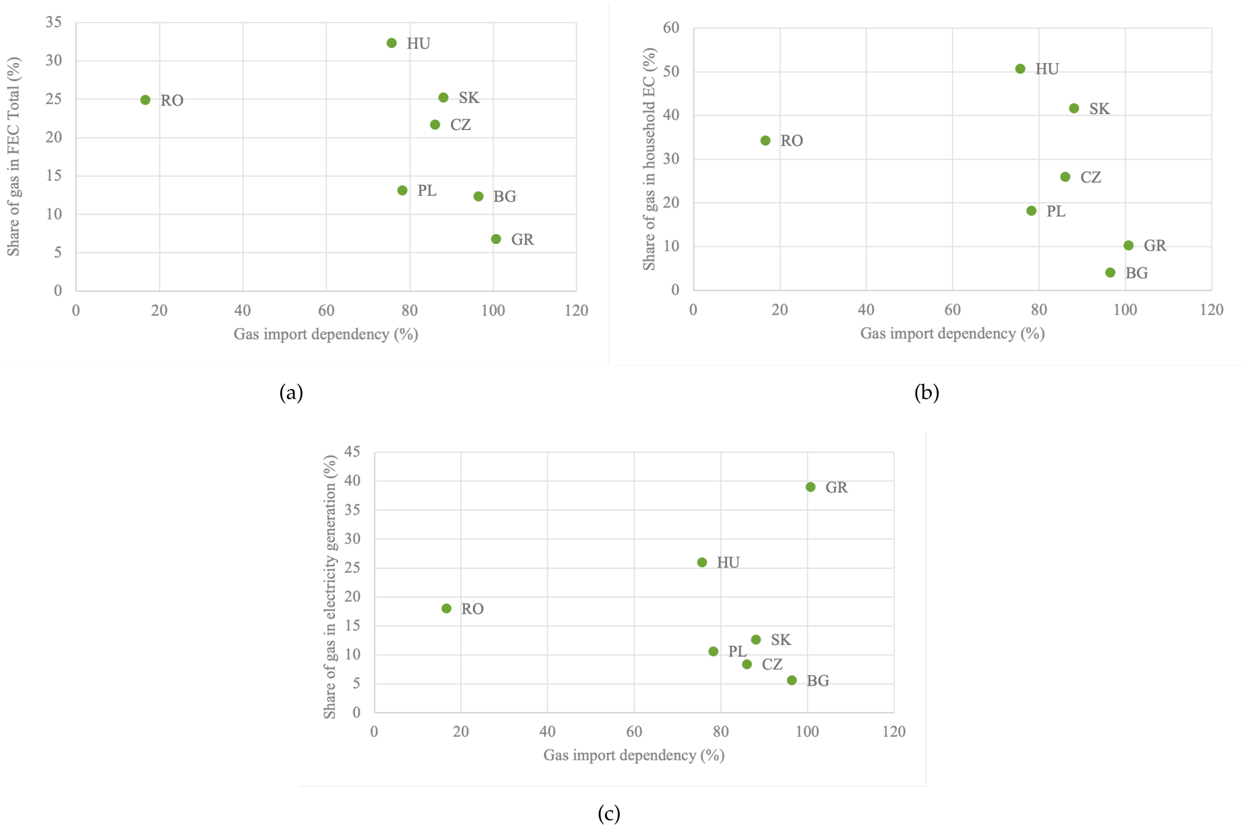


Figure 1. Comparing graphically the dependence on gas per energy end-use per country compared to its gas import dependency. (**a**) Share of gas in final energy consumption compared to gas import dependency. (**b**) Share of gas in household energy consumption compared to gas import dependency. (**c**) Share of gas in electricity generation compared to gas import dependency.

Table 1. Comparing graphically the dependence on gas per energy end-use per country compared to its gas import dependency.

Countries	Bulgaria	Czechia	Greece	Hungary	Poland	Romania	Slovakia	France	Germany
Dependency on Russian gas [16]	77%	92%	40%	64%	48%	22%	65%	24%	60%
General gas import dependency [17]	96%	86%	100%	76%	78%	17%	88%	95%	89%
Gas share in FEC [18]	12%	22%	7%	32%	13%	25%	25%	21%	27%
Gas share in household EC [19]	4%	26%	10%	51%	18%	34%	42%	28%	38%
Gas share in electricity generation [20]	6%	8%	39%	26%	11%	18%	13%	6%	16%

The scatterplots illustrate how big of a role gas plays in the energy consumption of the analysed countries and how dependent the latter are from gas-exporting partner countries. Firstly, it can be noticed how Romania can “afford” to have rather high gas consumption patterns as it imports a rather small percentage of its consumed gas. On the other hand, the country presenting the highest gas import dependency, Greece, is particularly reliant on partner countries as it produces a high proportion of its electricity from gas. Thus, even though Greece has rather low consumption patterns of gas, it is still the most gas-reliant of the analysed countries due to its high share of gas in electricity generation. Bulgaria also presents high gas import dependency; nonetheless, unlike Greece, it utilises a very small percentage of gas, and thus is not deemed as a very gas-reliant country. Poland is also another country not too reliant on gas, however on a minor scale. The other analysed countries, and in particular Hungary, can all be defined as gas-reliant.

On another note, Figure 2 shows the allocated funding (in billion EUR) in each country for tackling the energy crisis between September 2021 and October 2022. The burden on state budgets will strongly affect the possibility of member states implementing low-carbon policies. Therefore, strategic planning to develop complementary policies is of the highest relevance. Poland presents the highest budget, as expected from the largest of analysed countries both demographically and economically. Surprising is perhaps Greece, which presents the second highest budget even though having a lower economic force compared to other countries. The rest of the analysed countries seem to have an allocated budget that reflects their socioeconomic conditions.

The presented data aimed to reflect that each country presents unique gas-related characteristics with different allocated budgets. A generalisation of such starting characteristics for central and southern Eastern European nations is thus not possible. Hence, each country will be analysed on its own and only once national results are obtained will these be analysed together, considering the hereby described national characteristics.

2.3. European Energy Policy Framework

The EU aims to be the first continent with neutral carbon emissions by 2050 and has been at the forefront of the promotion and implementation of decarbonisation policy measures [9]. As part of this effort is the European Green Deal, which “aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use” [3] (p. 2). The proposed policy mix focuses on three key principles related to energy. Firstly, to ensure an affordable, clean, and secure EU energy supply. Secondly, to prioritise the renovation and improvement of buildings in a resource and energy-efficient way. Thirdly, to develop a fully digitalised, and interconnected EU energy market, promoting circular economy [3].

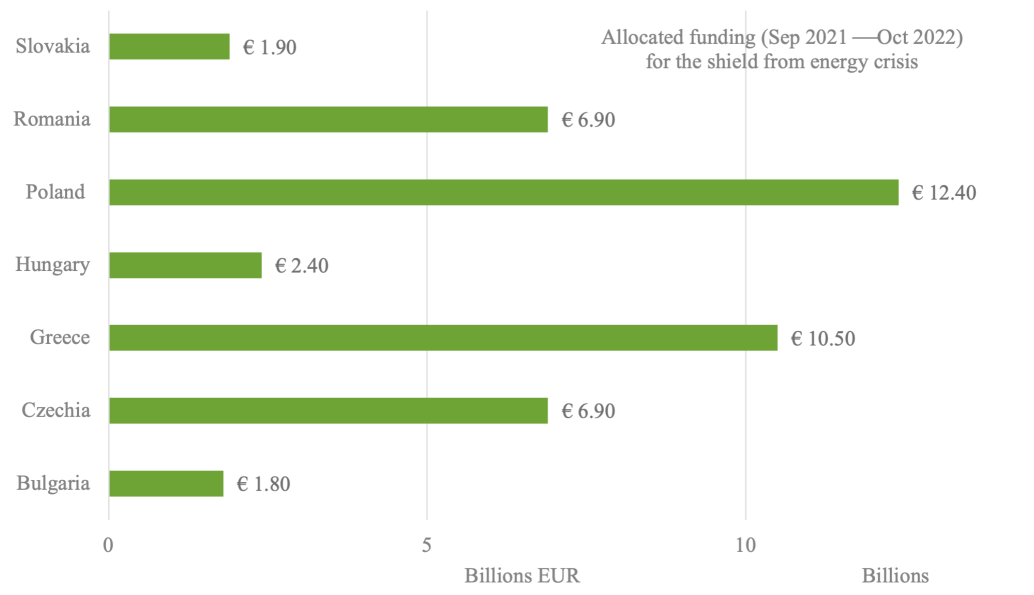


Figure 2. Governments earmarked and allocated funding (September 2021–October 2022) to shield households and businesses from the energy crisis [21].

Part of the European Green Deal is the "Fit for 55" package. This set of policy proposals also includes revisions of previous directives, such as the EED and Energy Performance of Buildings Directive (EPBD). The name of the package stems from the EU's objective of reducing by 55% its net greenhouse gas (GHG) emissions by the year 2030 compared to its 1990 levels. To ensure, a competitive and just energy transition by 2030, the package offers a careful combination of pricing, standards, support measures, and targets. Following the breakout of the war in Ukraine, the European Commission fastened its process of independence from Russian fossil fuels and thus, on 18 May 2022, presented the "REPower EU Plan" [22]. The latter foresees reducing dependence on Russian fossil fuel by further increasing some of the objectives set in the Fit for 55 package and fast-forwarding the sustainable transition. For example, the target for the renewable energy share in 2030 was increased from 40% to 45%, envisioning a doubled installation rate of heat pumps [22]. For the present research, three specific policy measures (present in the Fit for 55 package) were chosen to be analysed, simulated, and discussed. These will be further described in the following paragraphs.

2.3.1. Extension of the EU Emissions Trading System to the Residential Sector

The European Commission developed and put in force the new emission trading system (ETS2 here), which puts numbers on the fossil fuel emissions in buildings and transport sectors. It is a cap-and-trade kind of system like the ongoing ETS. It is regulated upstream, it does not directly involve buildings or vehicles but fuel suppliers, and will begin in 2026. These sectors will still be covered by the Effort Sharing Regulation, meaning member states' policies will continue to contribute to reducing emissions in the sectors. Carbon pricing is the measure that creates the market for new innovations, but the degree of this depends on (a) energy price elasticities and (b) cross-price elasticities. The impacts of the ETS price in these sectors could however generate higher costs to households, hence leading to higher energy poverty, in central and southern Eastern Europe.

2.3.2. Phasing Out of Fossil Fuel Boilers

To enable the decarbonisation of space heating and cooling in the households, the installation or sale of new fossil fuel boilers is to be phased out by 2030, plus the fossil fuel boiler lifetime. This might create a lock-in effect for households that are in the situation of energy poverty. They will use cheaper technologies due to the fact that more advanced technologies like heat pumps have higher upfront costs, despite their operational and ongoing costs being lower. To secure the avoiding of a lock-in is a policy framework that can give low-income households the possibility to switch to low-carbon heating systems. A revision of the Ecodesign and energy labelling regulation for heaters is going to lead to a downgrading of gas boilers to the low-energy (the two lowest) labels and more interest in the phase-out of the inefficient heating systems. A previous study from [23] announced that governments choose (a) natural gas for space heating, enlarging existing gas pipelines in the domestic sector, and (b) make use of subsidies for fossil fuel heating with the gas boilers, considering it an energy efficiency measure. The phasing out of fossil fuel boilers should indicate a clear timeline to avoid lock-ins and increase the costs of shifting to natural gas boilers.

2.3.3. Minimum Energy Performance Standards (MEPS)

Minimum Energy Performance Standards (MEPS) target buildings with renovations aimed at improving the energy efficiency in the residential sector reducing energy poverty, taking into account possible socio-economic differences. The EPBD recast [24] announced that the minimum energy performance standards shall at least ensure that all non-residential buildings are below (i) the 15% threshold as of 1 January 2030 and (ii) the 25% threshold as of 1 January 2034. The trajectory is expressed as a decrease in the average primary energy use in kWh/(m^2y) of the whole residential building stock over the period from 2025 to 2050. The average primary energy use in kWh/(m^2y) of the whole residential building stock needs to be at least equivalent to:

(a) The D energy performance class level by 2033;
(b) By 2040, a nationally determined value derived from a gradual decrease in the average primary energy use from 2033 to 2050 in line with the transformation of the residential building stock into a zero-emission building stock. Although evidence of the impacts of MEPS is not yet available, there was an impact assessment of the EPBD with the result that MEPS is a crucial instrument for the final energy savings and for the cost reduction, as well as for generating construction activity. The impact assessment did not isolate the impacts of MEPS on energy poverty nor did it address specificity regarding the central and southern Eastern European regions.

3. Methodology

In the following section, the methodology utilised to analyse, model, and simulate the three different considered policy measures will be explained. Firstly, it must be noted that a linear, static and Microsoft-Excel-based model was employed. In fact, the tool utilises simple predefined formulas, interconnecting various Excel sheets at the same time. More sophisticated models can be found in the literature, with the most notorious one being PRIMES, used by the European Commission and Directorate-General for Energy [25] to delineate the EU Reference Scenario 2020. The latter combines multiple objectives with different detailed constraints and, since 2016, was upgraded to include PRIMES-BuiMo (covering the residential sector), and PRIMES-Maritime (covering the maritime sector) [25]. Other models found include CAPRI, GAINS, GEM-E3, GLOBIOM, and POLES-JRC. Nonetheless, such complexity in modelling would be overwrought for the issue at hand. Thus, the simplified Microsoft Excel model was chosen, as it allows for modelling practices with Eurostat data in a simplified manner which allows also for more direct and simple communication of results. In fact, all the considered data were gathered from the Eurostat repository. The baseline year was chosen to be 2019, and a time horizon until 2050 was considered when performing simulations. Finally, as only linear and static data were examined, non-linear behaviours were not visible. Behaviours such as final energy consumption and energy price trends, which in real life are non-linear and affected by a multitude of factors, in this case will be represented linearly.

3.1. Assumptions

The Eurostat energy prices from the first semester of 2022 were considered for the separate national energy prices per fossil fuel type. Additionally, in this study, low-income groups were considered as all those households corresponding to the first income decile.

– ETS1: The estimated ETS1 prices originate from the EU recommendations to member states (September 2022) [26] as the analytical basis for updating the National Energy and Climate Plans (NECPs). The assumptions are based on the average price of EUR 80/tCO_2 eq that were reported since the beginning of 2022 and will be increasing following the expected trends as to achieve the 55% GHG reduction target and the expected energy price trends. The simulation with PRIMES is done in a way that the reductions come as response to prices and other policy drivers plus additional market considerations. Prices are then derived with iterations until achievement of the ETS cap (Figure 3).

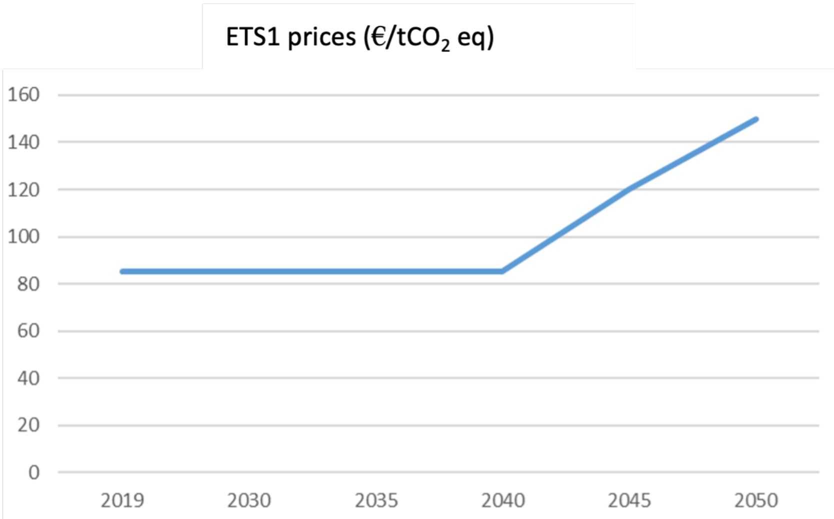


Figure 3. ETS1 price development.

– ETS2: The estimated ETS2 prices are a result of a study conducted by Vivid Economics [27] (as used in the previous study [23]). Two existing scenarios from Vivid Economics are evaluated for the purpose of modelling the electricity price evolution until 2040. Scenario 1 was used for carbon pricing policy (Central_MSR1), while the second one (Reg_MSR1) is used for their combination. The ETS2 price will remain constant after 2040 (Figure 4).

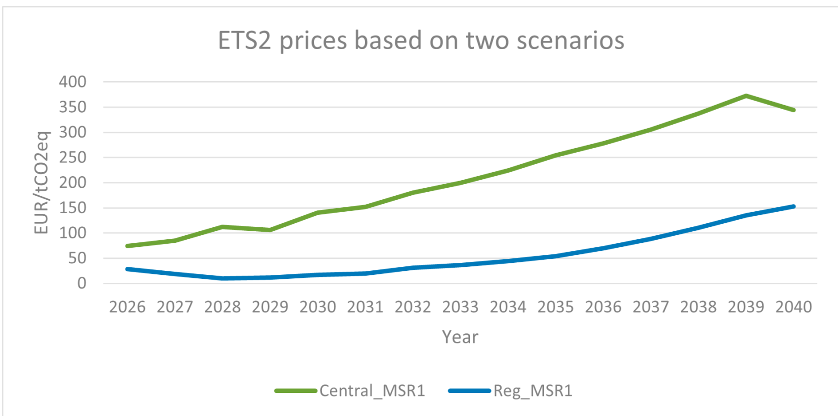


Figure 4. ETS2 prices until 2040.

– Fossil fuel prices: The EU Reference Scenario 2020 was used for the forecast of 2019–2050 fossil fuel prices (heating oil, natural gas, coal, and LPG). The estimations are derived from the EU recommendations to member states (September 2022) [26] as an analytical basis for updating the NECPs.
Furthermore, the prices of the first quarter of 2022 (Eurostat) were used as a basis and upon that the price growths were derived (Figure 5).
– Price elasticity of energy demand: Due to the unavailability of data for price elasticities of low-income households' energy demand, an average elasticity is used. The IAEE resarch [28] shows that energy poor households for our target group do not have high elasticities of energy demand. Therefore, our assumption of average elasticities coming from ETS2 introduction, in the case of low-income households, would mean that the consumption decrease comes without private investments in energy efficiency and thus only from a reduction in thermal comfort.

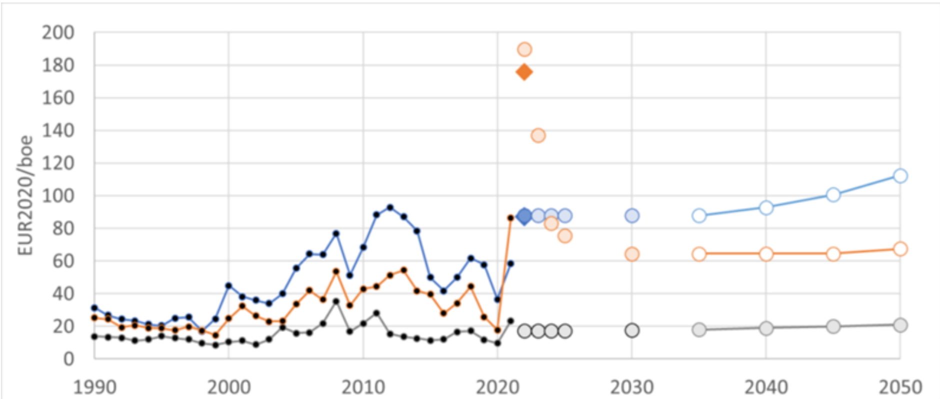


Figure 5. Envisioned fossil fuel price in the EU Reference Scenario 2020 (blue: oil, red: natural gas, grey: coal; BOE: Barrel of Oil Equivalent)

3.2. Scenario Analysis

Stemming from the proposed measures, six different scenarios were delineated. A linear calculation logic was applied based on the estimation of the final energy consumption by end-use (e.g., space heating, space cooling, and domestic hot water) for six different time intervals separately up to 2050 (e.g., 2019–2025, 2026–2030, 2031–2035, 2036–2040, 2041–2045, and 2046–2050), taking into consideration: (1) The increase in energy prices, as resulted by their forecast increase until 2050 and the imposition of carbon price (ETS2) and the subsequent reduction in the final energy consumption in accordance with the price elasticity of the energy demand. (2) The implementation of energy efficiency interventions and the delivered energy savings due to the implementation of the examined policy measures (MEPS and phasing out of fossil fuel boilers).

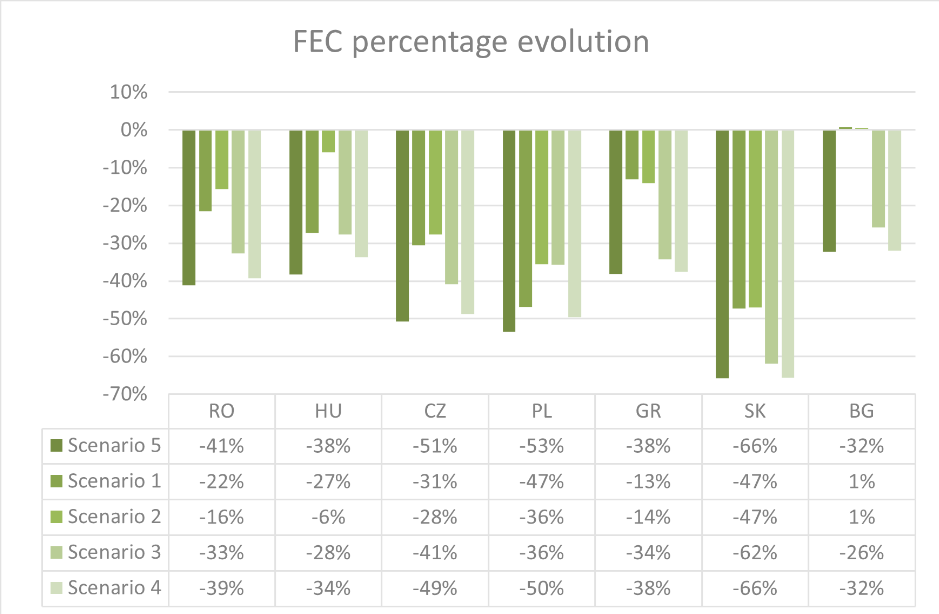
– Baseline Scenario assumes that no policy measures have been put in place (departing from the EU reference scenario) and it follows the European Commission's recommendations to member states (MSs) concerning their updating of the NECPs. This scenario is expected to present the highest energy consumption figures for all countries as no effort is made to reduce it in this scenario. On the other hand, the energy expenditure will depend on the energy mix of countries as countries presenting a higher share of fossil fuels will incur higher expenditures due to future energy price rises.
– Scenario 1 considers the implementation of the first proposed policy measure (ETS2) solely. Here, an additional increase in prices due to carbon pricing is considered. This is the same logic employed in the study [23]. An initial decrease in consumption is to be expected as the costs of fossil fuels will increase greatly. Nonetheless, this will not be a structured reform, but rather people will consume less for purely economic reasons, as they will not be able to afford energy services as before. This policy is

expected to provide undesirable results as it does not foresee a phase out of fossil fuels, but rather relies on the "market phase out" of fossil fuels for monetary reasons, a tactic which would greatly hamper low-income groups. Poland will be an exception due to its high reliance on coal and low prices of the latter, meaning that a switch to other forms of fuel could be more costly than sticking to coal. Additionally, due to its high reliance on coal, the expenditure under scenario 1 for Poland can be expected to reduce greater than in other countries.

– Scenario 2 takes into account the sole implementation of the second proposed policy measure, that being the phasing out of fossil fuel boilers. In this case, it is assumed that all fossil fuel boilers (using heating oil and solid fossil fuels but also natural gas) will be phased out in 2035. It is envisioned that the actual phase-out will take 5 years and thus be de facto phased out in 2040. The investment cost per heat pump is considered to be EUR 10,000 for all countries. The energy consumption is not expected to greatly reduce as this is rather a quick and short-team measure, as the residential efficiency cannot be expected to be reduced by only improving boilers. Similarly, expenditures are not expected to greatly reduce except in countries highly reliant on heating oil (e.g., Greece) as this fossil fuel is the most expensive one with the the highest envisioned price rise.
– Scenario 3 represents the application of the third proposed policy measure (MEPS) solely. N.B. In the present report, the term MEPS is generally used to indicate the refurbishment of buildings according to some proposed standards. However, these are not necessarily the minimum requirements set in the European directive. In fact, it is hereby further assumed that 75% of all buildings will be renovated to reach energy class D by 2030, resulting in 40% energy savings and EUR 15,000 renovation costs per building. Thereafter, these buildings will be renovated to reach energy class C in 2035, resulting in 10% additional energy savings and EUR 10,000 renovation costs per building. These assumptions differ from the previous study, where it was assumed that 50% of the affected households would reach energy class E in 2030, followed by the remaining half in 2035, resulting in 30% energy savings and EUR 10,000 renovation costs per building. Additionally, it was assumed that all households would reach energy class D in 2040, resulting in 10% additional energy savings and EUR 5000 renovation costs per building. Furthermore, in this study, the same renovation costs are assumed for all considered countries (whereas in the previous study, higher renovation costs were considered for Hungary). This is expected to be the best-performing stand-alone policy as it is a structured policy improving the general efficiency of the building.
– Scenario 4 considers the combination of both scenarios 2 and 3. This scenario is expected to provide better results compared to scenario 3 in general from an energy consumption perspective. Nonetheless, when considering also expenditures, countries that are highly reliant on fossil fuels (e.g., Poland and/or Hungary) might present higher expenditures compared to scenario 3 due to the presence of more fossil fuel boilers, which, considering also the low price of fossil fuels, might not give economically beneficial results in the short term.
– Scenario 5 considers the combination of all scenarios. The combination of all three policy measures is expected to provide the best results, as it tackles the energy efficiency issue globally and from all perspectives. It greatly combines policy measures more focused on short-term gains with other ones that consider long-term gains specifically.

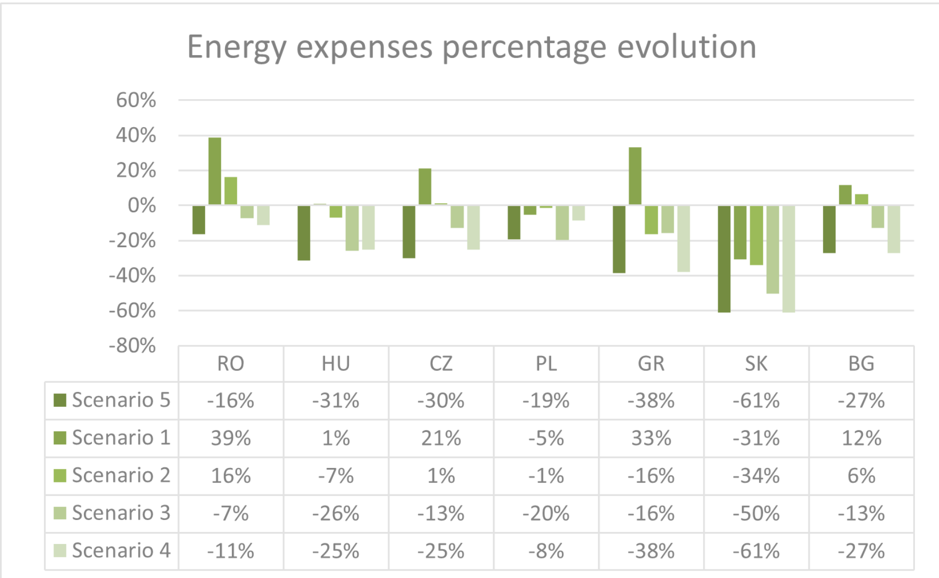
4. Results

In general, for all analysed countries, the combination of all scenarios, namely Scenario 5, provided the most desirable results in terms of final energy consumption reduction in the low-income households (without reducing thermal comfort) in 2050. Moreover, the combination of policies led to the highest reduction in energy expenses in 2050, excluding Poland, where the introduction of MEPS as a stand-alone policy resulted in the lowest energy expenses. Nonetheless, the difference in the final energy expense reduction in 2050 compared to 2019 levels for Poland between scenarios 3 and 5 was only 1%. However, this underlines Poland's great dependency on coal, as 34% of its energy consumed comes from coal (141 times higher when compared to the percentage of utilised coal in Greece). This will entail higher expenditure costs in scenario 5 due to the higher carbon costs related to the ETS2 pricing (unlike scenario 3 where the envisioned baseline fuel price increase is considered). The two graphs below (Figures 6 and 7) provide a percentage comparison of the envisioned savings in final energy consumption and in energy-related expenses from 2019 to 2050 for each country when implementing the policy measures assumed in each scenario. Essentially, the difference in values between 2050 and 2019 was expressed as a percentage, where scenario 5 provides the best results. In the rest of this section, a detailed deconstruction of the results per scenario per country can be found, differentiating between energy consumption and expenditure.



	RO	HU	CZ	PL	GR	SK	BG
Scenario 5	-41%	-38%	-51%	-53%	-38%	-66%	-32%
Scenario 1	-22%	-27%	-31%	-47%	-13%	-47%	1%
Scenario 2	-16%	-6%	-28%	-36%	-14%	-47%	1%
Scenario 3	-33%	-28%	-41%	-36%	-34%	-62%	-26%
Scenario 4	-39%	-34%	-49%	-50%	-38%	-66%	-32%

Figure 6. Resultingenergy consumption changes in 2050 compared to 2019 as a percentage per country.

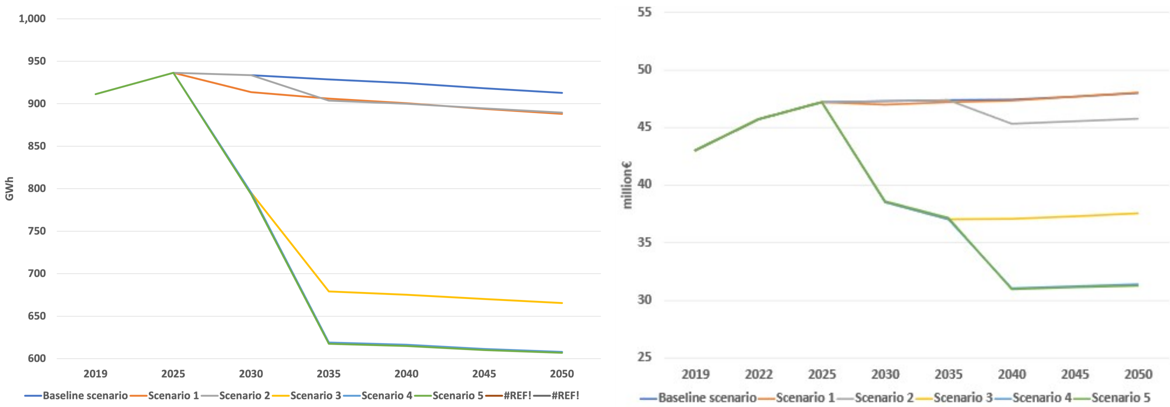


	RO	HU	CZ	PL	GR	SK	BG
Scenario 5	-16%	-31%	-30%	-19%	-38%	-61%	-27%
Scenario 1	39%	1%	21%	-5%	33%	-31%	12%
Scenario 2	16%	-7%	1%	-1%	-16%	-34%	6%
Scenario 3	-7%	-26%	-13%	-20%	-16%	-50%	-13%
Scenario 4	-11%	-25%	-25%	-8%	-38%	-61%	-27%

Figure 7. Resulting energy expenses changes in 2050 compared to 2019 as a percentage per country.

4.1. Bulgaria

Bulgaria clearly illustrates how policy measures not designed ad hoc for the country can present great counter effects. In fact, scenarios 1 and 2, together with the baseline scenario, present higher energy consumption and expenditures in 2050 compared to 2019. The case of Bulgaria clearly shows how short-term measures such as that in scenario 2 will provide only short-term gains (in this case resulting only from the initial implementation of the measure). Similarly, an unstructured measure such as that of scenario 1 will only damage low-income groups in the long run (Figure 8).

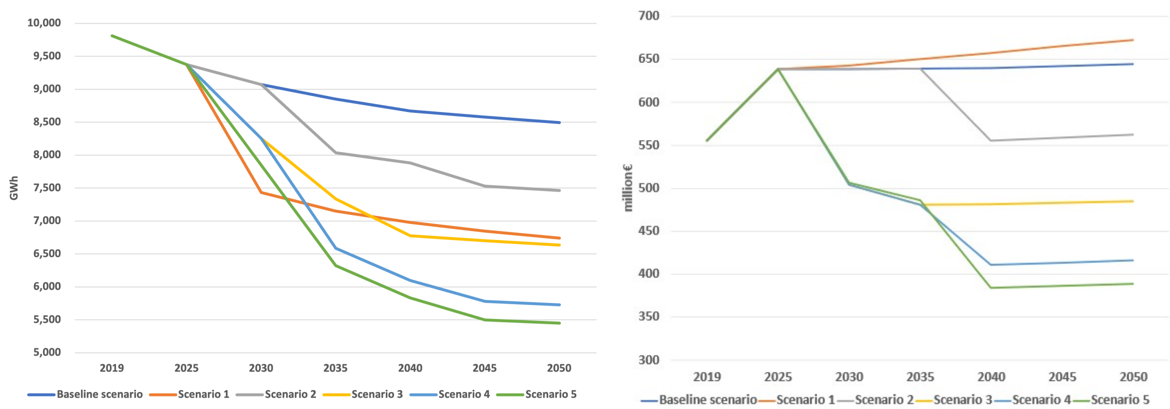


(a) (b)

Figure 8. Country analysis for Bulgaria. (**a**) Final energy consumption: comparison of different scenarios in Bulgaria. (**b**) Final energy costs: comparison between scenarios in Bulgaria.

4.2. Czechia

All proposed policies will present a reduced energy consumption in the long run in Czechia, although not a reduced expenditure. As for Bulgaria, scenarios 1 and 2 together with the baseline scenario would entail higher expenditures in 2050 compared to 2019. This is once again due to the unstructured nature of the measures. In the case of scenario 2 specifically, the gains of this measure only bring the expenditure levels in 2040 back to what they were in 2019. Nonetheless, due to rising energy prices, these will continue to rise in the period 2040–2050 (Figure 9)

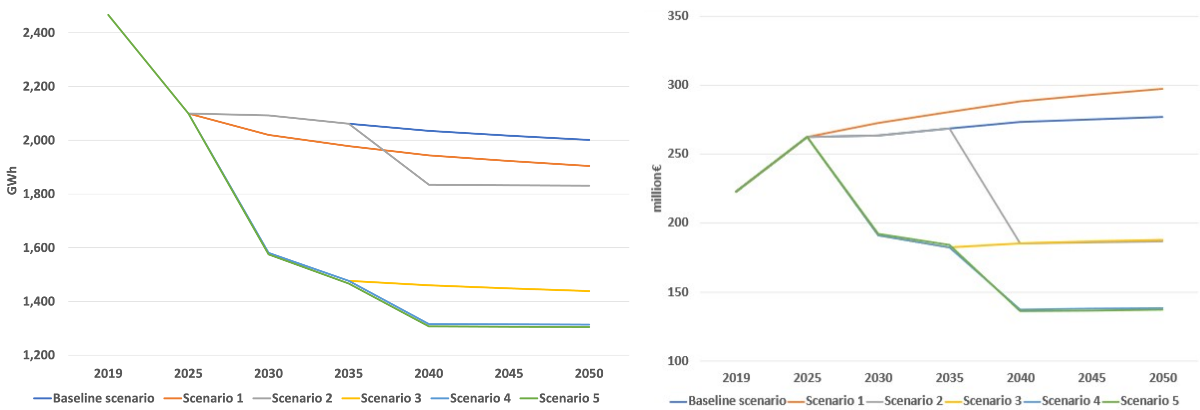


(a) (b)

Figure 9. Country analysis for Czechia. (**a**) Final energy consumption: comparison of different scenarios in Czechia. (**b**) Final energy costs: comparison between scenarios in Czechia.

4.3. Greece

All scenarios lead to lower energy consumption in Greece with only the baseline and scenario 1 leading to higher expenditures. In this case, scenario 2 leads to lower expenditures due to the high share of heating oil in Greece. In fact, this is the most expensive fossil fuel, and its phase out will thus lead to great price reductions. Specifically, in Greece scenarios 2 and 3 have the same expenditure decrease, although with the latter presenting a drastically higher reduction in energy consumption. This is preferable, as essentially in scenario 2 what is happening is a detachment from an expensive fossil fuel rather than an increase in energy efficiency (Figure 10).

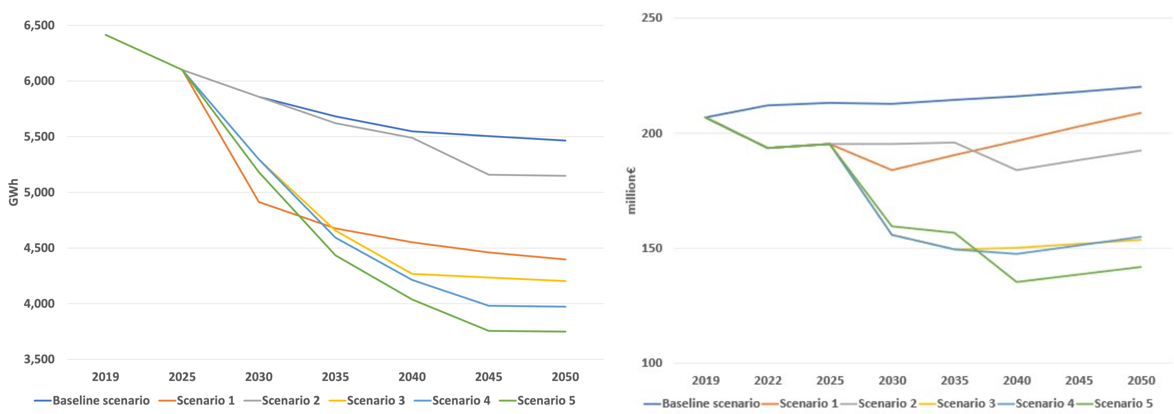


(a) (b)

Figure 10. Country analysis for Greece. (**a**) Final energy consumption: comparison of different scenarios in Greece. (**b**) Final energy costs: comparison between scenarios in Greece.

4.4. Hungary

In Hungary, the baseline scenario entails both a higher energy consumption and expenditure in 2050 compared to 2019. Interestingly, scenario 1 presents a substantial decrease in energy consumption however coupled with an increase in expenditures. This is due to a high share of gas in its final energy consumption. In fact, since it will not be possible to phase it out completely just by applying the ETS to the residential sector, low-income groups will try to reduce its consumption as much as possible although still incurring higher energy costs (Figure 11).

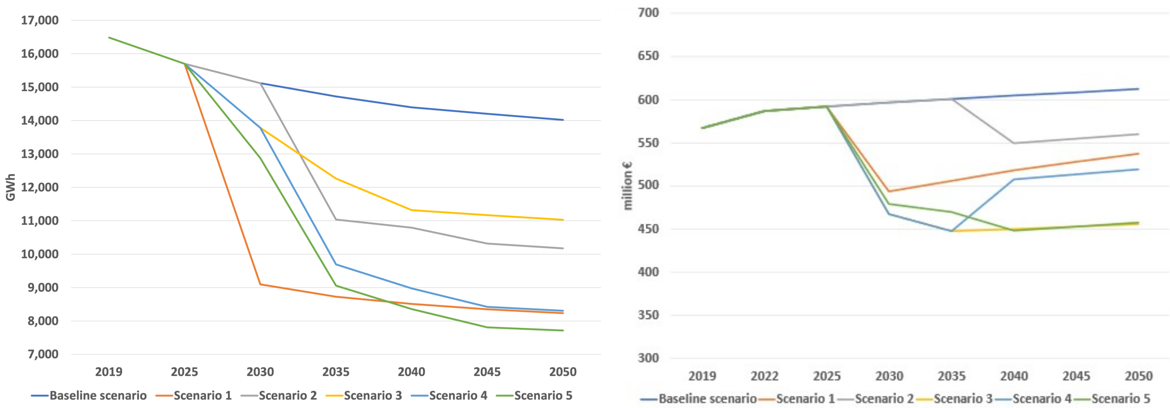


(a) (b)

Figure 11. Country analysis for Hungary. (**a**) Final energy consumption: comparison of different scenarios in Hungary. (**b**) Final energy costs: comparison between scenarios in Hungary.

4.5. Poland

All scenarios result in lower energy consumption in Poland whereas all scenarios except the baseline one result in lower expenditures. Due to Poland's high coal share in its energy mix, scenario 1 results in a greater reduction in energy consumption compared to scenarios 2 and 3. Additionally, scenario 1 presents also lower energy expenditures in 2050 compared to scenario 2. It can be thus argued that scenario 1 is effective in a greatly solid fossil-fuel-dependent country (Figure 12).

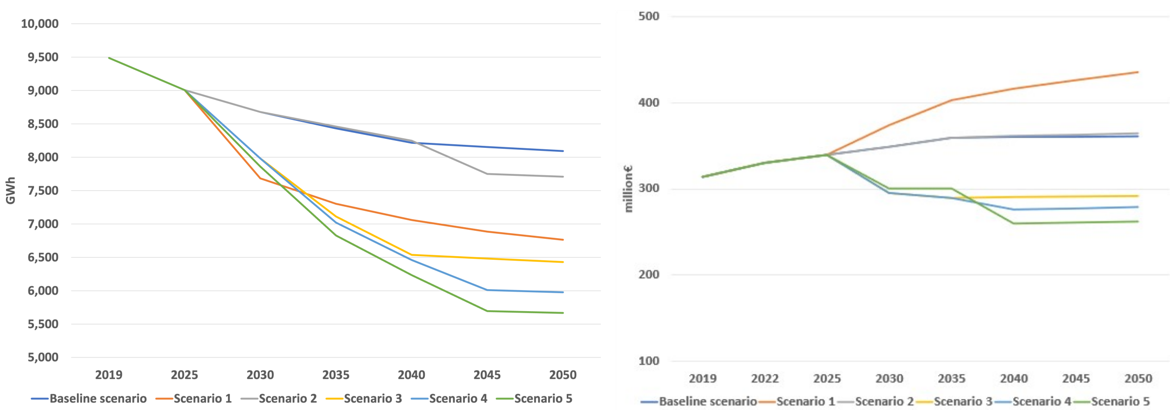


(a) (b)

Figure 12. Country analysis for Poland. (**a**) Final energy consumption: comparison of different scenarios in Poland. (**b**) Final energy costs: comparison between scenarios in Poland.

4.6. Romania

Romania presents lower energy consumption with all suggested scenarios. Interestingly, scenario 1 performs better than scenario 2 in terms of consumption. However, in terms of expenditure, scenario 1 presents higher values even when compared to the baseline scenario. Romania is highly dependent on biomass, which was assumed to remain constant in usage and price. Natural gas being the second most used fuel, its reduction will be minimal compared to the incurred costs in scenario 1 (Figure 13).



(a) (b)

Figure 13. Country analysis for Romania. (**a**) Final energy consumption: comparison of different scenarios in Romania. (**b**) Final energy costs: comparison between scenarios in Romania.

4.7. Slovakia

Slovakia presents lower energy consumption and expenditure in all scenarios. The scenarios yield similar results when comparing the energy consumption and expenditure.

Interestingly, scenarios 4 and 5 present practically the same results, highlighting how the ETS extension does not have a great influence and effect in Slovakia (Figure 14).

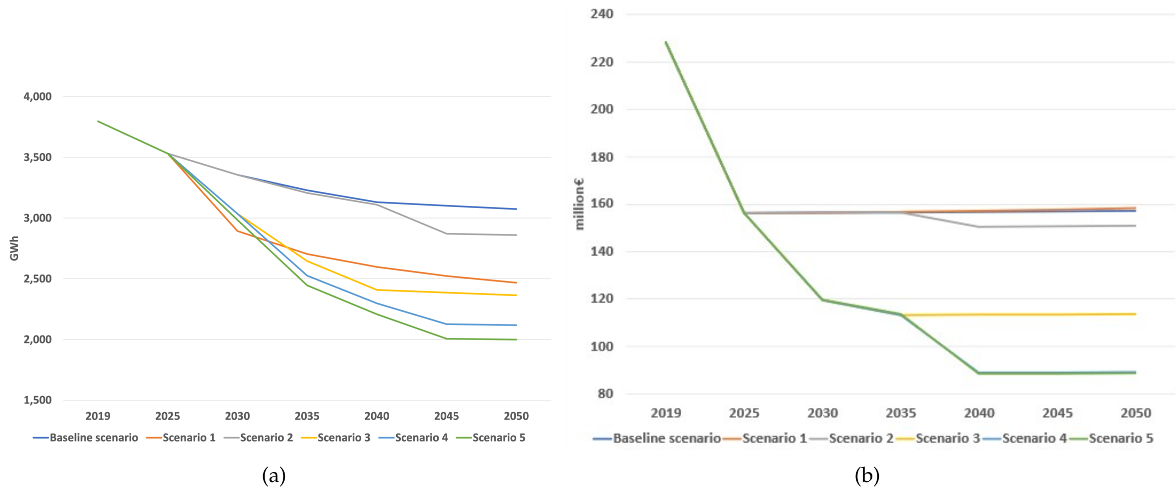


Figure 14. Country analysis for Slovakia. (**a**) Final energy consumption: comparison of different scenarios in Slovakia. (**b**) Final energy costs: comparison between scenarios in Slovakia.

5. Discussion

5.1. Insights on the Low-Income Households Policy Specifics

How these results transfer to the specific household is evaluated using qualitative and quantitative indicators. Energy poverty indicators are well known and include five dimensions (low income compared to costs, high share of income spent on energy, inability to pay bills, housing faults, and the inability to keep warm). To avoid redundancies for precision [29], distributional aspects of the three policies on low-income households for every scenario are described using three factors (energy costs, income, and energy efficiency) [30], where the quantified adverse effect is based on the income dimensions. In addition to compensation variation showing that energy poor households without proper public funding end up with higher levels of income poverty, research [31] shows that energy poverty not only changes living conditions but also influences health, social activity and inclusion [32], local environment, education, and many other aspects of life. It is, therefore, important to also look closely at the non-energy impacts of the proposed policies that are to help with the adverse effects of transition to the low-income groups. In all the aspects of any of the policies targeting energy poverty alleviation (like evaluation or monitoring), all the indicators should be taken into consideration to avoid additional negative effects on the low-income households (Figure 15).

5.2. Insights on the Energy Retrofit and Investments

From the percentage change of the average income without financing, it becomes clear that, no matter the expenditure decreases in the medium run and the thermal comfort improves, the disposable income is too low and therefore blocks the investments, making it impossible for low-income households. Additionally, evidence [33] shows that vulnerable households use a higher discount rate compared with average, therefore choosing short-term solutions as opposed to long-term investments. Covering the upfront costs using the Social Climate Fund and additional funding directed to vulnerable groups would result in a positive change of the average income of the low-income groups and external positive effects (Figure 16).

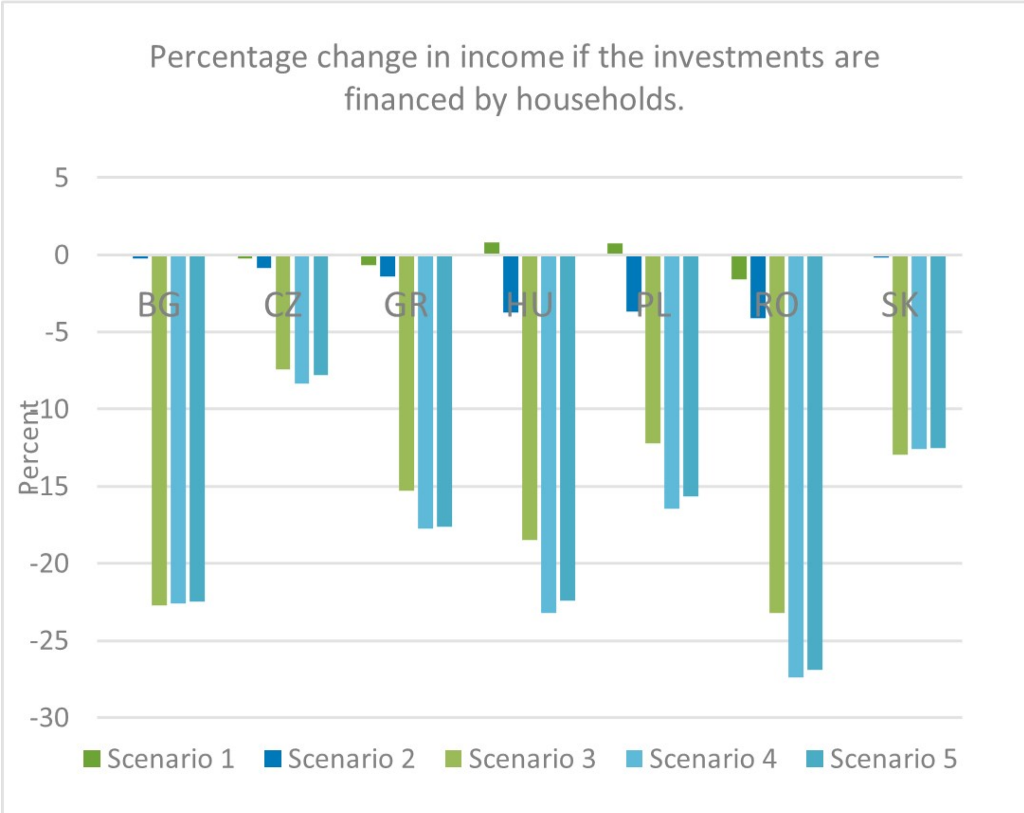


Figure 15. Percentage change in average income of the low-income group in 2050 compared to 2019 without investment financing.

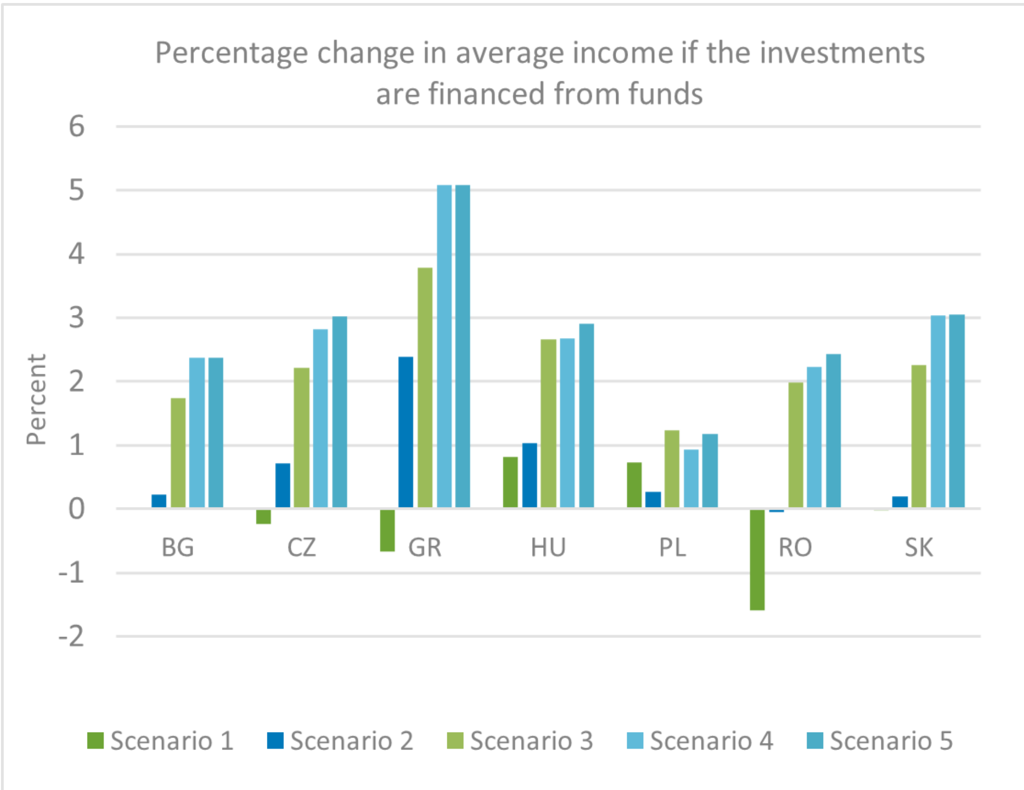


Figure 16. Percentage change in average income of the low-income group in 2050 compared to 2019 with investment financing.

6. Policy Implications

The study investigated the impacts of the recent energy policies on the low-income group of households. Based on the analyses, the following recommendations are suggested:

- The financing possibilities should be shifted from new and upgraded fossil fuel boilers to new and renewable heating systems before 2025. Phasing out of fossil fuel boilers from the market will not automatically lead to the replacement of existing fossil boilers, especially in the case of low-income households due to the existing high upfront costs as well as policies encouraging the installation of gas boilers. In the countries' short-term measures for the energy crisis (next to the income-support ones), there are still subsidies for fossil fuel use in heating as well as for installing fossil fuel heating systems, for example, in Bulgaria, Greece, Poland, and partly in Croatia. Therefore, it is important to phase out such subsidies even before 2025, as on average boilers have a lifetime of 20 years and it would require a minimum of 5 years to fully implement the phase-out (thus, to be carbon neutral by 2050, these changes would have to be made 25 years before). This process will speed up if funds are allocated for phasing out fossil fuel boilers and shifting to clean heating systems.
- Include subsidy schemes for the energy efficiency with as high as possible funding rates (total investment wherever possible) for low-income households. Measures should also include technical guidance and assistance. These subsidies should be starting before 2025, with information available for the low-income groups. It is also relevant to emphasise that the introduction of MEPS should accompany such phase-out as important in low-income households. For example, the Clean Air Program, 22.7 billion EUR, is planned to run until 2029 in Poland, providing 90% of investment costs for low-income groups of households to invest on efficient heat resources.
- Prioritise the Energy Efficiency First principle. In view of the updates of the NECPs and the new EED Article 3 (for the E1st principle), countries can benefit and start planning based on the energy efficiency requirements. Through MEPS, for instance, (when introduced with the phasing out of fossil fuel boilers) their implementation is not resulted in additional emissions, or higher costs for the low-income, despite the extra costs of the plan.
- Scenario 5 (all three measures included) provides a relevant signal and generates important effects on the consumption and energy expenditure of low-income groups. Even if we consider the phase-out as significant and cost-effective for using simplified repayment analysis, without MEPS there is no change in the quality of life and thermal comfort of the low-income households plus there is no lower energy demand and costs.
- The Social Climate Fund (for which it is obvious), the ETS2 auctioned revenues and the funding streams from Recovery and Resilience plan should include concrete energy efficiency actions for low-income citizens. In some countries, the Social Climate Fund and expected revenues from ETS2 allowances are enough for covering the cost of three measures (increased energy expenditure, investment costs for new heating and refurbishments), but only for low-income households. Part of the available funding allocated to the residential sector will focus on energy and transport poverty as a whole, thereby including a much larger number of households in each country than the specific target group of this study (the lowest income decile households). All of these programmes (even SCF in some way) include a budget for the bigger energy efficiency programs (with an average of 40–50% financing rate), with no specific support to low-income households. Those are to be financed with a higher percentage.
- Regulation is to include insight into the energy behaviour of low-income groups. There is a lack of data to determine the price elasticity and changes in energy consumption, all the behaviour changes. An incentive based on the price, ETS2, for example, results in lower thermal comfort deriving from lower energy consumption. This is why it is important to provide a good combination of policies and measures.

7. Summary and Conclusions

Despite the unavailability of data concerning energy poverty indicators from the months following the start of the Ukrainian war and price increases, a disruption of positive trends in energy poverty reduction can be observed beginning in 2021. These trends, in combination with price rises, expected inflation, risk of increased poverty, lower GDP, and weakened growth indicate the existing burden on countries to lower these adverse effects. Considering the inflation due to energy prices, energy poverty indicators will likely worsen in 2022 compared to 2021. EU member states have opted to alleviate the higher burden of energy costs with price regulations, energy bill assistance as well as tax reductions on energy bills. Nevertheless, these are not considered structural measures for the low-income groups and they should be combined with energy efficiency upgrades and heating decarbonisation. Moreover, the higher upfront costs of energy efficiency investments combined with the well-known and documented structural barriers do not make energy efficiency as a key priority of low- and middle-income groups, although the payback time of such investments is shortened due to the higher energy prices. Their reduced disposable income (due to the higher energy prices) is hampering the possibility to invest in renovations and clean heating solutions, while the incumbent fossil fuel subsidies further delay the investments in clean heating. Therefore, if the available funding, such as subsidies on energy efficiency and heat pumps are not increased for low-income households, the energy crisis and inflation may even delay energy efficiency investments to remove fossil fuels for heating in these households. To combat this, a complementary package of support with financial, technical, and information measures from the national and local authorities can help accelerate energy efficiency investments and a switch to clean heating. Additionally, the dependence on imported gas of the analysed countries varies widely. This needs to be considered when evaluating the ability of a country to react to the changes deriving from the implementation of three targeted Fit for 55 policies. The dependence on imported gas influences the energy price, and with it, member states' new expenditures to cover the energy costs of households via bill aid. However, the EU Emissions Trading System extension (ETS2) and phasing out of fossil fuel boilers will lead to the diversification of energy sources due to the requirement of cleaner sources or electrification in heating and price incentives (in the case of ETS2). A lower fossil fuel usage and therefore a lower gas import are expected due to these policies. The combination of the three policies can provide the best results both in terms of utilisation of energy and expense reduction for all countries (except Poland). When no additional policy measures were implemented, the highest envisioned energy consumption was incurred. With regards to energy expenditures, for half of the analysed countries, these would be higher when implementing the ETS2 prices than in the baseline scenario. This is due to the higher ETS2 energy prices and an inefficient phase-out of solid fossil fuels, as the latter would happen only due to higher fuel prices, without a coordinated phase-out policy measure. Moreover, new ETS2 as an alone policy measure can incur the highest energy reduction, which also results in thermal comfort loss for low-income groups, as no structural effects in the demand reduction take place. In addition, the implementation of measures aimed at improving energy efficiency in general, such as the introduction of MEPS, rather than targeting energy prices will provide more homogenous energy improvements throughout, resulting in homogenous price trends and more equally spread benefits to low-income households.

8. Recommendations for Future Research

The present study suggests several areas that could be explored in future research. These areas primarily stem from the lack of data on crucial parameters necessary for accurate calculations. The authors aim at gathering more detailed data in one EU member state (presumably Croatia) and test the developed methodology. The subsequent paragraphs delineate the key parameters that require further investigation and were not encompassed in the current research:

(a) Evaluation of price elasticities among low-income groups: Price elasticity plays a crucial role in evaluating the susceptibility of low-income households to price hikes stemming from the execution of ETS2 and other policy scenarios. It is important to delve into the non-linear effects of ETS2 and other policy scenarios, as indicated in a prior study. The response to heightened energy prices involves investing in energy efficiency measures and switching fuels or suppliers. However, low-income groups typically possess limited options, and their reduction in energy consumption primarily stems from decreased demand. Consequently, if the average elasticity is considered, any savings in energy expenditure that do not arise from fuel switches or energy efficiency measures will negatively impact the vulnerability of low-income groups. Factors such as wealth distribution and income disparity should be examined to attain accurate elasticities, as different countries exhibit distinct socioeconomic characteristics. Additionally, elasticities will be influenced by the fuel composition in final energy consumption.

(b) Determination of replacement rates for fossil fuel boilers across different income groups: Information regarding the rate of boiler replacement is necessary for calculating the overall costs of fossil fuel boilers as well as reductions in energy consumption and CO_2 emissions. Research has indicated lower rates of boiler replacement among low-income households compared to other groups. However, the response rates specifically for these groups are not available. In general, low-income households might exhibit slower responses to market ban measures due to their higher discount rates in comparison to the average household. This implies that low-income households may prefer short-term solutions or find themselves in situations where they have limited choices for long-term investments.

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