IAM COMPACT

Expanding Integrated Assessment Modelling:
Comprehensive and Comprehensible Science
for Sustainable, Co-Created Climate Action

Towards a just transition in the EU:

the distributional effects of environmental policies

26/08/2025

The IAM COMPACT project has received funding from the European Union's HORIZON EUROPE Research and Innovation Programme under grant agreement No 101056306.

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1.1 Background

IAM COMPACT is a Horizon Europe research project, with the objective to support the assessment of global climate goals, the collective progress towards them, and the feasibility space in delivering on those goals. It aims to involve relevant stakeholders in the process to help promote acceptable, robust, sustainable transitions, as well as to enhance trust on both ends, yielding outputs intelligible in terms of real-world implications and actionable in terms of concrete policy recommendations.

Stakeholder engagement in IAM COMPACT is organised into themes (for stakeholders within the EU) and regions (for stakeholders outside the EU). The themes and regions were collaboratively determined within the project, with Bruegel coordinating the process. Our project team received 46 research questions from the Policy Steering Groups (PSGs), which were then grouped into seven new modelling studies. After internal discussion among modelling teams, an initial scenario design for each study was agreed and then presented to our Core Working Groups (CWGs) for discussion and co-design in three separate workshops.

This policy brief is part of the theme *Citizens in the Transition*[1], which focused on lifestyle changes in mobility, diets, and housing, household decarbonisation, and distributional impacts of climate policies, and produced three modelling studies. The study presented here assesses how, in the absence of redistribution mechanisms, different strategies for European climate policy may affect welfare for specific groups in European societies, looking at income, gender, and rurality.

1.2 Motivation

Addressing climate change requires a profound societal transformation that significantly impacts production systems and consumption patterns, affecting all segments of society. It is therefore essential to design efficient and equitable policies that avoid deepening existing inequalities within and between countries. The implementation of environmental policies will have direct within-region implications for social inequality, such as income or gender inequality. Considering the diverse nature of household behaviour and demand, the assessment of the within-region distributional impacts of alternative climate policies and their implications across different population groups has been identified as a major priority by different cross-regional institutions, including the European Commission (Bednar-Friedl et al 2024). However, inequality and vulnerable groups are significantly underrepresented in most of the dominant tools used to assess the system-wide implications of alternative policy scenarios (Low et al 2025). These models often lack detailed information on household categories or socioeconomic groups, limiting their ability to capture the socioeconomic and distributional consequences of the climate transition. Therefore, it is essential to develop methodologies and tools that reflect real-world social and economic diversity, enabling more nuanced analyses of how different climate pathways impact various segments of the population. This becomes crucial to identify vulnerable populations for an effective design targeted compensatory measures (Alonso-Epelde et al 2024).

In this analysis, we develop and apply an innovative integrated modelling framework that enables us to assess how alternative strategies for implementing the current EU climate policy portfolio affect different consumer groups both within and across Member States.

[1] https://iam-compact.eu/news-events/core-working-group-workshop-citizens-transition

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2 Scenario Design

The analysis of the distributional implications is based on an integrated framework built on a geographically and sectorally expanded integrated assessment model (*GCAM-Europe*[2]) with a tool designed to conduct in-depth distributional analyses (*MEDUSA*[3]). We use GCAM-Europe to estimate future changes in energy prices as well as food and water prices under different scenarios. These price changes are then fed into MEDUSA, a microsimulation model that estimates highly disaggregated distributional impacts associated to those price changes for all 27 EU Member States, considering numerous socioeconomic and demographic characteristics of households, such as income level, place of residence, type of family or the feminization degree of the household. The model assumes that households maintain the same consumption behaviour; thus, welfare impacts indicate the additional money required for each household to sustain their current consumption levels. The combined use of these two models enables the exploration of research questions that remain unaddressed in the existing literature, particularly regarding the distributional implications of alternative climate and policy scenarios.

In this study, we simulate three alternative policy scenarios, along with a benchmark baseline, each representing a pathway towards achieving the EU's current emission reduction targets for 2030, but representing climate policy with different degrees of sectoral and regional granularity (Table 1). For the purpose of isolating the relative price impact of climate policy, all scenarios (including EU_NOCLIMPOLICY) consider existing Member State specific energy taxes (electricity, gas, and transport fuels) up to 2024 and assumes them to stay constant until 2030.

Table 1. Within-region distributional analysis: scenario overview

Scenario	Description
EU_NOCLIMPOLICY	In this baseline scenario, we assume the absence of any effective climate policy to reach the EU's 55% target in 2030. While several cross-sectoral policies and objectives are currently in place at both the EU level and within individual Member States, this theoretical scenario serves as a benchmark. It enables comparison with alternative pathways to assess the impact of various climate policy interventions.
EU_FF55	This scenario is based on the implementation of the existing portfolio of emission reduction policies in the "Fit for 55" policy package, including renewable energy shares, energy efficiency targets or additional sector-specific policies (e.g., ETS I and II schemes).
EU_FF55_FREE	In this scenario, the EU achieves the same level of carbon dioxide (CO_2) emissions mitigation as in the EU_FF55 scenario. However, in this case, EU emissions reductions are achieved through emissions constraints without explicitly considering the current climate policies. With this approach, the model endogenously calculates a shadow carbon price in each period, to follow the cost-optimal pathway for reducing emissions.
EU_NECP	The scenario follows the same approach as EU_FF55, but it divides the Energy Efficiency and Renewable Energy targets in FF55 by the targets announced by individual EU Member States in their National Energy and Climate Plans (NECPs), on top of EU-wide policies. Due to the design of this scenario, the projected emission levels can slightly differ from the achieved in both the EU_FF55 and EU_FF55_FREE scenarios

In summary, this set of scenarios presents alternative narratives that combine "least-cost" approaches with more prescriptive mitigation pathways. While all scenarios achieve the same overall level of CO_2 emissions at the EU level, the distribution of mitigation efforts across countries and sectors varies depending on the specific scenario.

[2] https://github.com/bc3LC-GCAMEurope
[3] https://github.com/bc3LC/medusa

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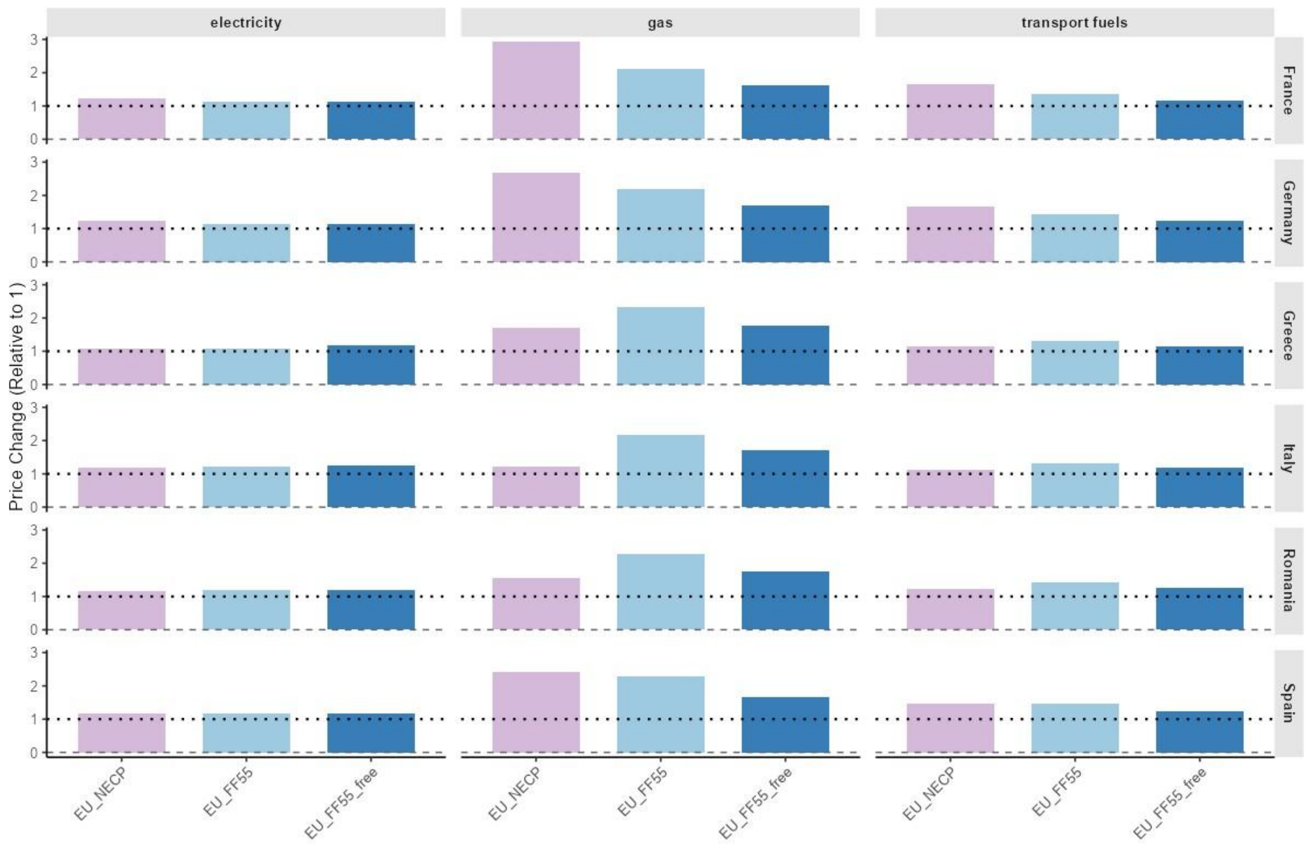
3 Model Results

3.1 Price impacts

The implementation of environmental policies will directly impact the energy system by increasing the share of non-emitting technologies in the energy mix. This shift will, in turn, affect energy prices and, indirectly, the prices of other end-use sectors (e.g., food) across different EU Member States. These price changes vary significantly across scenarios. In the less prescriptive scenarios, such as EU_FF55_FREE, mitigation efforts are distributed based on a "least-cost" approach across countries and sectors, and the projected price increases are relatively moderate. In contrast, scenarios where mitigation is exogenously directed toward specific sectors in line with actual policy goals (e.g., EU_FF55) and also towards specific countries (e.g., EU_NECP), tend to result in higher price increases, since such policies achieve climate change mitigation through a sub-optimal policy mix such as e.g. renewable energy feed-in tariffs and sector-specific carbon pricing mechanisms (e.g. ETS I and II), which potentially are better in line with other policy targets, and/or more realistic in terms of implementation within the existing EU and national policy paradigm.

Figure 1: Price changes across scenarios by region and fuel in 2030 from GCAM-Europe (index, relative to EU_NOCLIMPOLICY).



3.2 Socioeconomic Impacts

This section presents the distributional and social impacts associated with the price changes in the alternative emission reduction scenarios. We explore the socioeconomic effects by Member State, as well as distributional and inequality at both the EU and national levels. Importantly, the results only look at the direct welfare impact from price changes assuming consumption patterns in 2015, and do not consider the potential alleviating impacts of redistributing tax revenues and price-induced consumer responses, including technology switches. It thus provides a conservative estimate or an upper bound.

3.2.1 Households Welfare Impacts by Member State

Figure 2 depicts the average welfare impacts by Member States. The figure shows that, on average, the scenario with the lowest welfare impacts at the EU level is the EU_FF55_free scenario, followed by EU_FF55 and EU_NECP, although the aggregated impact of the latter two scenarios is very similar. These results, on average at the EU level, align with expectations, as the "cost-optimal" **EU_FF55_free is the most cost-efficient scenario**, given that the model assumes the entire EU reduces emissions through the lowest possible carbon price. In contrast, the other scenarios (EU_FF55 and EU_NECP) include current policies proposed by the European Commission and various Member States, which not only aim to reduce emissions at minimum cost, but also incorporate additional policy parameters into the equation, such as the heterogeneous nature of mitigation capacities in different sectors and Member States, support for specific key technologies, and other policy goals such as public health, industrial competitiveness, and energy security.

If we explore the differences between Member States, Figure 2 shows that under the EU_FF55_free scenario, welfare losses range from 13% in Poland to below 2% in Sweden. Likewise, despite some differences, under the EU_FF55 scenario the most affected countries remain similar to those in EU_FF55_free, with Poland being the most affected and Finland the least affected, followed by Sweden. However, under the EU_NECP scenario, the most affected Member State becomes Luxembourg, followed by Ireland, while the least affected is now Bulgaria. Moreover, the EU_NECP scenario shows the greatest differences when compared to EU_FF55_free, highlighting once again that the policy packages implemented by different Member States are not solely aimed at minimizing the cost-efficient reduction of emissions across the EU.

As can be seen in the EU_FF55_free, the largest welfare losses are mainly concentrated in Central and Eastern European Member States. In addition to Poland, the Czech Republic, Slovakia, and Hungary experience the highest welfare losses. The higher welfare impacts in Poland and other CE-MS are due to price effects and the consumption patterns of households in these Member States. Price impacts are greater because of the high dependence on fossil fuels. Moreover, carbon pricing would significantly increase consumer prices, given the relatively low initial price levels, for example, due to lower current energy taxes. At the same time, households in these MS allocate a larger share of their income to energy products. For instance, households in Poland dedicate around 9% of their expenditure to fossil fuel-based energy products (such as heating from fossil fuels and transport fuels), while households in MS like Denmark allocate only about 3% of their expenditure to these commodities. Hence, higher prices combined with larger expenditure shares on energy lead to greater welfare impacts in Poland and other CE-MS. In contrast, a carbon tax would have a smaller effect on households in Sweden, Finland, and Denmark. As mentioned before, despite the differences, the EU_FF55 scenario follows a similar trend when compared to EU_FF55_free. However, under the EU_NECP scenario, the differences compared to the other scenarios are more pronounced. For example, in Member States such as Bulgaria, Romania, Hungary the welfare impacts are much smaller under the EU_NECP scenario, whereas in other countries such as Luxemburg, Ireland or Netherlands suffer a greater impact under this scenario. Although it depends on each Member State, under the EU_NECP scenario we observe that most of the smaller impacts are in CE-MS, with the exception of some countries such as Poland and the Czech Republic, which continue to experience significant welfare impacts.

In the EU_FF55_free scenario, the carbon price ensures the most cost-efficient emission reductions at the EU level, without considering the differing costs faced by individual Member States. However, the EU_NECP

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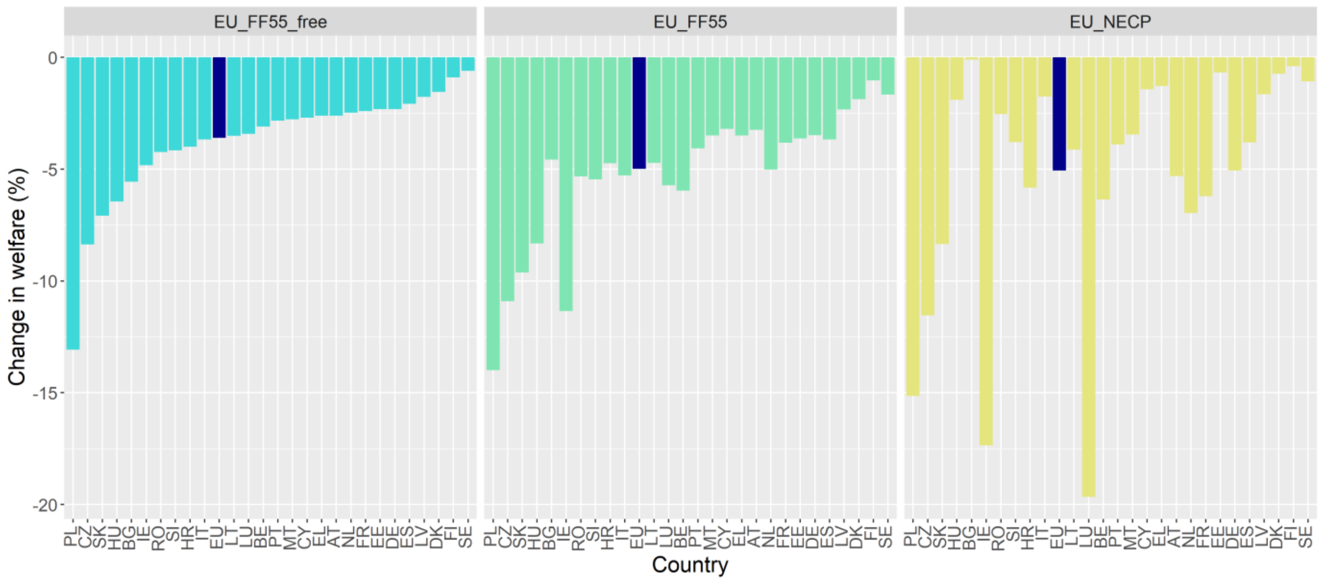
establishes specific targets for each Member State based on their Nationally Determined Contributions (NDCs). Hence, our results show that under the EU_NECP scenario, it is possible to achieve the same level of emission reduction at EU level, but with lower welfare implications for some Central and Eastern Member States (CE-MS). Although EU_FF55_free, or even EU_FF55, are likely more cost-efficient in reducing emissions, the EU_NECP results highlight clear trade-offs between cost-efficiency and the distributional impacts of climate policy between Member States.

Figure 2: Welfare impacts by Member State (ordered by the welfare impact) and scenario (%) from MEDUSA



3.2.2 Vertical analysis

3.2.2.1 Distributional impacts at EU level

Figure 3 shows the distributional welfare impact of the policy scenarios by EU expenditure deciles[4], i.e., we distribute the 200.000 households included in MEDUSA as if the EU was a single economy, allowing us to explore the distributional effects of the different emission reduction scenarios. In terms of the distributional impacts, Figure 3 reveals that welfare will be asymmetric across the income distribution but similar across scenarios. Thus, in policy scenarios households belonging to the middle low deciles (from D1 to D4, i.e., households with lower income) would be more affected by the decarbonization cost in the EU, whereas households in higher income brackets are less affected by the policy scenarios. Therefore, in line with many concerns, and in the absence of redistributive policies, the cost of the emission reduction in the EU could have regressive impacts at the EU level.

[4] Expenditure is used since it is considered a better approximation of permanent household income (Goodman, & Oldfield, 2004). Equivalent expenditure deciles are calculated from household expenditure relativized by the modified OECD equivalence scale. The modified OECD scale values the reference person in the household at 1, all other persons aged 14 and over at 0.5, and all other persons under 14 at 0.3.

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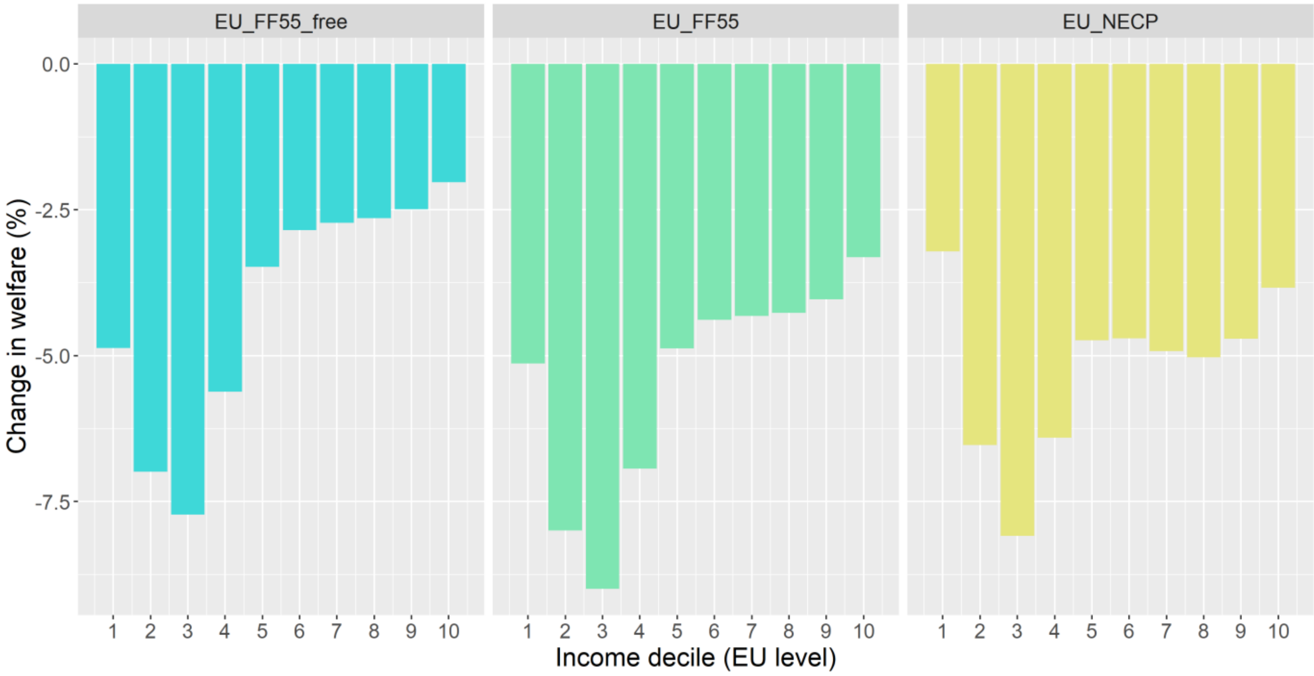
Figure 3: Welfare impacts by income groups at EU level (%) from MEDUSA. D1 is lowest income households in the EU whereas 10 is the wealthiest.



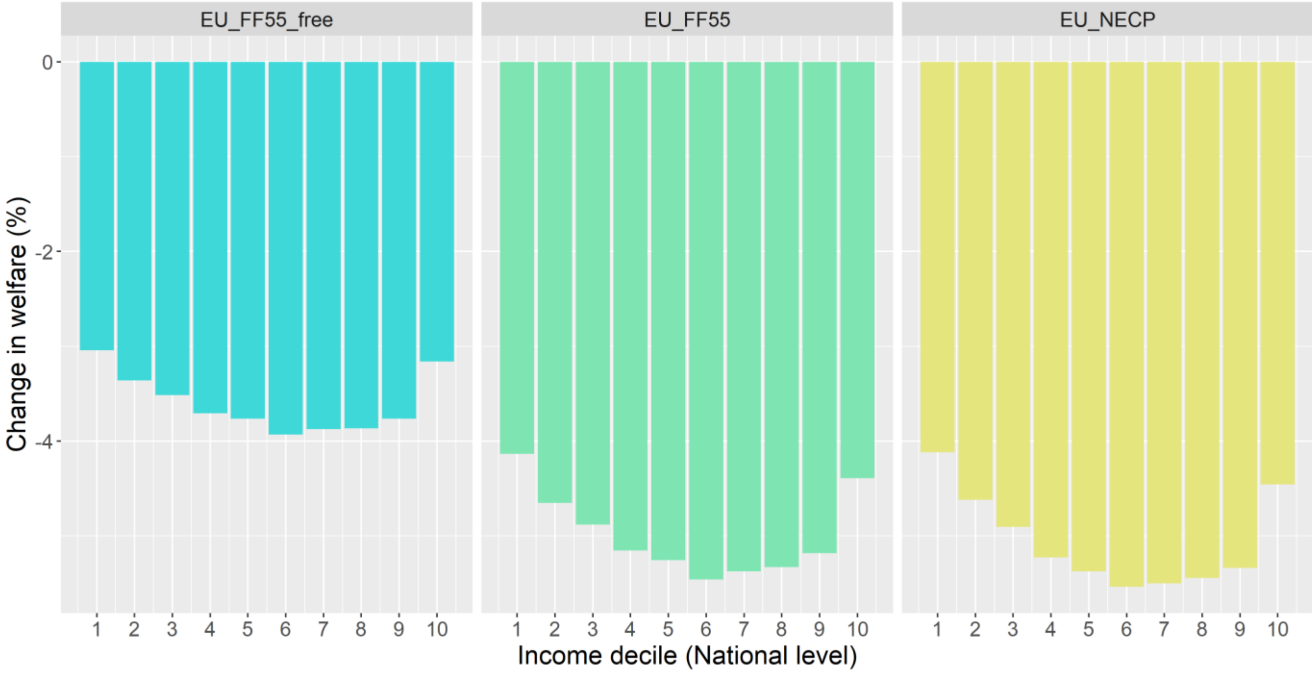
These distributional results are directly related to the income distribution at the EU level, as well as the varied impacts among Member States. As seen in the average welfare analysis by country (see Section 3.2.1), the Central and Eastern Member States (CE-MS) would experience larger welfare impacts, given their current larger dependency on fossil fuels. Simultaneously, these regions are associated with lower income groups in the EU income distribution. This explains the regressive impacts at the EU level on the different scenarios, as the households most affected by the reform are in countries with lower average incomes that need to increase their current taxation more substantially.

Although the regressive tendency is similar in the different scenarios, the results indicate that welfare impacts are lower under the EU_FF55_free scenario, compared to the EU_FF55 or the EU_NECP scenario. This outcome is clearly related to the previous analysis (Section 3.2.1), which already shows that the EU_FF55_free scenario is the most cost-efficient policy. However, the trend across EU income groups differs slightly between scenarios, with the EU_NECP scenario showing the lowest welfare impacts for the bottom income groups in the EU, and highest welfare impacts for the above-median income groups. As we already highlighted before, under the EU_NECP scenario, lower costs for some CE-MS also mean that lower-income groups in the EU (i.e., the first income deciles) are less affected by decarbonization. The lower welfare impacts in EU_NECP is specially more pronounced among very low-income groups (D1). This suggests that the EU_NECP scenario is less regressive than the FF55 scenarios at EU level. These results highlight how the design and implementation of emission reduction policies can significantly influence welfare outcomes at the EU level and shape their distributional implications.

3.2.2.2 Distributional impacts at average national level

Although the previous analysis offers relevant insights and results about the distributional impact of the cost of the decarbonization at the European level, it does not allow us to analyse how these policies can affect national inequality in the different Member States. Therefore, Figure 4 presents the distributional welfare impact of the decarbonization scenarios by national expenditure deciles of each country.

Figure 4: Welfare impacts by national income groups and scenario. D1 is lowest income households in each Member States whereas 10 is the wealthiest.



At the national level, the impact is less regressive, with welfare losses being higher for the middle- and high-income brackets across all scenarios. This contrasts with the EU-wide results (Figure 3) discussed earlier, which show that the emission reduction scenarios could increase inequality at the EU level. As we also showed in the analysis on the previous deliverable D5.2, the distributional impacts can be explained by the consumption pattern of the energy products of European households (see Figure 5). Although not only energy products are affected by the emission reduction scenarios, they are the commodities most affected. Therefore, at the national level, we can see that energy expenditure constitutes a significantly larger share of total spending for lower-income households compared to higher-income ones. It is also important to note the differences between energy products: transport fuels constitute the largest share of expenditure for middle-income households (as private car ownership is less common among lower-income households), whereas electricity accounts for a larger share among the poorest.

While this is the average picture across the income distribution, there are important differences in the structure of energy consumption both between and within Member States. Average energy expenditure as a share of household income among countries ranges from around 4% in Malta to nearly 14% in Poland, with significant differences in the shares of different fuels among the Member States. Within countries, we find that in lower-income regions, transport fuel expenditure tends to increase more in proportion with income compared to the EU-wide pattern of transport expenditure, while the EU-wide pattern is more typical of higher-income Member States. Electricity, however, makes up the largest share of expenditure of lower-income households across the vast majority of EU countries. This is mainly because in lower-income households, a larger proportion of income

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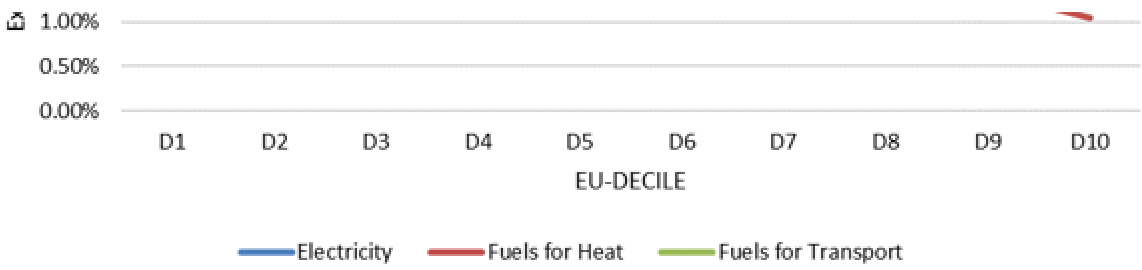

Considering these consumption patterns and examining the price impacts of the different scenarios, we can see that higher prices for fossil fuels used in transport are a key factor explaining why upper-middle-income groups in many Member States are more affected by emission reductions in the EU, regardless of the policy design. Therefore, although in many Member States, and across different scenarios, electricity and heating prices are significantly impacted, thus disproportionately affecting the poorest households, this effect is clearly offset by the larger impact of transport fuel prices, which causes the policies to have a greater effect on middle-income households (Figure 4).

Moreover, the effect on different Member States also plays a key role in shaping the average national income impacts. As we have seen, in most scenarios, Central and Eastern Member States (CE-MS) are more affected by emission reductions, as they are more dependent on fossil fuels than Western Member States. Therefore, the greater impact on transport prices, combined with the fact that CE-MS are more affected overall, means that in these countries, middle- and higher-income groups are more impacted by the policies. This is because transport fuel expenditure tends to increase more with income in these Member States.

4 Policy Implications

The introduction of ambitious carbon policies in the EU will play a key role in increasing current inequalities between Member States, although the national inequality impacts are not so clear. We have seen that although introducing a general carbon price across the EU to achieve the Fit for 55 emission reduction targets (EU_FF55_free) may be the most cost-efficient option analysed, it may not be the most desirable when inequality and distributional implications are considered. This option would impose higher costs on Member States that are more dependent on fossil fuels, countries that also tend to have a larger share of lower-income households. As a result, the policy would have negative distributional implications at the EU level, affecting low-income households more severely, while having a smaller impact on those in wealthier Member States. However, more country-focused approaches, such as those in the EU_NECP scenario, may reduce the risk of these regressive impacts. This is because they not only consider the overall and average cost of emission reductions at the EU level, but also account for the varying capacities of different Member States to reduce emissions without imposing excessive costs on low-income households. Finally, our results suggest that although emission reductions may have a greater impact on inequality at the EU level, the distributional effects at the national level may be less regressive and will depend on which commodities are most affected in each Member State. Therefore, if emission reductions lead to higher costs for fossil fuels used in transport while keeping electricity prices relatively stable, the policies may be less regressive, affecting middle-income groups more than low-income ones. However, these impacts may vary across Member States.

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IAM COMPACT

Policy Brief

Towards a just transition in the EU:

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In a nutshell

IAM COMPACT supports the assessment of global climate goals, progress, and feasibility space, and the design of the next round of Nationally Determined Contributions (NDCs) and policy planning beyond 2030 for major emitters and non-high-income countries. It uses a diverse ensemble of models, tools, and insights from social and political sciences and operations research, integrating bodies of knowledge to co-create the research process and enhance transparency, robustness, and policy relevance. It explores the role of structural changes in major emitting sectors and of political, behaviour, and social aspects in mitigation, quantifies factors promoting or hindering climate neutrality, and accounts for extreme scenarios, to deliver a range of global and national pathways that are environmentally effective, viable, feasible, and desirable. In doing so, it aligns climate action with broader sustainability goals, while developing technical capacity and promoting ownership in non-high-income countries.

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