IAM COMPACT

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

Responsive science in support of climate policymaking
IAM COMPACT Final Conference, Athens, 29 August 2025

Distributional impacts of EU climate policy

Jon Sampedro, Xaquín García-Muros, Eva Alonso-Epelde, Clàudia Rodés-Bachs, Dirk-Jan Van de Ven (BC3)

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Implementing transformational strategies to address climate change (e.g., “Fit for 55”) will have system-wide effects on production systems and consumption patterns

Beyond their overall efficiency, it is essential to evaluate how these strategies **impact different segments of the population**.

The IPCC and the European Commission underscores that existing (scenario) analysis are limited to "*understand the limited understanding of the within-region distributional impacts of climate policies*"

The dominant tools to global scenario analysis (IAMs) often **fail to consider the socioeconomic and distributional consequences** of the climate transition across different households and social groups

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OBJECTIVE

To develop an **innovative modelling framework** that bridges this gap and to assess how different strategies for implementing the current EU climate policy portfolio **impact various consumer groups within and across Member States**

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The methodological framework combines **GCAM-Europe**, a well-established IAM, and **MEDUSA**, a specialised tool for high-resolution distributional analysis.

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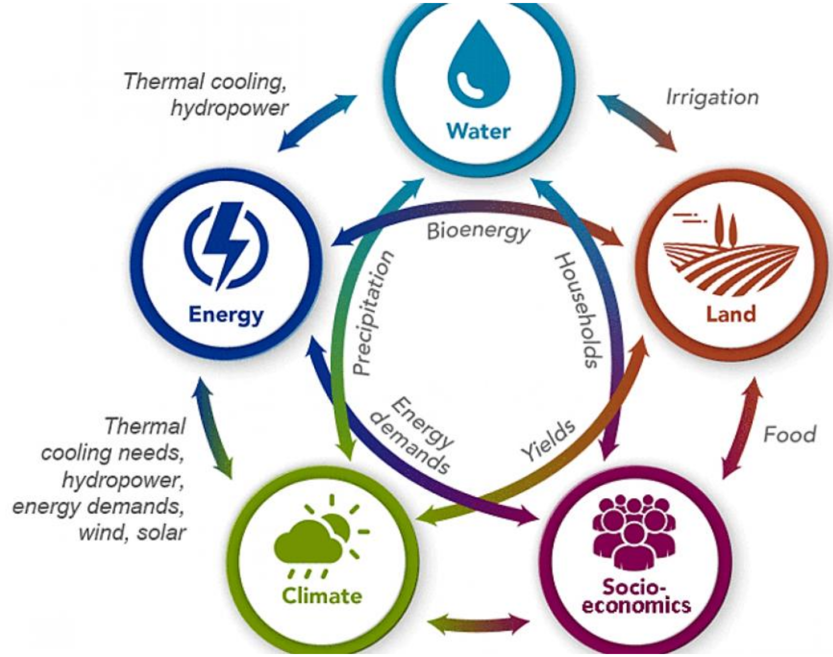
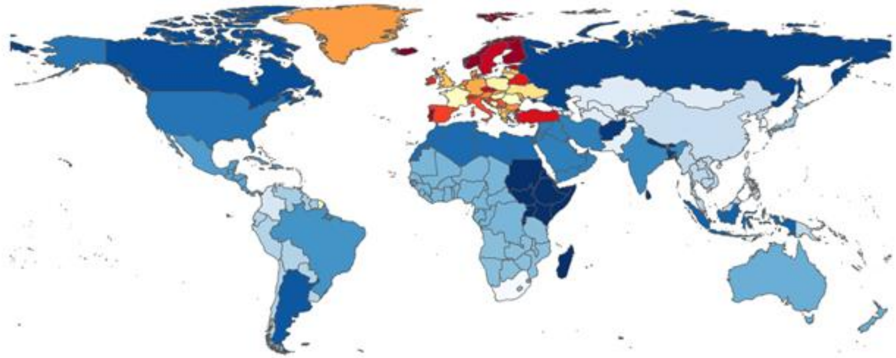
- The Global Change Analysis Model (GCAM) is an open-source community model developed by JGCRI (USA)
- It analyses the **interdependencies between energy, AFOLU, water, emissions, and climate systems** within a single computational platform from now to 2100
- **GCAM-Europe adds detailed regional and sectoral** representation for Europe
- This allows for **analysis of climate and environmental policy effects** within and between European countries, as well as global spillover effects

GCAM / GCAM-EUROPE framework





Adapted from Calvin et al 2019

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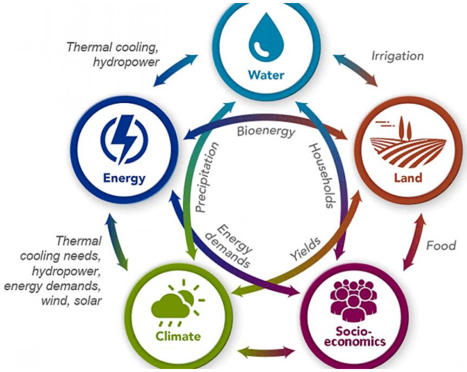
Study design: Methodology - GCAM-Europe

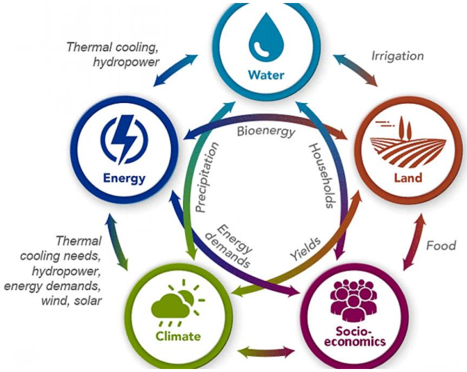


KEY ASSUMPTIONS

- Socieconomics:
  - Population
  - GDP growth
- Costs / efficiencies for energy technologies
- Agricultural/land costs, crop yields, profitability, water/fertilizer requirements and carbon contents
- Water runoff/availability
- Depletable and renewable resource supply curves
- Policies in place:
  - Emission constraints
  - Temperature limits
  - Renewables / efficiency targets
  - Land constraints / afforestation targets

OUTCOMES

- ENERGY SYSTEM:
  - Demand and flows
  - Technology mix by sector
  - Energy prices
- AFOLU:
  - Land allocation
  - Forest and agricultural production by crop
  - Commodity prices
  - Food/Feed balances
- WATER:
  - Water withdrawals/consumption by region for all uses (e.g. irrigation or municipal)
- EMISSIONS:
  - GHG and air pollutant emissions by region/sector/tech (24 species)
- CLIMATE:
  - Radiative forcing / temperature increase
  - CO_2 concentrations
  - +Land/Ocean metrics (HECTOR)
- ECONOMY
  - Policy Costs
  - Carbon prices



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Study design: Methodology - MEDUSA

Data

Household Budget Survey

Inputs

Manual

Other model

Price shocks

Outputs

Vertical and horizontal distributional impacts

Intersectional distributional impacts

Energy and transport poverty indices

MEDUSA - Modelling Equity and DistribUtional impacts for Socioeconomic Analysis

Module 1: Distributional impacts

calc_di() → Calculates distributional impacts and saves results and graphs

ex_shocks() → Saves a CSV file with the predefined format for applying price shocks

available_var_impact() → Returns the variables for distributional analysis

ex_var_intersec() → Saves a CSV file with the format for intersectional variables set up

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Module 2: Energy poverty indices

calc_ep() → Calculates energy poverty indices

Module 3: Transport poverty indices

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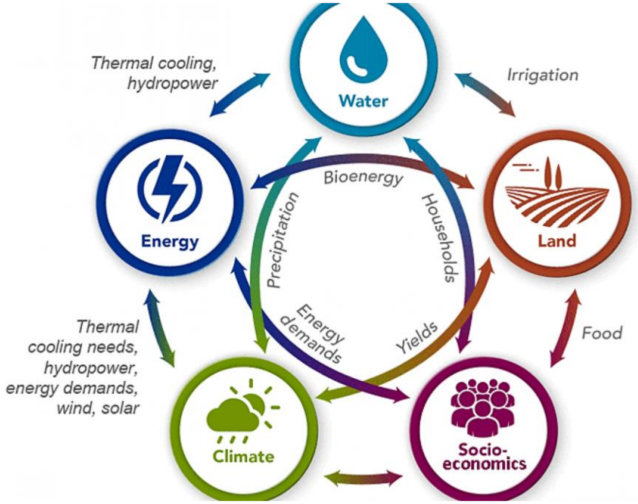

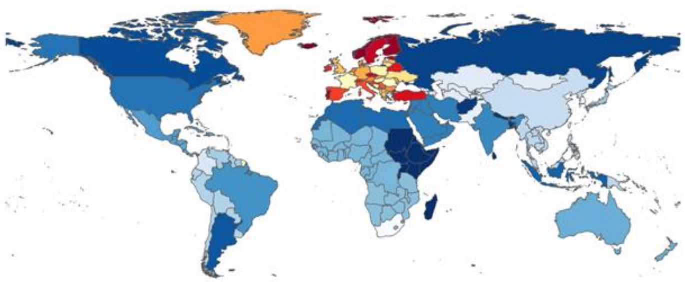

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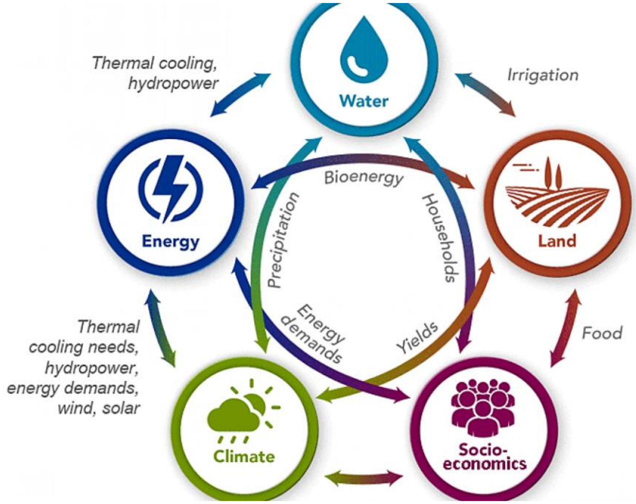

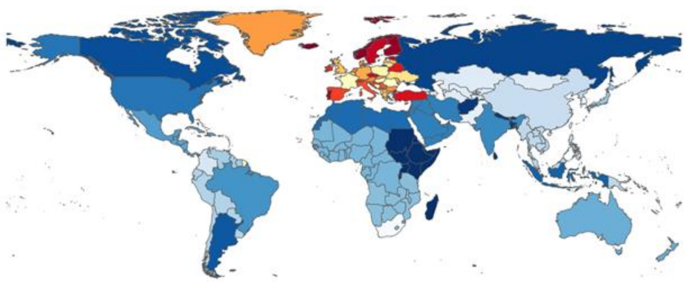

PRICES

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GCAM-EUROPE calculates how (mostly) energy prices change across scenarios. These price changes are fed into MEDUSA to estimate distributional impacts

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Scenario	Description
EU_NOCLIMPOLICY	In this baseline/benchmark scenario, we assume the **absence of any climate policy**
EU_NECP	The scenario includes renewable energy and energy efficiency targets **as defined in country-specific National Energy and Climate Plans** (NECPs). It also includes EU-wide targets for the EU ETS (1 and 2) and vehicle emission standards, as well as country-specific coal phase-out strategies
EU_FF55	This scenario is similar to the EU_NECP scenario, but **instead of applying NECP-specific targets, an EU-wide targets for 2030 in line with FF55*** are applied for renewables and energy efficiency allowing the model to optimally allocate efforts for these targets over the different member states
EU_FF55_FREE	In this scenario, the EU achieves the **same level of CO2 emissions mitigation as in the EU_FF55** scenario. However, EU emissions reductions are accomplished through emissions constraints without considering the current climate policies, **allowing the models to select the cost-optimal pathway** for reducing emissions

** EU-wide targets: renewables 42.5% of final energy; and energy efficiency 11.7% reduction in final energy w.r.t. 2020*

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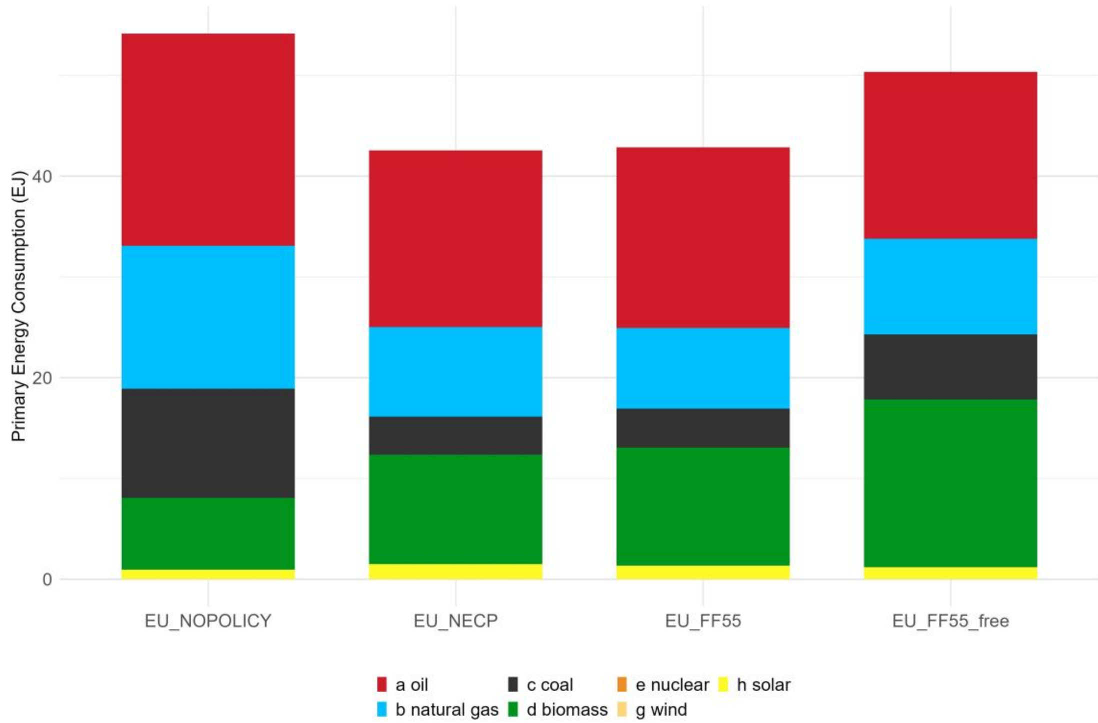
- Reduction in TPE, deeper in scenarios with EE targets
- Shift from fossil fuels to clean energy sources
- A rapid increase in biomass deployment due to its cost-efficiency (larger in the “FREE”)



EU-wide primary energy consumption in 2030, by scenario and fuel (EJ)

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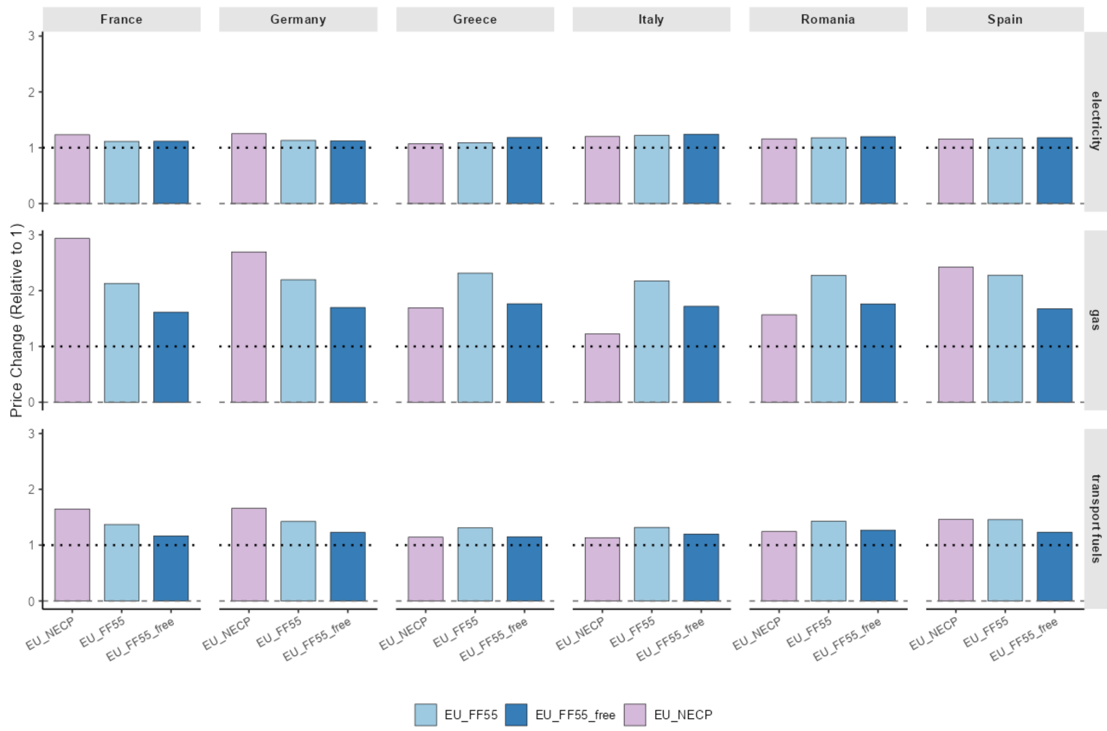
- Changes in energy demand and mix -> **change energy prices**
- Price changes are moderate in the less prescriptive scenarios
- Vary across countries
- Apart from energy prices, there are also some indirect changes in other sectors (e.g., food)



Price changes for electricity, gas and transport fuels for a representative subset of regions in 2030. Indexed changes, compared to the EU_NOPOLICY baseline.

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How do these price changes affect different consumer groups in each country?

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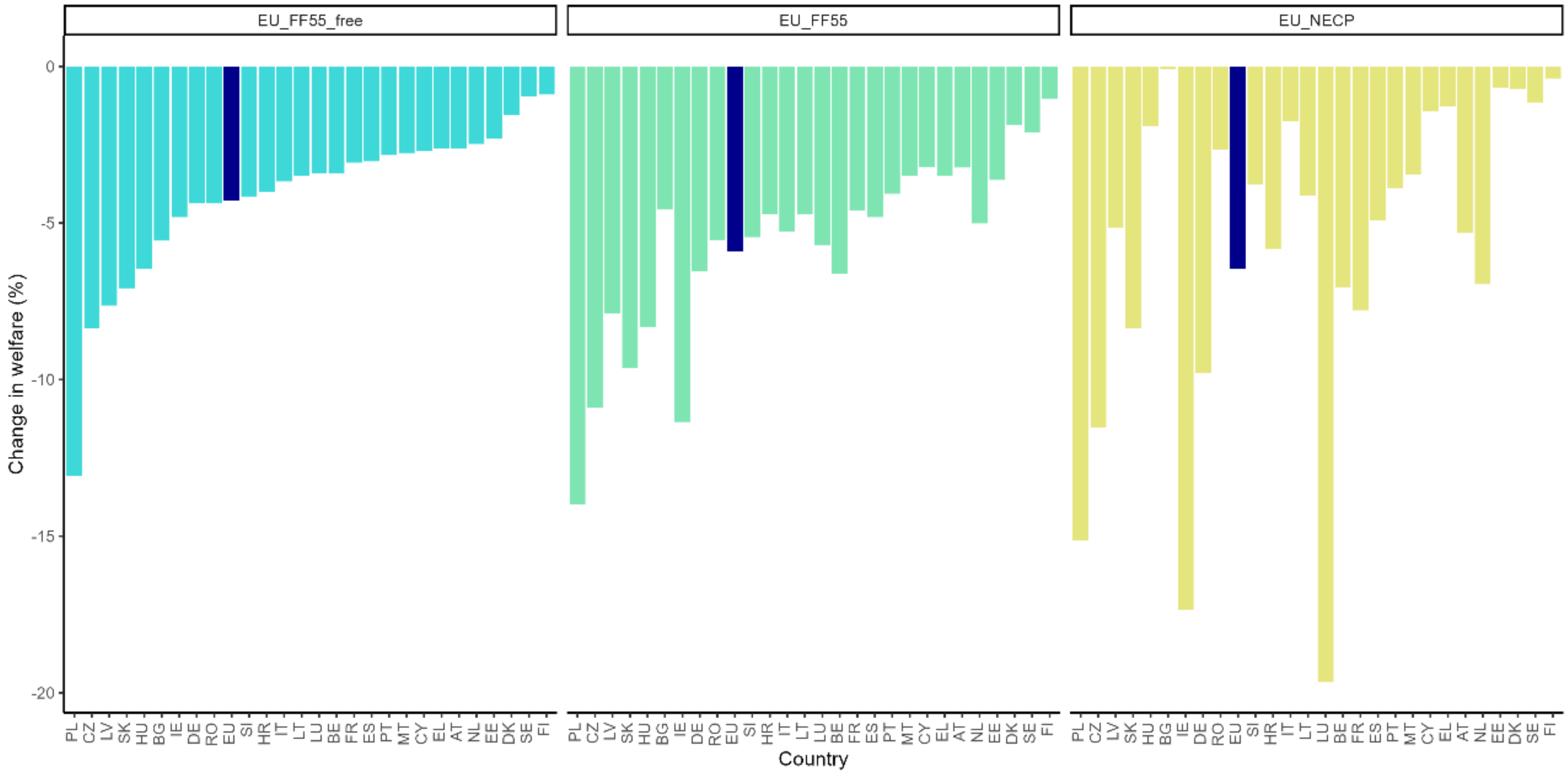
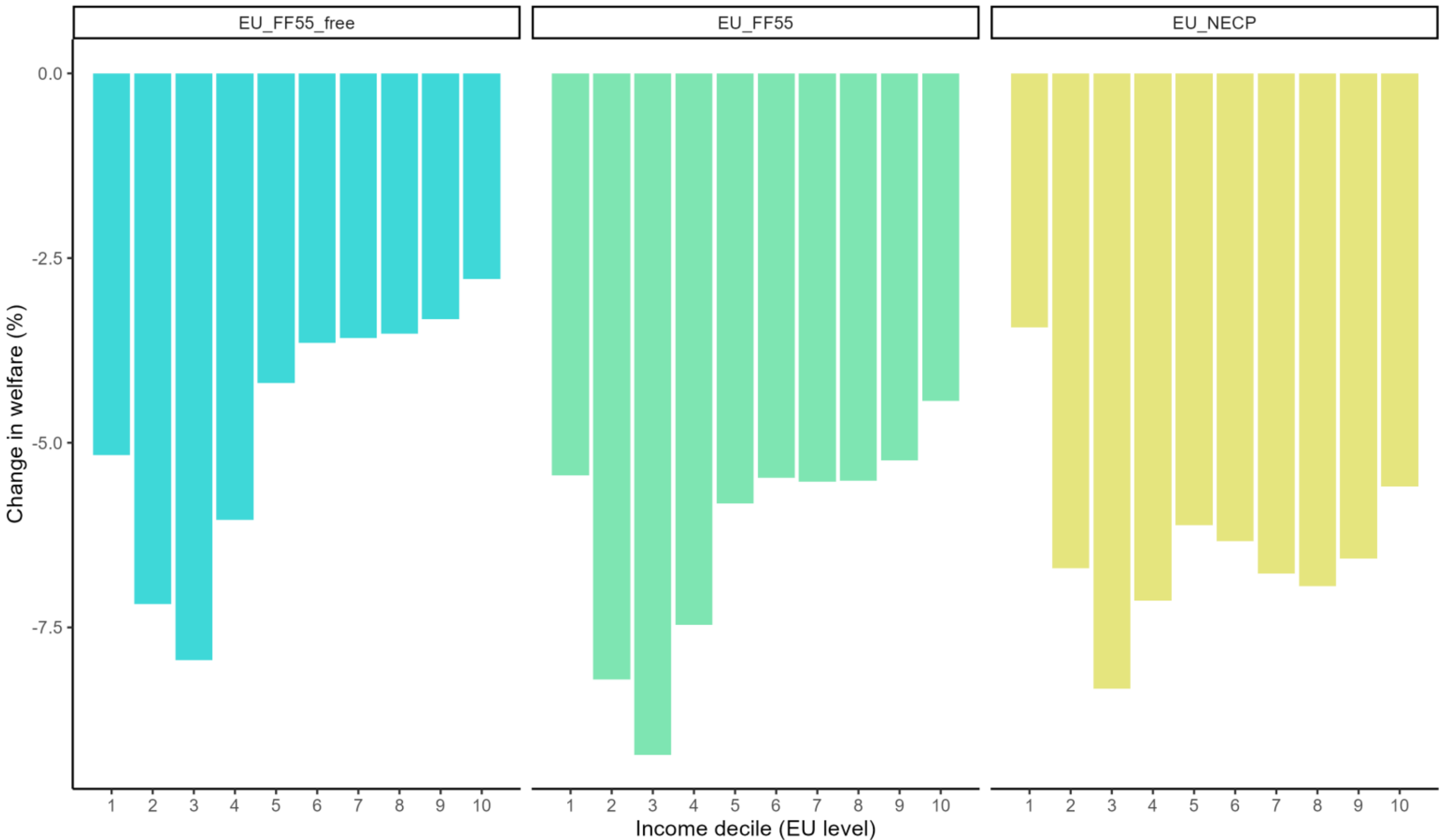
Results: Households Welfare Impacts by Member State

- Larger changes in (energy) prices produce larger welfare impacts ("free" vs others)
- Central and Eastern European Member States (CE-MS; e.g., Poland) are the most affected countries: large share of expenditures in energy + low initial prices
- Lowest impact on Western and Northern Member States (e.g., Finland)



- Households belonging to the middle-low deciles (D2-D4) would be more affected by the decarbonisation cost in the EU -> **regressive** impacts (if no redistribution!)
- CE-MS, which have the largest impacts are associated with lower income groups in the EU income distribution
- EU_NECP scenario is less regressive than the FF55 scenarios at EU level



Results: Vertical Distributional impacts at average national level

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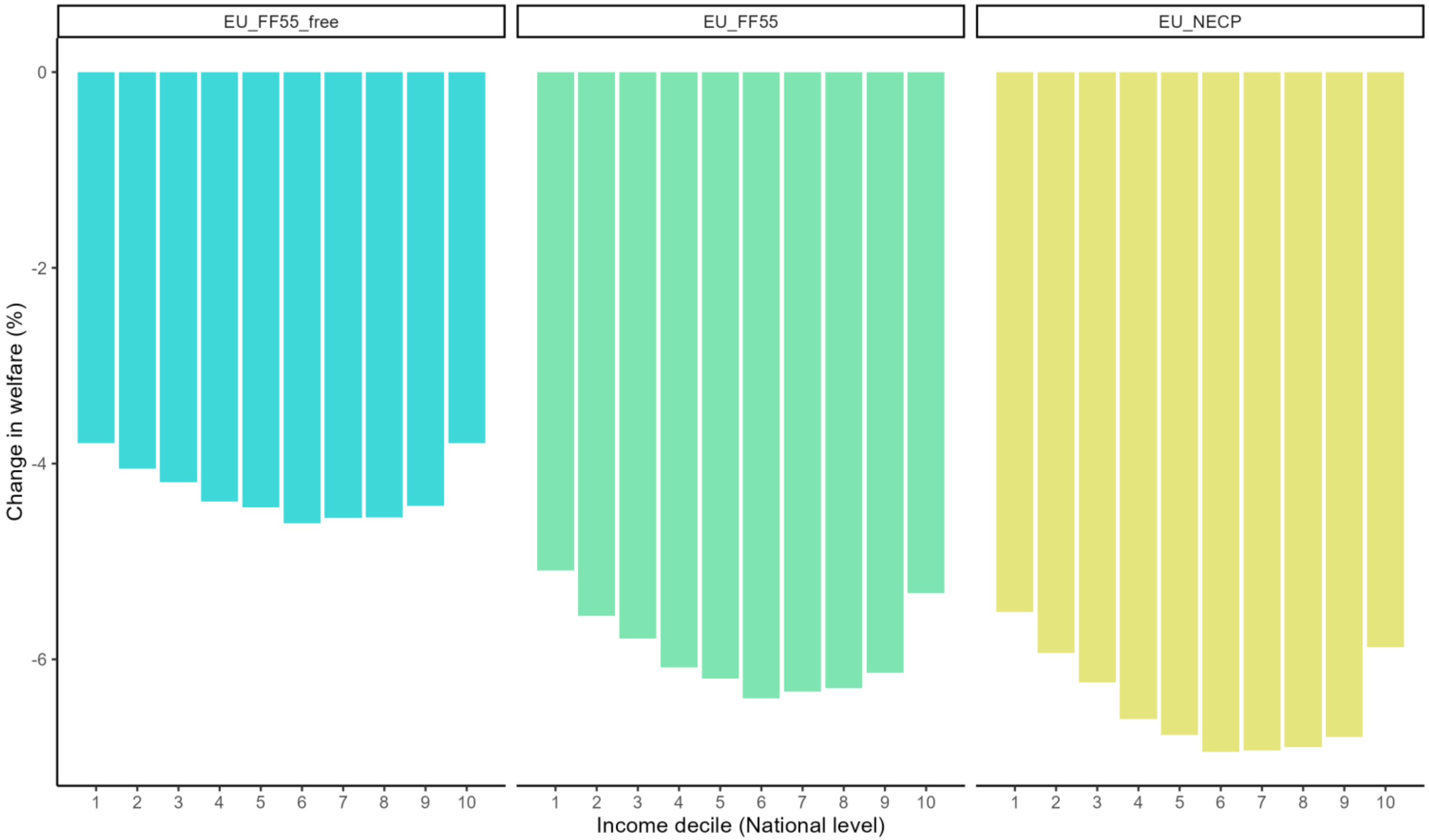
- At the national level the **impacts are less regressive** -> higher impacts in middle-high income groups



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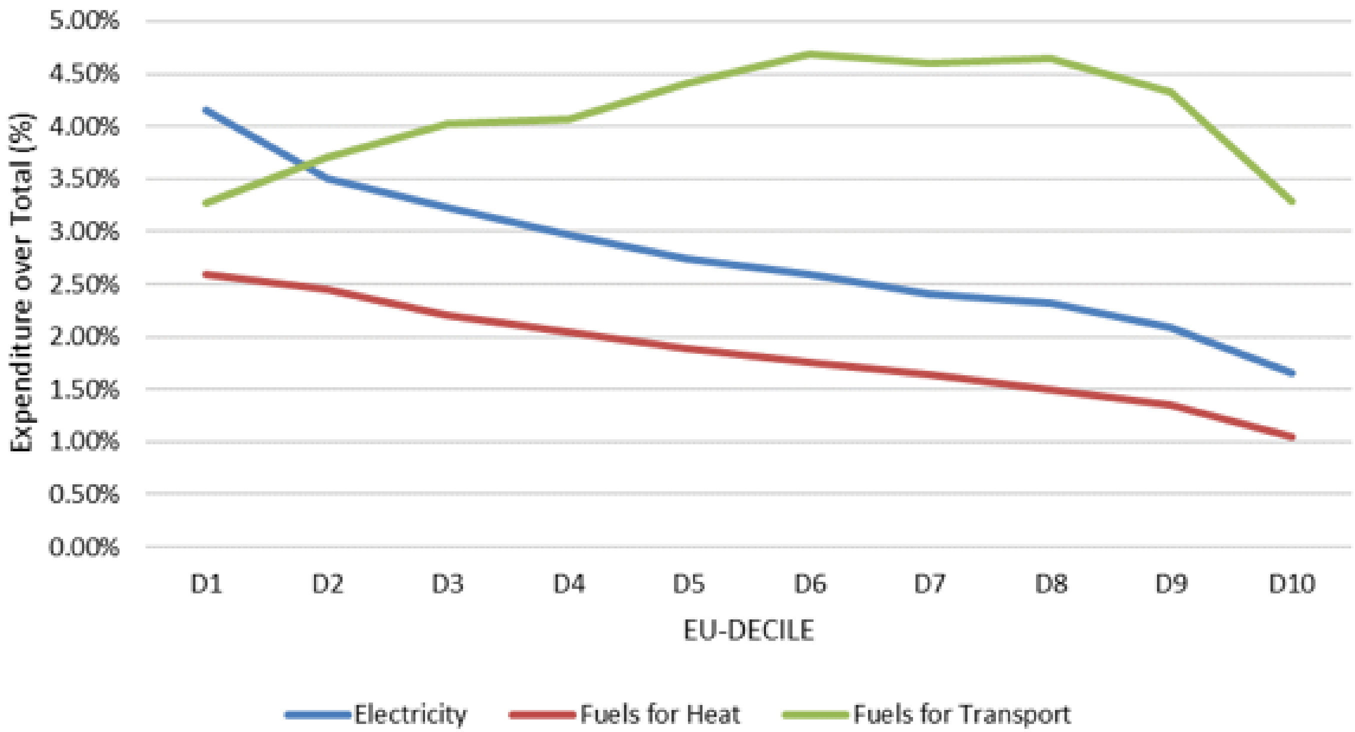
Results: Vertical Distributional impacts at average national level

- At the national level the **impacts are less regressive** -> higher impacts in middle-high income groups
- Most affected prices are **transport fuels**, more largely consumed by these wealthier consumers



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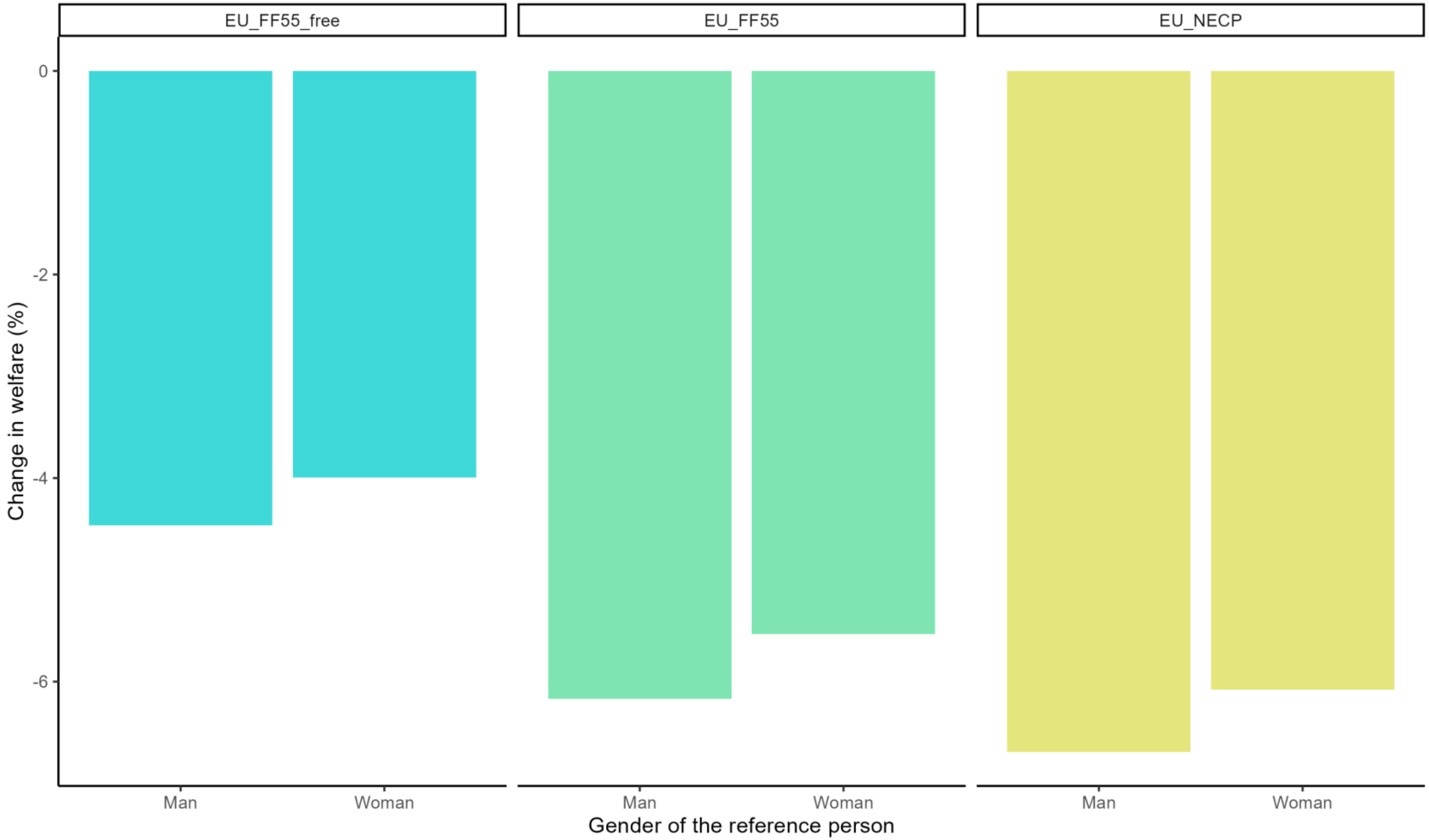
- In all scenarios, **larger welfare losses on man-headed households** -> explained by the large changes in transport fuels (gender bias in car ownership)



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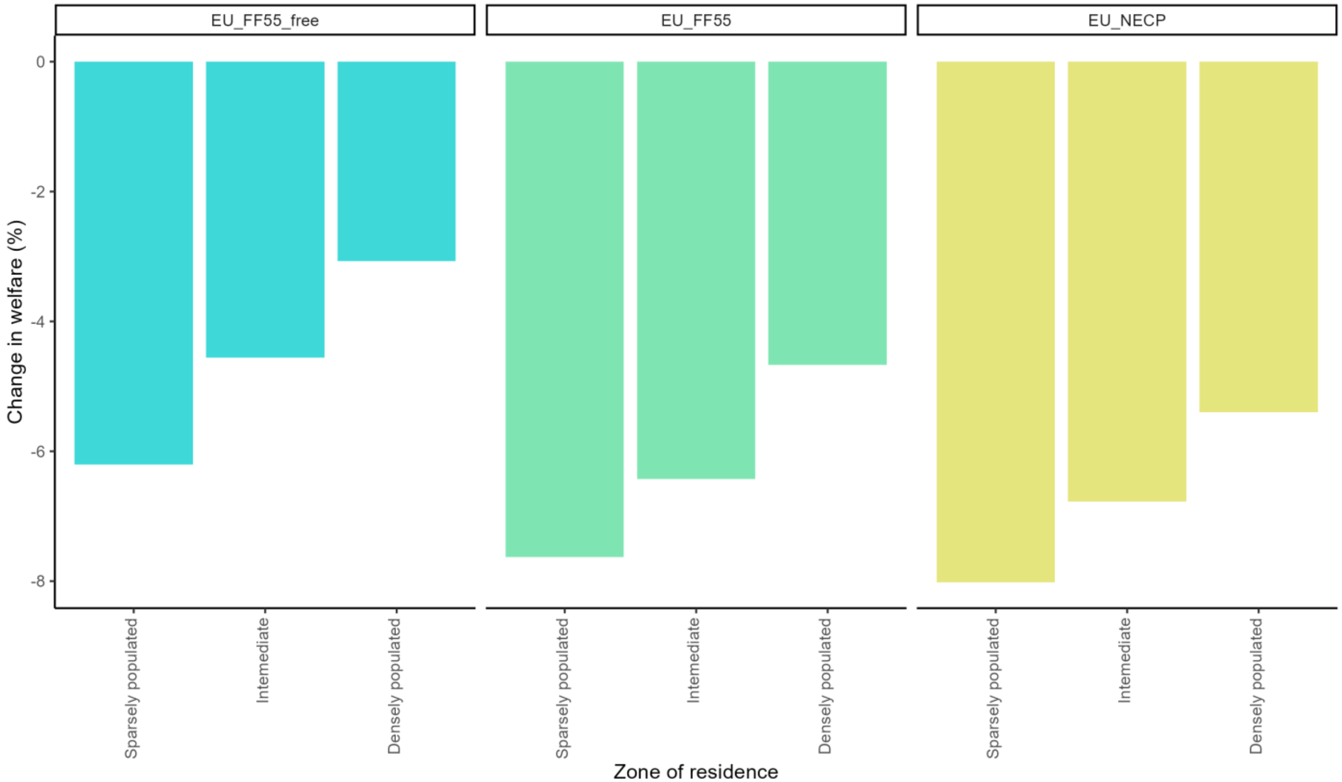
- **Rural households are the most affected** -> larger proportion of their income to mobility + more reliance on private cars (lack of alternatives)



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- **Rural households are the most affected** -> larger proportion of their income to mobility + more reliance on private cars (lack of alternatives)
- Changes by scenario and income distribution; in rural areas, income inequality is higher, and access to and use of private vehicles is more strongly associated with higher-income groups.

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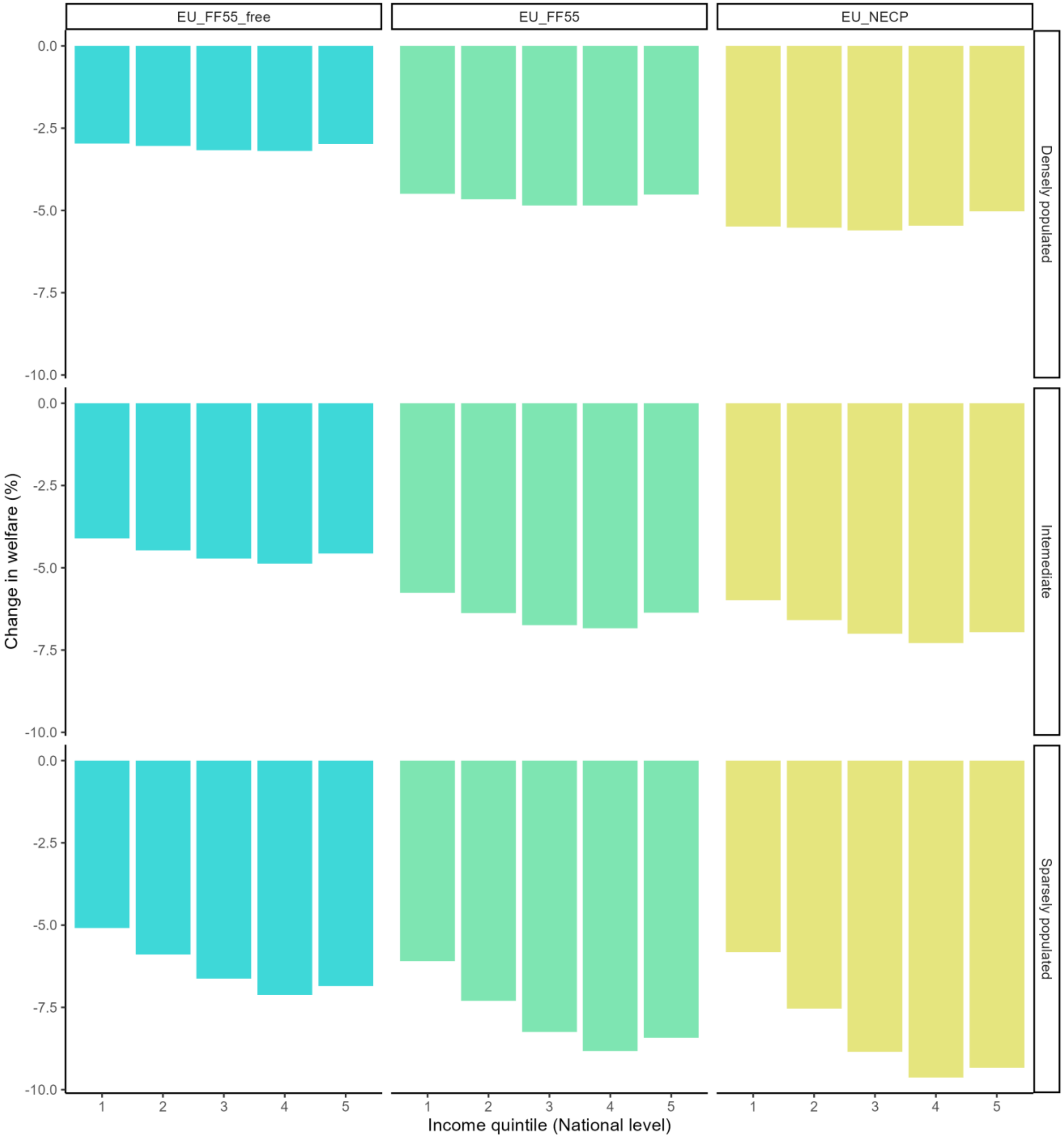
- Rural hc mobility

- Change: higher, a higher-i

income to

inequality is sociated with



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We develop and apply a methodological framework that allows to **identify the households most affected by the energy transition** -> it informs the design of redistribution and compensation mechanisms designed to **mitigate the adverse effects of the energy transition on the most vulnerable households**

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POLICY IMPLICATIONS

- The most cost-efficient option to achieve the emission reduction targets set out in the FF55 package (*EU_FF55_FREE*) places a disproportionate burden on lower-income households of the EU, especially in CE-MS countries.

* More country-focused approaches (e.g., NECP), although less efficient from an economic perspective, demonstrates ability to mitigate **impacts on inequality**

- Higher transport fuel prices disproportionately affect male-headed and rural households, creating **potential barriers to public acceptance** of the policy.

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Thank you!

Authors

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