REEEM

Macroeconomic and distributional impacts of decarbonisation pathways

Policy Brief

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About this report

This policy brief summarizes the insights gained from a thorough scenario analysis of the impacts of different decarbonisation pathways on the economy, with a special focus on EU-28 countries and different income groups. Five scenarios, each representing a specific decarbonisation pathway and implying different policy instruments to reach the respective emission reduction target are estimated with a computable general equilibrium model with a special emphasis on the energy system. Results for macroeconomic variables, such as development of economic growth, household income devlopment and consumption patterns are reported. The economic impacts of pursuing different reduction targets are analysed and main challenges to ensure economic growth are discussed.

Authors

Roland Montenegro (University of Stuttgart), Ulrich Fahl (University of Stuttgart), Claudia Hofer (University of Stuttgart), Viktorija Bobinaitė (Lithuanian Energy Institute), Vidas Lekavičius (Lithuanian Energy Institute), Jurica Brajković (Energy Institute Hrvoje Požar)

REEEM partners

About REEEM

REEEM aims to gain a clear and comprehensive understanding of the system-wide implications of energy strategies in support of transitions to a competitive low-carbon EU energy society. This project is developed to address four main objectives: (1) to develop an integrated assessment framework (2) to define pathways towards a low-carbon society and assess their potential implications (3) to bridge the science-policy gap through a clear communication using decision support tools and (4) to ensure transparency in the process.

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Aiming at a low-carbon energy society

The European Union (EU) wants to transform itself into a competitive low-carbon energy society. Such a transformation has system-wide implications which can be strongly influenced by the transformation strategy. The success of this transformation process depends partly on the mitigation strategies of non-EU countries since the EU is strongly interlinked with them in a global market. However, it also depends on the active participation of different groups of European society. While politicians and industry have always been considered relevant stakeholders for this process, awareness of the importance of households is only rising slowly. However, they must be considered essential actors in the energy transition process.

Transformation strategies must, therefore, be evaluated with respect to their economic effects on different stakeholder groups such as specific industry sectors or households. Hence, this analysis focuses on the macroeconomic effects of carbon pricing, e.g. on industry production and income distribution. Indicators such as Gross Domestic Product (GDP) development, sectoral productivity, level of carbon prices and employment levels are evaluated. The analysis, thus, complements the energy system based research activities within the REEEM project.

Scenarios for a low-carbon EU

The economc analysis compares a Reference scenario with four different transformation pathways. The **Reference Scenario (REF)** can be understood as a Business-as-Usual scenario and comprises assumptions on CO_2 emissions, GDP development, employment development, and emission targets. Assumptions are mainly based on the EU Reference Scenario 2016 [1] and the global Reference Technology Scenario [2]. For the EU regions, a 43% CO_2 emission reduction in 2050 compared to 2005 is presumed while no reduction targets hold for the non-EU regions.

The **Base Pathway (Base)** forms the first transformation pathway and assumes a proactive position towards emissions reduction. The European target is to reduce its emissions by 80% in 2050 compared to 1990. This target is reached through an 83% reduction from Emission Trading System (ETS) sectors and national reduction targets for non-ETS sectors ranging from 50% to 80% and reaching an EU wide reduction outside the ETS of 75%. For non-EU regions, differing reduction ambitions are assumed according to the REEEM Regional Push scenario [3]. While more ambitious regions pursue a reduction consistent with the 2°C target, the remaining regions pursue varying reductions between the –80% EU target and the 2°C target.

As stated in the introduction, households, i.e. individual consumers, are becoming relevant actors in transforming the energy system. Therefore, the **Local Solutions Pathway (LS)**, while holding industry targets for ETS and non-ETS sectors constant, assumes a higher emission reduction for households, transportation, and commercial sectors. This leads to a slightly increased overall emission reduction of 80% compared to 1990, quite similar to the Base Pathway.

The **Paris Agreement Pathway (PA)** is implemented as the most ambitious pathway and specifies emissions' reduction for EU and non-EU regions such that the global temperature rise is limited to 2°C. CO_2 emissions are reduced in accordance with the 2DS scenario [2]. A European cap-and-trade system covering all sectors and economic activities is assumed.

Last, a scenario where the **Paris Agreement Pathway is only followed by the EU (PA_EU)** is defined. For this scenario the high ambitions from the PA pathway are assumed for EU regions only. For the remaining regions the REEEM Regional Push ambitions are implemented.

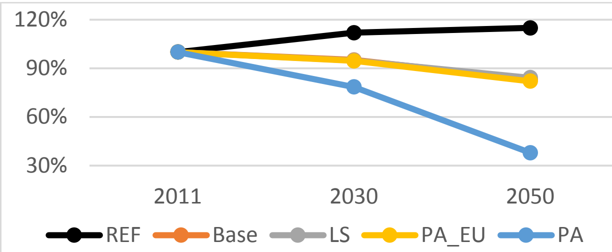

Figure 1: Global CO_2 emission reductions for different scenarios, compared to 2011 (2011 = 100%)

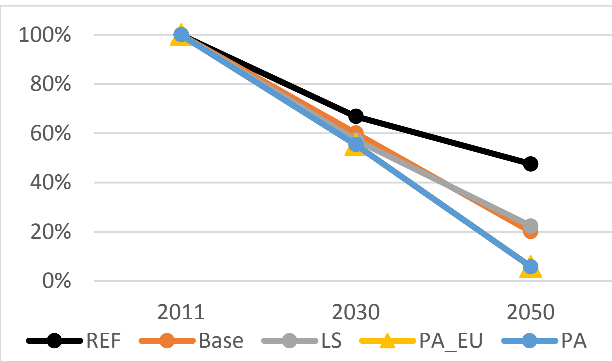

Figure 2: European CO_2 emission reductions for different scenarios compared to 2011 (2011 = 100%)

General equilibrium modelling for impact assessment

The macroeconomic and distributional impacts of the scenarios are assessed using the **Computable General Equilibrium (CGE) model NEWAGE** ("National, European, World Applied General Equilibrium"). NEWAGE describes the economy through production functions and reveals interdependencies between different sectors as well as interdependencies among different economies. Since macroeconomic effects are to be analysed, the use of a global CGE model which allows for cross-sector and cross-country effects is advisable.

NEWAGE represents the world economies through **18 regions**, 9 of them within Europe. **18 different production sectors** are depicted, representing 5 energy production sectors and 6 energy-intensive industry sectors, among others. The electricity sector is disaggregated into **18 generation technologies** in order to capture the electricity system in detail. In addition, households are represented in the form of **five different income groups**, representing income quintiles and each facing its own consumption function. Furthermore, the **government** is also represented in order to account for redistribution mechanisms through taxes.

The model is limited mainly by two factors: First, the exogenous representation of technology development through an autonomous energy efficiency index which is assumed to be constant for all scenarios and therefore reduces the flexibility of the model to react to emission constraints. Second, the inability to internalize positive externalities from environmental policies meaning that benefits such as improved air quality or avoidance of costs resulting from extreme weather conditions are currently not included in the cost evaluation. **These limitations make NEWAGE overestimate the costs of emissions' reduction**.

Despite its limitations and assumptions, NEWAGE allows for a deeper comprehension of the net effects and impacts of energy system transformation strategies on European society[1].

[1] For a more detailed description of NEWAGE, its architecture and relevant modelling assumptions see [3].

Macroeconomic impacts on the economy

The described transformation pathways were analysed with **special focus on macroeconomic indicators**, such as GDP and Gross Value Added (GVA). While GDP is commonly used as an indicator of economic growth, GVA can be interpreted as an indicator of competitiveness[2].

In terms of GDP, the **European economy continues to grow** in all scenarios. Although economic growth is reduced when stronger emission reduction ambitions prevail, GDP of the EU-28 increases by at least 55 percentage points in 2050 compared to 2011 (see Figure 3). A similar picture holds for the non-EU countries, although GDP growth is generally higher and only the Paris Agreement scenario provokes a reduction in economic growth.

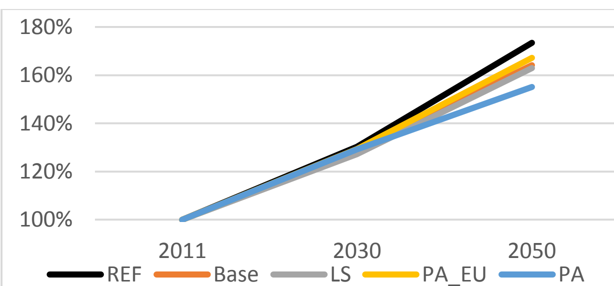

Figure 3: GDP development of the EU-28 relative to 2011 (2011 = 100%)

When evaluating the pathways in terms of CO_2 productivity, i.e. GDP per ton of emissions (see Figure 4), the **PA_EU scenario seems to be the most efficient one for the EU** reaching the highest decrease in European CO_2 emissions while allowing the second highest growth in European GDP.

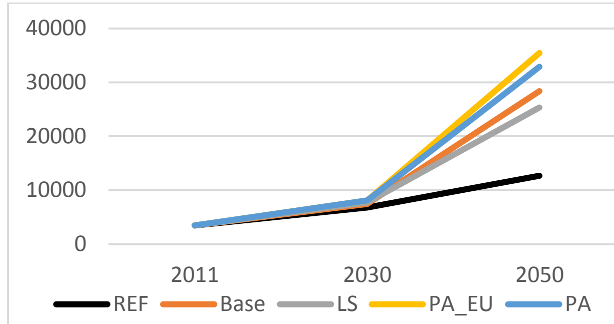

Figure 4: CO_2 productivity of the EU-28 for different scenarios

However, this statement must be taken with caution especially since the scenarios "Base", "LS" and "PA_EU" yield very similar results in terms of GDP growth and emissions reduction. Besides, the **scenario assumptions and model limitations described earlier might influence the ranking of the scenarios**. If, for example, innovation and positive externalities from environmental policies were accounted for endogenously, it is very likely that the PA scenario will improve in terms of efficiency. Therefore, the non-EU regions should still be encouraged to also reduce their emissions.

Although for the EU the PA_EU scenario seems most efficient, it **affects the single countries / country groups differently**. While for Germany (DEU), Italy (ITA), France (FRA), the United Kingdom (UKI), the Benelux states (BNL: Belgium, Netherlands, Luxembourg) and remaining Northern European countries (EUN: Ireland, Denmark, Estonia, Finland, Latvia, Lithuania, Sweden) it is the scenario with the second highest GDP growth this does not hold for Poland (POL), Spain and Portugal (ESP) and remaining Southern and Central European countries (EUS: Austria, Cyprus, Czech Republic, Greece, Hungary, Malta, Slovakia, Slovenia, Bulgaria, Croatia and Romania). For these regions, the Base pathway would

[2] For a more detailed description of modeling results, scenario comparisons and indicator interdependencies see [3].

allow for higher GDP growth due to lower CO_2 reduction targets (see Figure 5).

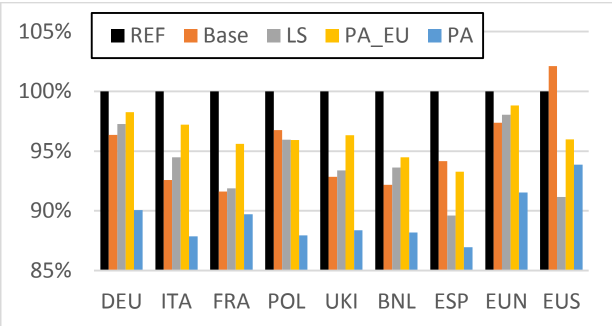

Figure 5: GDP in 2050 for different EU regions and scenarios (REF = 100%)

In order to extend the analysis to the sectoral level, the GVA developments were also examined. The **GVA indicates whether a certain sector gains from the path-specific CO_2 reduction policies**. Although one may assume that energy-intensive industries will generally suffer from stronger CO_2 reduction targets, the model results suggest a more complex and heterogeneous picture.

Similar to GDP developments, **GVA increases for all sectors and all scenarios**. However, while in the medium term (until 2030) the differences between pathways remain rather small (max. +/- 5.5 %, compared to REF) in the long term (until 2050) these deviations increase to a maximum of +/- 23 %, showing that emission reduction policies and, hence, carbon scarcity rather affect the economy in the long term.

Furthermore, when comparing the decarbonisation pathways with the reference pathway it becomes evident that, **depending on the scenario, for some sectors, the increases in GVA will shrink while for other sectors they will grow**. Interestingly, the Iron and Steel (IRS) and the Non-Metallic Minerals (NMM) sectors improve their GVA growth compared to the REF scenario in all other scenarios. For some sectors, namely Chemicals (CHM), Non-Ferrous Metals (NFM), Paper, Pulp and Print (PPP) and Food and Tobacco (FOT), the effect is ambigous, showing gains compared to REF for some scenarios and losses compared to REF for others. Four sectors, namely Vehicles (VEH), Machinery (MAC), Rest of Industry (ROI) and Services (SER) apparently suffer from any of the decarbonisation pathways compared to REF (see Figure 6).

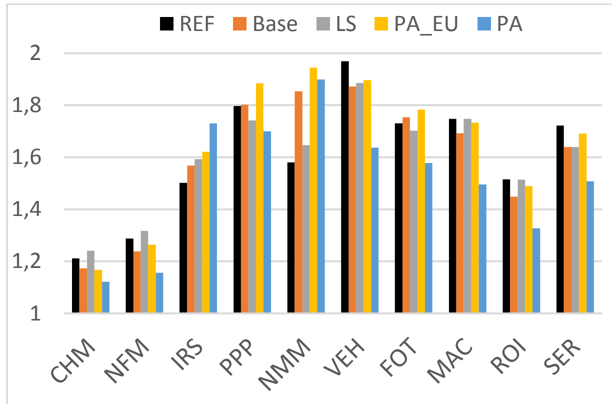

Figure 6: GVA for the EU-28 in 2050 for different sectors and scenarios, compared to 2011 (2011 = 1)

Distributional impacts on different household groups

Furthermore, the **effects on different income groups** with regard to income and consumption patterns as well as tax burden were identified. These are summarized in the following in order to allow for a thorough analysis of impacts on a more disaggregated household level. Results are presented as average numbers for all EU regions.

Generally, **households having higher income continuously spend a lower share of their total consumption expenses on energy goods**, regardless of the scenario (see Figure 7). Consequently, lower income groups will suffer more from increases in energy goods prices.

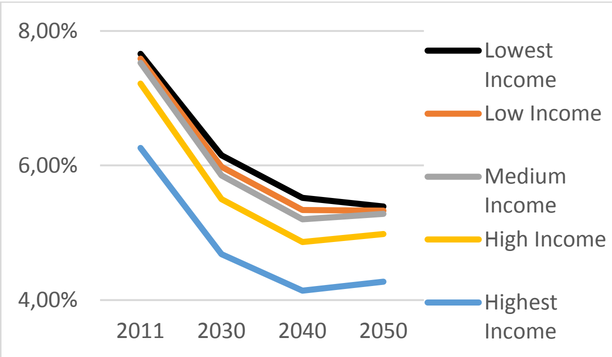

Figure 7: Share of energy goods in total consumption for different income groups (averaged over all scenarios, standard deviation always smaller then 0.006)

Moreover, similar to the GDP developments, income increases for all household groups over time. However, precise evolution differs between income groups. While between 2011 and 2040 the higher income groups also experience a higher income growth, this pattern changes for 2050, where the lower income groups experience higher increases in income compared to the higher income groups, except for the Base pathway. This development is caused by the increasing price of CO_2 certificates posed more strongly on higher income groups, which, through the redistribution of taxes revenues, increases the payments from government to households and benefits the lowest income groups because a higher share of their income is provided from government's payments. Hence, **carbon taxation can be utilized as an instrument to prevent the growth of income inequality** (see Figure 8).

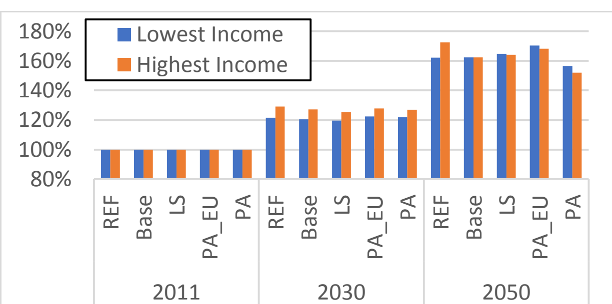

Figure 8: Gross income development in the EU-28 for the lowest and highest income groups and different scenarios (2011 = 100%)

The previous graph indicates that **different carbon taxation mechanisms** (as represented by the different scenarios) **influence the household burden**. It can be shown that, although the share of income spend for the carbon tax is always higher for lower income households and generally also increases less strongly for higher income groups the gap between higher and lower income groups can be decreased through a better-balanced carbon cap and trade system (see Figure 9). This gap, while being biggest in the Base pathway (a difference of 1 percentage point), can be reduced to 0.6 percentage points in the PA_EU pathway.

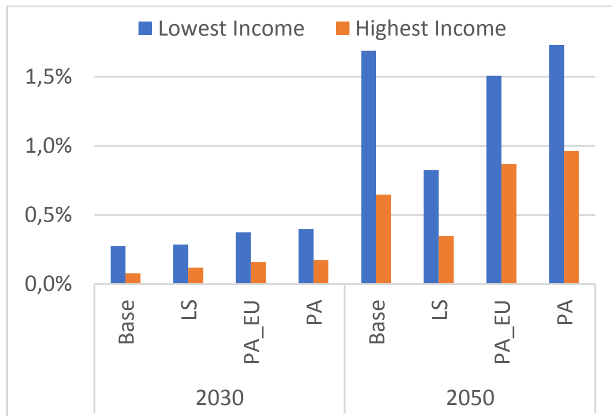

Figure 9: Development of the average carbon tax burden in the EU-28 as a share of gross income for the lowest and highest income groups and different scenarios

Conclusion

From the detailed analysis of macroeconomic and distributional impacts of different decarbonisation pathways the following conclusions can be drawn[3]:

1. The European economy is capable of decarbonisation without considerable economic losses, regardless of the scenario.
2. Within the analysed scenario framework, the PA_EU scenario seems the most efficient one, leading to the highest decrease in emissions while allowing for the second highest GDP growth. However, the remaining world regions should still be encouraged to follow ambitious emission reduction targets because of the large positive external effects expected but not represented within the applied model.
3. The decarbonisation pathways affect different countries differently. Countries more negatively affected might, therefore, need support in order to fulfil their reduction targets.
4. Households having lower income continuously spend a higher share of their total consumption expenses on energy goods and are therefore more strongly affected by increases in energy goods prices.
5. Carbon taxation can be utilized as an instrument to prevent the growth of income inequality.
6. Different carbon taxation mechanisms influence the household burden. Also with regard to household effects, the PA_EU scenario is preferable to the other scenarios.

[3] Since this policy brief is only a summary of insights and effects, the respective Focus Report [3] is recommended for more details.

References

[1] P. Capros, d. V. Alessia, N. Tasios, P. Siskos, M. Kannaviou, A. Petropulos, S. Evangelopoulou, L. Höglund Isaksson and S. Frank, "EU Reference Scenario 2016 - Energy, transport and GHG emissions Trends to 2050," 2016.

[2] International Energy Agency, "Energy Technology Perspectives 2017," International Energy Agency, Paris, France, 2017.

[3] R. Montenegro, U. Fahl, C. Hofer, V. Bobinaitè, V. Lekavičius and J. Brajković, "Focus Report on economic impacts, REEEM," 2019.