# A comprehensive socio-economic assessment of the increased 2030 EU climate target

Matthias Weitzel[1], Toon Vandyck[1], Luis Rey[1], Marie Tamba[1], Umed Temursho[2], Krzysztof Wojtowicz[1]

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Abstract:

With the European Green Deal, the European Commission wants to bring the European Union on track towards reaching climate neutrality by 2050. Recently, it proposed a new, more stringent target for 2030 – a reduction of greenhouse gases to 55% below 1990 levels. To evaluate the implications of the more ambitious target, a comprehensive impact assessment analysed various aspects, including socio-economic consequences. Here, we present the modelling framework used to derive macro-economic and sectoral impacts, closely aligning the economic modelling to energy system modelling. The modelling toolbox further included tools to decompose aggregate results of a computable general equilibrium model; in particular, we downscale labour market outcomes to skill and occupation levels and household responses to distributional impacts.

[1] European Commission, Joint Research Centre (JRC), Seville, Spain

[2] IOpedia, Seville, Spain; Institute of Public Policy and Administration, Graduate School of Development, University of Central Asia, Bishkek, Kyrgyz Republic

# 1. Introduction

In 2019, the European Commission announced the "European Green Deal", with a core target of reaching climate neutrality by 2050.[1] To make the near term emission pathway compatible with this long-term goal, the European Commission thoroughly analysed the economic, social and environmental implications of strengthening the existing 2030 climate target (European Commission, 2020a). In late 2020, the European Council backed the proposal of the European Commission to reduce emissions in 2030 by 55% relative to 1990, also becoming Europe's updated National Determined Contribution (NDC) under the Paris Agreement.[2]

For initiatives with significant economic, social or environmental consequences, the European Commission has to carry out and publish impact assessments. An in-depth analysis on the European Union's (EU) long-term strategy "A clean planet for all" was carried out to support the EU's net zero target for 2050 (European Commission, 2018; Weitzel et al., 2019b). As a consequence of this new long term target, the European Commission also revisited the interim target for 2030. The original target of a 40% reduction of greenhouse gas emissions below 1990 levels had been set up in 2014, aiming for a long term target of reducing emissions by 80-95% in 2050. Further, current policy pathways indicated an overachievement of the 2030 target, particularly due to decarbonisation dynamics in the power sector and lower coal use (European Commission, 2020a). This allowed for a "ratcheting up" of the EU NDC, in line with the architecture set up in the Paris Agreement, to revisit the NDC targets periodically. The adjustment of the 2030 target required an in-depth impact assessment, including an analysis of socio-economic consequences arising from an increased EU climate ambition.

In the impact assessment (European Commission, 2020a), a modelling toolbox was employed to assess consequences for achieving different level of the potential emission reductions[3] and investigate different policy pathways to reach the increased reduction targets. For the latter, policy pathways were developed that varied in their reliance on regulatory measures such as standards or carbon pricing to reach the targets. In this paper, we focus on the socio-economic impacts by drawing on results from the computable general equilibrium (CGE) model JRC-GEM-E3. The model is embedded in a wider modelling toolbox, taking inputs from other models, in particular detailed energy models. Key outputs are changes in variables that describe the macro economy, such as GDP and its components or aggregate employment, and changes in sectoral activity. As the JRC-GEM-E3 model uses the representative agent concept, some of its output is downscaled with the help of additional data sources in order to assess distributional implications and labour market consequences with are of key concern to achieve a "just transition".

The remainder of the paper is structured as follows: section 2 describes the modelling toolbox, especially the JRC-GEM-E3 model and extensions to downscale its results, and presents the scenarios for analysis, and section 3 describes results for the macro economy, sectoral impacts, labour market outcomes and distributional effects for different income groups.

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[1] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[2] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/European%20Union%20First/EU_NDC_Submission_December%202020.pdf

[3] The impact assessment contains analysis for potential reduction targets of 50% and 55%. In this paper, we focus on the scenarios developed for the 55% reduction option.

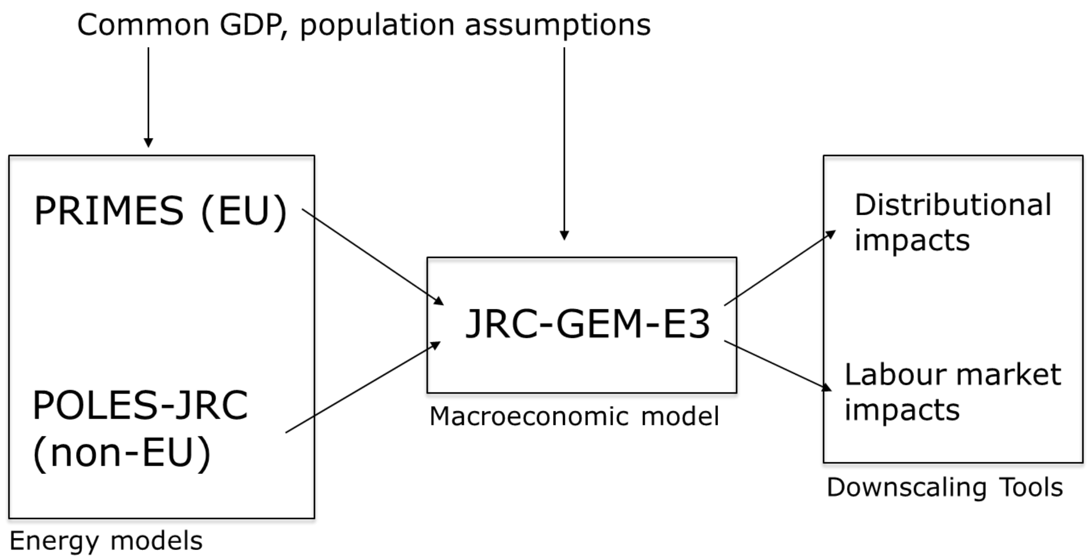
## 2. A toolbox approach for a comprehensive socioeconomic analysis

The European Commission assessed the consequences of the increased climate ambition with a number of models and quantitative tools. The use of this toolbox allows assessing various aspects of the transition to a more carbon friendly economy in a coherent manner: individual tools can shed light on a certain aspects of interest where the respective models have their strengths, while the close integration fosters consistency of the entire analysis (Weitzel et al., 2019b).

In this paper, we focus predominantly on the economic analysis carried out with the computable general equilibrium (CGE) model JRC-GEM-E3. The model covers the entire economy, in particular interactions between different sectors and regions. Within the modelling toolbox (Figure 1 presents the part of the overall modelling framework relevant for this paper), the model received inputs from energy system models PRIMES (E3MLab, 2018) and POLES-JRC (Després et al., 2018). Energy and CGE model are calibrated to the same exogenous macro trends for GDP and population; in addition, the JRC-GEM-E3 model is calibrated to the energy balances of the energy models. Likewise, in the scenario running, some parameters from the energy models are taken as inputs into the economic model.

We further complement the CGE model with two downscaling tools, which decompose two aggregate results into results that have higher granularity and thus can provide additional, policy-relevant results. First, we decompose the labour market implications of the CGE model into changes in demand for different skills and occupations under the transition. This is done by complementing the CGE results with additional projections on sectoral skill and occupation profiles in economic sectors. Second, we decompose the representative household results of the CGE model into results of different income groups, building on household survey data. This highlights the distributional consequences of climate policy scenario as well as role of potential transfers of carbon revenue to households.

**Figure 1: Schematic overview of analytical framework.**




### 2.1. JRC-GEM-E3 and consistency with energy models

A common starting point is important for delivering consistent results. Therefore, models involved in the exercise were calibrated to a common baseline. Here, the JRC-GEM-E3 model was calibrated to the energy balances and emissions of the PRIMES (for the EU) and POLES (for non-EU regions) models (Wojtowicz et al., 2019). Further, European non-$CO_2$ emissions were taken from the GAINS model, which in turn was calibrated to activity levels consistent with PRIMES. A soft link between models was also informing the scenarios, e.g. by incorporating changes of the electricity generation mix, the share of electric vehicles or the switch for cleaner residential energy use from the energy system models into the CGE model in the scenarios.

### *2.1.1. A brief overview of the JRC-GEM-E3 model*

The JRC-GEM-E3 model is a global, multi-region, multi-sector, dynamic-recursive CGE model designed to analyse energy, climate and environmental policies (Capros et al., 2013). The model version used in this paper is based on cost-minimizing firms disaggregated into 31 sectors, including crude oil, refined oil, gas, coal and electricity generation, the latter further disaggregated into 8 generation technologies. The generation technologies are modelled using a Leontief production function, production in other sectors are described by nested constant elasticity of substitution (CES) production functions. International trade flows are captured by an Armington specification and intermediate input and supply chain linkages between sectors are included based on the GTAP10 data, described in Aguiar et al. (2019).

Production factors labour, capital and resources are assumed to be mobile between sectors, but not between regions. The model has the option to reflect involuntary unemployment through a wage curve representation (Capros et al., 2013). Baseline labour supply and unemployment rates are calibrated to the 2021 Ageing Report (European Commission, 2020b) for the EU and to ILO (2017) for non-EU regions. Investments are determined by the rental price of capital and the cost of the (sector-specific) investment good. Holding the real interest rate fixed allows a variation of the balance of payments.

A consumption matrix (Cai and Vandyck, 2020) translates final consumption of production sectors into consumption by purpose. Household's purchases of the different consumption categories are governed by a Stone-Geary utility function. Important consumption categories for this analysis include expenditures for housing, expenditures for household appliances, expenditures for general household energy use, as well transportation related expenditures which are divided into purchase of transport equipment like vehicles, operation of transport equipment including energy needed to run vehicles (as well as other expenditures on insurance and maintenance) and public transport. Notably, the expenditures for transport and other energy, mainly for heating, are accounted for in separate consumption categories. Purchases of durables (vehicles and appliances) are determined by the price of the durable goods and the price of the cost of operation, while purchases linked to the operation of these durables (operation of vehicles and household energy, respectively) are determined by the stock of durables and the cost of operation (Capros et al., 2013).

All GHGs other than $CO_2$ from land use (change) and forestry are covered. Besides $CO_2$ emitted from fossil fuel combustion and industrial processes, all non-$CO_2$ Kyoto GHGs are modelled explicitly in JRC-GEM-E3: methane ($CH_4$), nitrous oxide ($N_2O$), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and sulphur hexafluoride ($SF_6$). Emission data for non-$CO_2$ emissions comes from GAINS model (IIASA, 2016) for EU countries and from POLES-JRC (Després, 2018) for non-EU regions. Abatement cost information for non-$CO_2$ abatement costs likewise comes from GAINS for EU countries and from POLES-JRC for non-EU regions and from GLOBIOM for non-EU agricultural sectors

(Havlík et al., 2014), and abatement is implemented by preserving various bottom up technologies in JRC-GEM-E3 (Weitzel et al., 2019a).

### *2.1.2. Baseline harmonization with energy models*

To be consistent with the complementary assessment of the energy system, the JRC-GEM-E3 model was calibrated to reflect the same socio-economic trends as boundary conditions (GDP, population) as the energy models used for the assessment (Figure 1). In addition, JRC-GEM-E3 was calibrated to reflect the energy balances of the energy models PRIMES (for the EU) and POLES-JRC (for non-EU regions).

The calibration method is described in more detail in Wojtowicz et al. (2019). In short, a time series of input output tables is calibrated forward, taking into account a number of constraints representing overall economic activity, and energy use in particular sectors with the help of a multi-regional generalized RAS method (Temursho et al., 2020a). This ensures that energy use and hence emissions in the main economic sectors of interest very closely resemble those in the energy models.

### *2.1.3. Alignment in policy scenarios*

Climate policies aimed at reducing emissions are implemented in JRC-GEM-E3 in the following three ways: explicit carbon pricing under an EU emission trading scheme (ETS), endogenous modelling of energy efficiency policies, and an exogenous representation of policy outcomes based on results from the detailed energy system model PRIMES (and POLES-JRC for non-EU regions).

The basic reasoning for replacing endogenous model responses for some sectors with exogenous inputs is that the underlying processes might be better represented in a more detailed model than in a CGE model. Using information on adjusting input shares in production functions constitutes a one-way soft-link (Delzeit et al., 2020), as no information is fed back to the PRIMES model. Substitution of inputs towards cleaner fuel within the energy bundle and out of the energy bundle towards value added and materials come at a cost in a CGE model. We therefore also include cost information when we use exogenous adjustment of energy inputs in JRC-GEM-E3 for a consistent assessment. There are three main areas where we make use of this approach: electricity generation, commercial transport sectors, and household energy use (transport and other use including heating).

For electricity generation, we replace the JRC-GEM-E3 production function[4] that aggregates electricity from the different generation technologies into a single supply sector with a Leontief function and adjust its share parameters based on electricity generation as modelled in PRIMES. The energy system model has a much more detailed power module, taking into account intermittency of renewables, storage and grid constraints, joint heat and power generation etc. In addition, we adjust changes in the aggregate electricity sector's output price to price changes of PRIMES when the models disagree in their price response (e.g. when moving to more expensive generation technologies or maintaining backup capacity that would not be accounted for in the CGE model) through a total factor productivity shock on electricity generation. We further adjust the (myopic) investment expectations based on the generation mix in the next time period such that a higher required capital demand from renewable electricity generation does not come at a surprise and leads to strong increases in capital prices in the rest of the economy. On the other hand, as the

[4] This can either be a CES function, or a Weibull function, see Capros et al. (2013).

climate policy scenarios phase out (fossil) power plants that would have run longer in the baseline, capital that is released from these generation technologies is eliminated to limit capital mobility. This ensures that investment activity needed for the transition of the power sector has to come from additional investment rather than capital mobility between sectors. In practical terms, this approach means we are importing the bottom-up response of the power sector to renewable policies and carbon pricing into JRC-GEM-E3.

In the commercial transport sectors, fuel use of different energy carriers is imposed exogenously by collapsing the CES energy nest into a Leontief production function and adjusting the share parameters to reflect changes in the fuel mix (e.g., though electrification) and efficiency improvements. We account for a more expensive vehicle fleet (e.g. as a result of more stringent vehicle emission standards and of electric vehicles penetration based on a cost of ownership rational) by adjusting the non-fuel part of the production function of the transport sectors. Before accounting for general equilibrium effects that can shift sectoral activity levels and induce further changes in the substitution between the value added component and energy inputs JRC-GEM-E3, this would represent the energy use as projected in PRIMES model. This implementation provides consistency with detailed bottom-up modelling, which tracks different vehicle fleets reacting to incentives arising from specific policies that would be challenging to represent accurately in a top-down CGE model.

As mentioned above, JRC-GEM-E3 differentiates two different purposes of energy with the help of a consumption matrix, separating energy use for private transport and other household energy, which is mostly heating and electricity. For private transportation, we adjust the shares of different fuels in the consumption matrix based on PRIMES model results, reflecting a shift towards cleaner transportation. As for the commercial transport sectors, this captures changes in the composition and the use of the private vehicle fleet, resulting in demand changes for different transportation fuels (e.g. more electricity and less oil) as well as improvements in efficiency. Any additional cost to change the existing fleet by introducing a higher share of more efficient or electric vehicles is introduced by adjusting the “efficiency” of consumption of the vehicles consumption category in the consumption matrix, i.e. to obtain the same “unit” of consumption in this category, more inputs are required.

Similar adjustments are made for household heating and electricity use. As for private transport, the share of fuels used to heat (and to run appliances) is adjusted based on the more detailed PRIMES modelling. In JRC-GEM-E3, the share and the efficiency of fuel use is translated into changes of parameters in the consumption matrix to replicate energy use. This is prior to taking into account general equilibrium effects, so in the model an increase in consumption in response to declining effective prices in the Regulation scenario can be observed. Note that the price changes in the consumption categories take into account efficiency gains; therefore, consumption quantities are to be interpreted as efficient consumption units, e.g. setting the thermostat at a certain level for heating or kilometres driven in the case of household transport. At the same time, the efficiency gains are enabled by investments into the stock of appliances or building renovations, which come at additional costs. These costs are modelled as increases in the required (or subsistence) consumption in the Stone Geary consumption function (for appliances) and through an efficiency parameter in the purchase in the “housing” consumption categories, resulting in additional expenditure on the housing consumption category.

While the energy use and resulting emissions is informed by detailed energy system modelling, in the remainder of sectors emission reductions are implemented either via carbon taxes or efficiency measures in JRC-GEM-E3. To implement energy efficiency policies, a price signal is modelled that induces changes in the production technology, without leading to government revenues nor to substantial changes in output prices that would have effects downstream in the value chain. Specifically, a tax is implemented on energy inputs in the sectors covered by ETS in addition to the ETS carbon price. This tax enters the cost minimization scheme of the producer and induces a substitution away from the energy and towards the value added bundle. The hypothetical revenue of the tax is however recycled back to the same industry as an output subsidy.[5] This means that the policy increases the unit cost of production (and hence output prices) only due to changes in the production structure which then translate into different input demands (e.g. higher capital input).

For non-ETS sectors, no explicit carbon price is modelled, however, an emission shadow value is introduced to capture policies aimed at reducing emissions not covered by the EU ETS, including most non-$CO_2$ emissions. Abatement of non-$CO_2$ emissions is captured by bottom-up marginal abatement cost curves (Weitzel et al., 2019b); however, non-$CO_2$ emissions are similar across all scenarios.

## 2.2. Additional tools for further insights

We use additional tools to shed further light on the macroeconomic results that rely on the representative household and can hence hide important consequences for particular groups of the population. We use further data sources to shed light on distributional aspects and consequences for a transformation in the occupations and skills needed for a greener economy.

### *2.2.1. Labour market consequences*

We complement the macroeconomic results from the CGE model with a deeper analysis of the evolution of the labour force, exploring how the shifts in employment between sectors and regions affect the evolution of occupations and skills in the EU across climate scenarios. In this context, we refer to an occupation as an aggregate of jobs presenting similar main tasks and duties, while skill levels refers to the level of formal education or on-the-job training required to perform said tasks and duties, as defined by the International Labour Organisation[6].

For this purpose, we use CEDEFOP's latest projections on future skills demand and supply in Europe. These projections aim to reflect both potential shifts in the structure of the economy (i.e. economic growth and changes in its sectoral composition), as well as in occupational and skill structure (i.e. how jobs may change within each sector, as a result of other factors such as IT advances leading to stronger digitalization). The dataset includes projections on the occupational and skill breakdown (41 occupations in 9 occupational groups[7] and 3 skill levels[8]) for 66 economic sectors out to 2030.

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[5] This can also be referred to as shadow emission value or shadow energy value as it is not generating revenue. In technical terms, output based rebated would be equivalent when modelling only one homogenous firm in a sector.

[6] https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_172572.pdf

[7] Full list in Appendix A.

[8] High-skilled occupations in ISCO 1-3, medium-skilled in ISCO 4-8, and low-skilled in ISCO 9.

We perform a match and aggregation process of CEDEFOP's 66 sectors and the 31 JRC-GEM-E3 activities into 20 aggregate economic sectors. We overlay the CEDEFOP projections over the sectoral employment results from the CGE model for the baseline and the scenarios. For each scenario, we obtain new projections of EU occupations and skills to 2030 that are driven by employment increases and decreases in different sectors as reported in JRC-GEM-E3. With this methodology, we can identify how shifts in economic structure resulting from a policy scenario (sectoral and regional composition) may affect which occupations and skills will be required in the future. Note that this method allows us to identify occupation and skills transition resulting from transitions between sectors, but not for additional transition within sectors.

### 2.2.2. Distributional impacts

Finally, we use the results to assess whether the policies are able to deliver a "just transition". While JRC-GEM-E3 only has a single representative household, we can use the price changes for 14 consumption goods and combine them with detailed household level data from the Household Budget Survey (HBS)[9]. In the HBS data, specific quantities and prices of good purchases are not reported. In such cases, one can estimate the change in the welfare of households (in the HBS data) using the following formula[10]:

$$\Delta U_h \cong \sum_k p_k C_{hk} \frac{\Delta p_k}{p_k} = \sum_k C_{hk} \Delta p_k$$

where $c_{hk}$ is household h's initial (before a policy simulation) consumption of product *k*, $p_k$ is the purchase price of product *k* (assuming that all households pay the same price for product *k*), and $\Delta p_k$ is the corresponding price change due to a policy shock. Note that we do not take into account changes in factor prices, since the HBS income data is largely incomplete for such purposes.

We assume that the price changes of COICOP products that are sub-categories of aggregate consumption categories represented in JRC-GEM-E3 to be equal to the corresponding aggregate price changes as obtained from the JRC-GEM-E3 model. This allows for substitution effects within the macro model within a COICOP category, e.g. between electricity, gas, liquid fuels, solid fuels, and heating energy within "Fuels and Power". When comparing a scenario to a baseline, the substitution within a COICOP category is then assumed to be modelled in JRC-GEM-E3. One potential drawback of the approach is that there is only one average price change for the COICOP category, disregarding heterogeneity in the shares of sub-categories within the COICOP category between different household groups.

Additional carbon pricing revenue relative to the baseline is allocated to households on an equal-per-equivalent-household basis. We use the 2010 wave of the HBS data without addressing potential inconsistencies with the national account data. As a result, aggregating the micro-level welfare impacts over all households would give a number that does not necessarily match the welfare outcome for the aggregate, representative household as calculated in the economy-wide JRC-GEM-E3 model. To address this issue, we add an additional two-step adjustment to the procedure. In the

[9] https://ec.europa.eu/eurostat/web/microdata/household-budget-survey See Temursho et al. (2020b) for more details on the HBS data and the linking of HBS data to JRC-GEM-E3 results.

[10] The welfare indicator is compensating variation, which is defined as the monetary transfer required to make a person as well off as before the policy reform.

first step, we rescale household-level impacts to match country-specific welfare impacts from JRC-GEM-E3. We do this in a way that the distributional pattern over income groups in terms of compensating variation relative to income is unaffected (equal percentage point shift for all). A second step then repeats this rescaling but on the EU aggregate level. Implicitly, the scaling also reflects source-side impacts (changes in factor income), as these contribute to the welfare impacts in the macro model, but are not represented explicitly on the micro level. The rescaling procedure brings consistency in aggregate outcome while maintaining the distributional patterns derived directly from the micro data. Therefore, the distributional impacts can readily be interpreted as a breakdown of the macro-economic results. For lump sum transfers to households, we deflate the 2030 values to 2010 by income per capita growth.

## 2.3. Scenarios

A number of scenarios reaching the 55% goal were assessed, making different behavioural, modelling and policy assumptions. The key policy assumption determined the mix of market based policies (e.g., carbon pricing in the EU ETS) and regulatory measures (e.g. vehicle emission standards or policies to increase building renovation rates) to reach the targets. Important behavioural assumptions include how producers respond to free allowances: do they price in the value of free allowances as an opportunity cost or do they maximize their market share by fully passing through the value of free allowances to consumers? Modelling assumptions further include assumptions of the labour market, i.e. keeping unemployment fixed or responding to changes in wages. While the policy options are intended to inform policy choices, the different modelling variants cannot be influenced directly by policy and are intended to assess how the results of the different assumptions would change in the modelling.

### *2.3.1. Policy options*

The impact assessment of the 2030 Climate Target Plan defines three main energy-modelling scenarios that reach 55% reduction levels that differ in the combinations of policy instruments.

- The **REG scenario** is based on regulatory measures that increase ambition on energy efficiency, renewables and transport. It keeps the scope of the EU ETS unchanged and does not expand carbon pricing to new sectors of the economy. Fossil fuels purchased by households are therefore not subject to a new carbon price signal. Further, the carbon price in the ETS is not increased substantially relative to the baseline. Households and firms instead have to bear cost increases resulting from efficiency measures, e.g. from more energy efficient technologies and expenditures from renovations.
- The **CPRICE scenario** instead assumes a strengthening of the carbon price signal and the EU ETS is extended to land transport and the buildings sector. It assumes a moderate intensification of transport policies, but no intensification of energy efficiency and renewables policies. The carbon price in this scenario rises above the level of the baseline scenario.
- Finally, the **MIX scenario** lies between the REG and the CPRICE scenarios. As under CPRICE, the buildings sector and transport are subject to carbon pricing in the ETS. However, the scenario also includes an intensification in both transport and energy policies, though to a more limited extent than under REG. The strengthening in the carbon price is therefore lower than under CPRICE.

For all policy scenarios, further policy choices reflect the design of carbon pricing mechanisms. The current policy architecture provides free allowances for industries at risk of carbon leakage. This is modelled as an output based rebate, as the carbon price continues to have an effect on efficient input choice, leading to a substitution to cleaner energy inputs and more efficient energy use. We assume that in all policy scenarios electricity generators always have to purchase allowances, while for industries we investigate a switch to auctioning in addition to maintaining free allowances. As buildings and land transport are not prone to leakage, in the MIX and CPRICE scenarios that extend the coverage to these sectors, full auctioning is always assumed.

In scenarios that increase the revenues from carbon pricing though higher carbon prices, increased coverage of the ETS, or removing of free allowances for industry there are several options to recycle the revenue. We analyse the impacts of two policy choices: a lump sum transfer to households, or a reduction of labour taxes. A lump sum transfer can help to offset undesired distributional consequences, while reducing labour taxes can increase the labour supply and potentially lead to a double dividend. We do not assume any transfer of ETS revenues between EU member states, although instruments exist that transfer some revenue through allocation of allowances between member states (Dorsch et al., 2020).

### *2.3.2. Modelling variants*

Several additional parameters determine the outcome of the modelling exercise. These either are policy parameters not directly in the hand of (European) policy makers or are modelling assumptions.

An important determinant of how EU climate action turns out depends on the behaviour of non-EU regions. In the baseline scenario, these countries are expected to miss their NDC targets – however, when the world would make the steps towards the 1.5 degree temperature target, a strong change of direction would be required that would have repercussions on EU climate policy. Under fragmented action, we only increase the EU target to meet its more ambitious climate target; for non-EU regions, we hold carbon prices fixed, and likewise, we maintain their share parameters of electricity generation technologies. This allows for leakage mainly through relocation of industry, but mutes the leakage through the energy market channel. Under global action, we also impose emission targets in non-EU regions that would bring the world on track towards reaching the 1.5 °C temperature target. Emission pathways and exogenous abatement responses for particular sectors as described in section 2.1.3 are based on Keramidas et al. (2020).

Important model assumptions relate to the treatment of the labour market in JRC-GEM-E3. The labour market can either be modelled taking a long-run view in which long run labour supply is fixed at an exogenous level and the wage rate adjusts to clear the labour market (perfect labour market assumption). Alternatively, the labour market can be described by a wage curve, reflecting an imperfect labour market. In this setting, increasing real wages increase the labour supply in the economy. This can be achieved e.g. by using carbon revenues to lower labour taxes.

Finally, in the case of free allowances, two possible response options by firms can be modelled. Firms can either pass on the value of the permits to their customers. In other words, firms operate to maximize their market share. On the other hand, firms could price in the value of emissions in the (marginal) price and use free allocation to maximize their (windfall) profits. In reality, the pass through rate of the value of free allowances depends on the competitive structure, and is found to vary between sectors in empirical studies (Cludius et al., 2020).

We did not assess all possible combinations of policy options and model assumptions. In the results section below, we instead describe how a switching from one assumption to another affects the outcomes.

# 3. Results

## 3.1. Macroeconomic Results

The effect on the macro-economy indicated relatively minor costs, in the range 0.23 to 0.39% of GDP, depending on the scenario assumptions. Interestingly, the regulation based policy (REG) lead to slightly lower GDP and consumption losses than a market-based approach (CPRICE), as it was able to mobilize efficiency gains in transport and residential sectors under lump sum transfers. However, when assuming an imperfect labour market and the use of the additional revenue from carbon pricing to reduce labour taxes, this result flipped, and the market based policy approach delivered lower GDP losses.

**Table 1. Impacts on key variables against the baseline**.

| | - Tax recycling<br>- Imperfect labour market<br>- Free allocation ETS<br>- Market share maximisation ETS | | | - Lump sum transfers<br>- No labour market imperfections<br>- Free allocation ETS<br>- Profit maximisation ETS | | |
|---|---|---|---|---|---|---|
| | REG | MIX | CPRICE | REG | MIX | CPRICE |
| Real GDP | -0.30 | -0.27 | -0.24 | -0.23 | -0.25 | -0.25 |
| Private consumption | -0.53 | -0.71 | -0.79 | -0.41 | -0.46 | -0.44 |
| Investment | 0.49 | 0.57 | 0.86 | 0.50 | 0.56 | 0.83 |
| Employment | -0.09 | 0.06 | 0.15 | 0.00 | 0.00 | 0.00 |
| "Fuels and power" prices | -1.62 | 4.55 | 9.96 | -1.92 | 3.47 | 8.07 |
| "Housing and water charges" prices | 2.67 | 1.77 | 0.14 | 2.68 | 1.82 | 0.19 |

## 3.2. Sectoral Results

The impacts of the 55% reduction target can be expected to be felt most in the fossil fuel sectors. Output in these sectors considerably drops, especially for coal, as the reduction in electricity generated by coal is a key component to realize lower emissions. Energy intensive industry such as ferrous and non-ferrous metals also are expected to have lower output, while the services sector is less affected. Some sectors contributing to abatement equipment and building renovations (e.g. construction) can even benefit from the increased climate ambition. The range of the scenarios originates from different assumptions mentioned above; higher carbon prices are typically leading to higher losses for industry, although revenue recycling for reduced labour taxes can offset this effect under some cases.

**Table 2: Output changes by sector.** Range across scenarios in brackets.

| | |
|---|---|
| Coal | -41.4 \| -40.6 |
| Crude Oil | -6.5 \| -4.3 |
| Oil | -5.7 \| -4.0 |
| Gas | -15.3 \| -12 |
| Electricity supply | -1.9 \| -1.6 |
| Ferrous metals | -4.0 \| -0.6 |
| Non-ferrous metals | -2.7 \| -0.8 |
| Chemical products | -0.9 \| -0.3 |
| Paper products | -0.6 \| -0.4 |
| Non-metallic minerals | -2.1 \| -0.1 |
| Electric goods | -0.1 \| 0.7 |
| Transport (air) | -4.8 \| -0.4 |
| Transport (land) | -1.5 \| -1.2 |
| Transport (water) | -0.6 \| -0.3 |
| Construction | 0.4 \| 0.4 |
| Market services | -0.3 \| -0.1 |

### 3.3. Jobs, Skills and Occupations

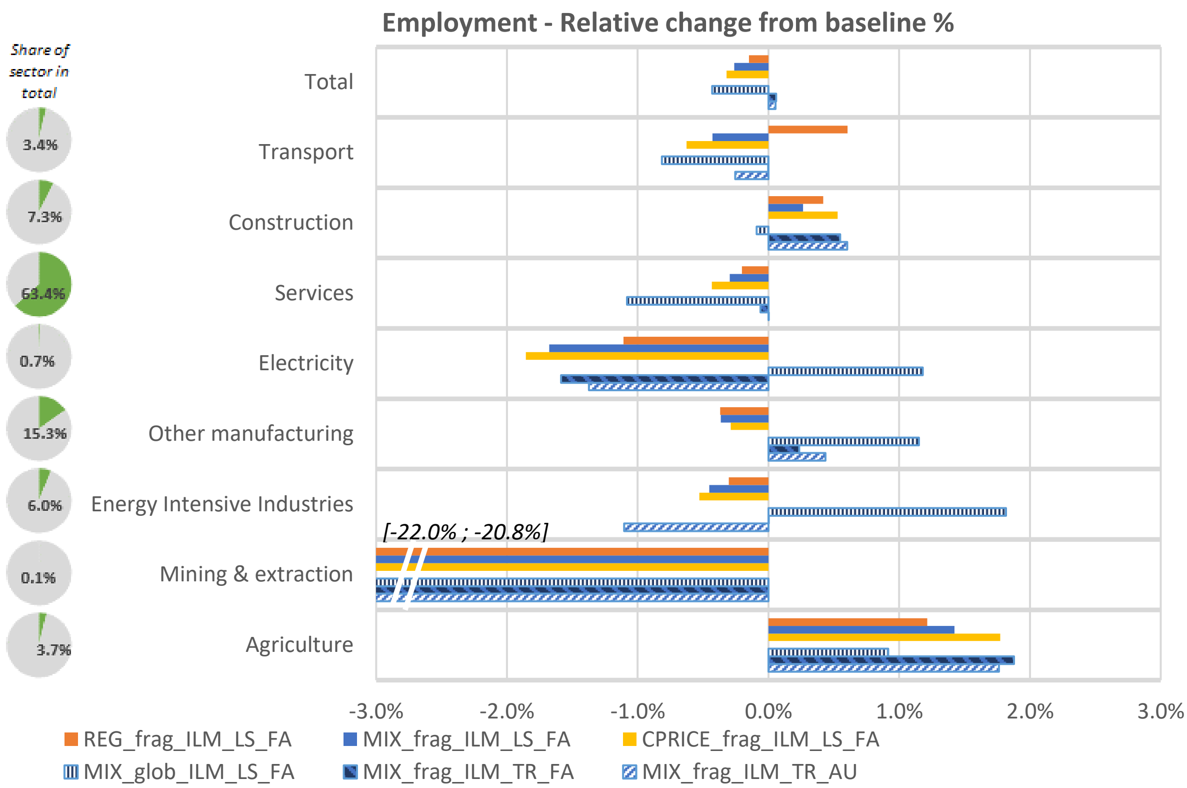
When the labour market is modelled with the assumption of a wage curve (i.e. imperfect labour markets in which unemployment responds to changes in wages), the aggregate effect of the policy shock on the labour market depends on the assumption on revenue recycling.[11] Under lump-sum transfers, employment is reduced by about 0.25% in the MIX scenario, ranging from 0.15 to 0.32% decreases in the REG and CPRICE scenarios. However, when revenue from carbon pricing is used to lower labour taxes, a double dividend can be achieved by reducing unemployment (see Table 1).

The sectoral employment shifts (Figure 2) for the EU are aligned with changes in domestic output presented in Section 3.2. Fossil extraction sectors are most negatively affected in relative terms, but also represent a small share of EU employment. Under fragmented action, agriculture and construction experience gains in employment. Energy intensive and power generation sectors are negatively impacted by more stringent policies, with the largest employment reductions felt in CPRICE. The impact is reversed in the case of global climate action, which leads to greater demand for emission intensive products made in Europe, as they are cleaner than the world average. The transport sector benefits under a REG scenario, but employment reduces in line with increases in carbon price in MIX and CPRICE respectively, through increased fuel prices. Implementing labour tax recycling is beneficial to all sectors, while moving from free-allocation to auctioning in ETS negatively impacts employment in the affected sectors (Energy Intensive Industries), but benefits most the others via lower labour taxes.

These sectoral shifts under various climate policy options will affect the composition of the labour force in terms of jobs and skills, based on their distribution across EU sectors and Member States, resulting in a potential occupation/skill mismatch and labour market frictions (Figure 3). As employment in services drops, so does employment in occupations mostly represented in the sector (e.g. professionals, clerks, services and sales workers) in total employment. Skilled agricultural workers experience gains, as these are primarily confined to the agriculture sector. In comparison, craft and related trades workers reduce, but by less than services, as these make up a large share of the workforce in both the construction and manufacturing sectors, which respectively benefit or lose from investments in the low-carbon transition. Under global action, the higher employment level in energy intensive manufacturing sectors increases the share of these occupations like plant and machine operators in the workforce. In contrast, auctioning of allowances for these sectors leads to reductions in craft and machinery occupations. Labour tax recycling benefits employment across all occupations.

[11] Under the perfect labour market assumption, aggregate employment changes are zero by definition. For sectoral effects, these typically are similar to those shown in the figure; the requirement to reach the overall constraint typically leads to an upwards or downwards shift, however, typically not affecting the ordering between sectors.

**Figure 2: Sectoral employment**. Changes relative to the baseline. LS – lump sum transfer / TR – tax recycling to lower labour taxes; FA – free allowances in ETS / AU – auctioning in ETS sectors.




The projections of skill levels on the scenario results suggest a general de-skilling trend from the introduction of climate policy; however, aggregate changes are small. The drop in employment in services and services-related occupations, which are generally higher skilled leads to a general reduction in the share of high-skilled jobs across all scenarios. In contrast, the share of medium-skill jobs increases across all scenarios, driven by gains in manufacturing and construction trades, and skilled agricultural occupations. The extent of the skill reallocation is also dependent on policy design. The REG scenario, which has the lowest reduction in total employment under the lump-sum redistribution option, also leads to the smallest skill-reallocation, while in CPRICE reallocation is the largest (although relatively small still). The labour tax recycling of revenues tends to reverse that trend, where medium-skilled and high-skilled jobs benefit from the general stimulus it generates across all occupations, while this impact is tempered slightly by the auctioning of revenues leading to a decline of energy intensive industry output and employment.

**Figure 3: Changes in occupational structure.** Changes relative to the baseline. LS – lump sum transfer / TR – tax recycling to lower labour taxes; FA – free allowances in ETS / AU – auctioning in ETS sectors.

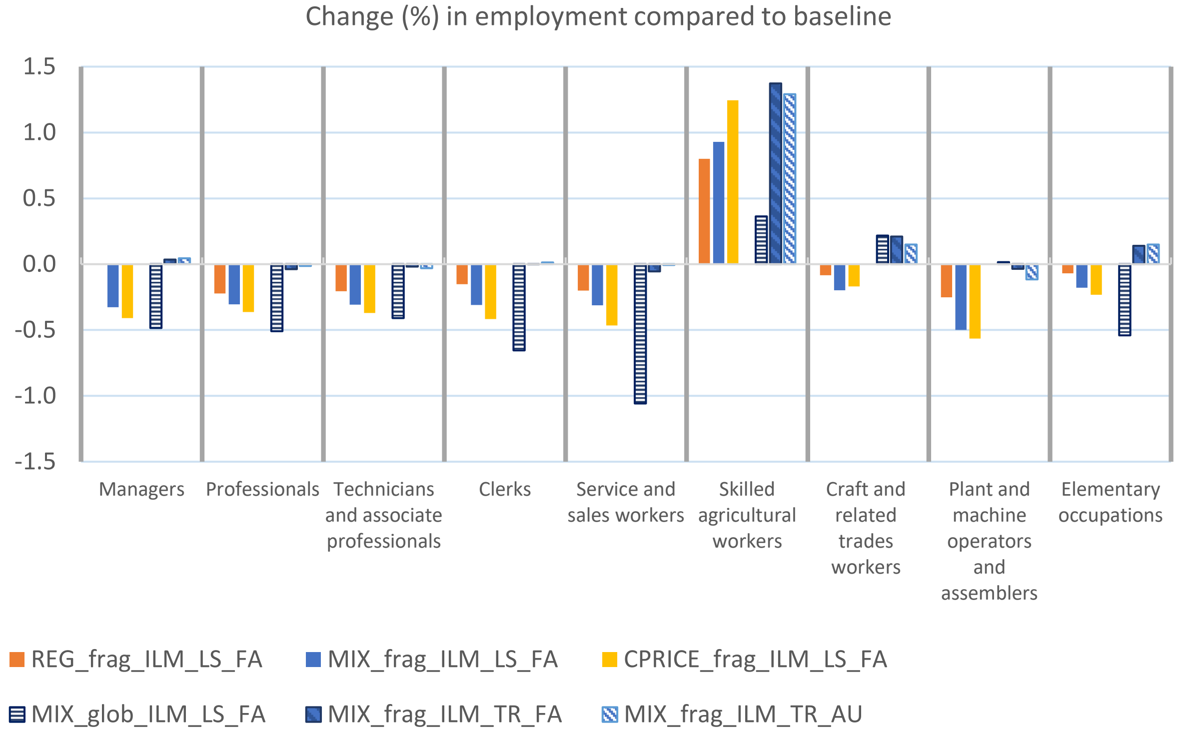
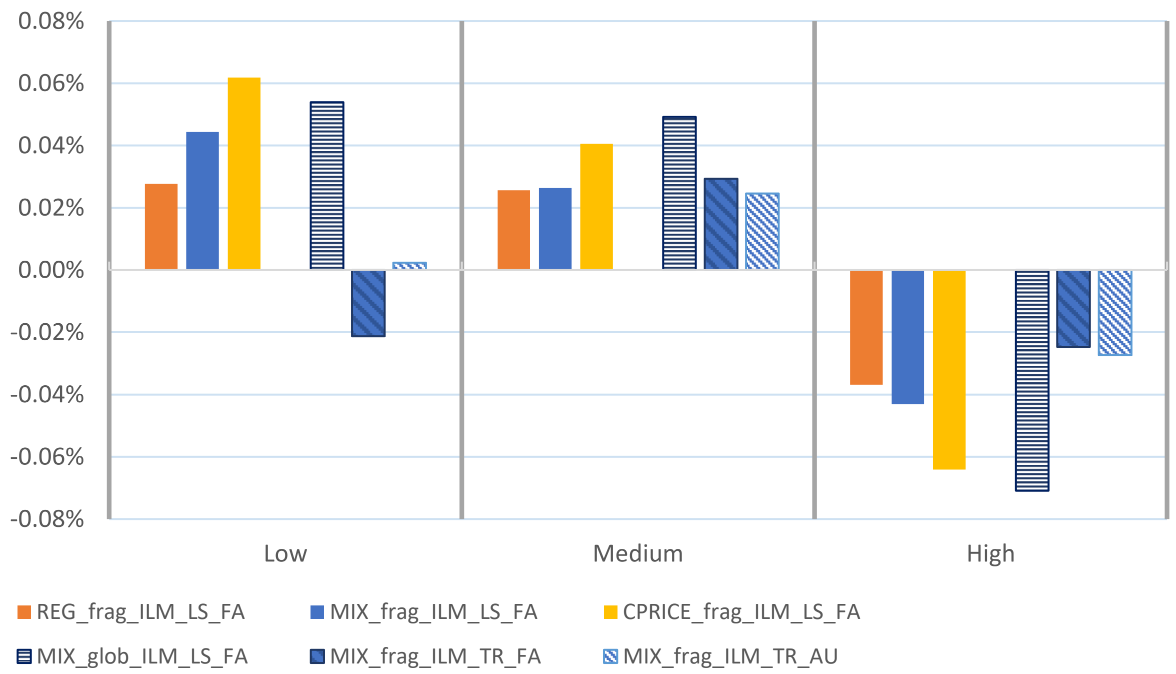



**Figure 4: Changes in skill level share in workforce.** LS – lump sum transfer / TR – tax recycling to lower labour taxes; FA – free allowances in ETS / AU – auctioning in ETS sectors.

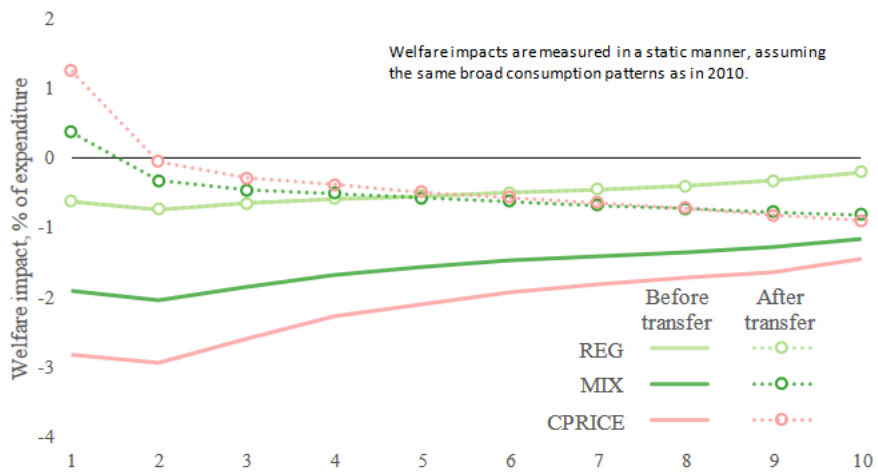


## 3.4. Distributional Results

Carbon pricing leads to increased costs for heating fuels (see Table 1), and poorer households spend a larger share of their budget on energy. This means that the price effects are more regressive under market-based policies. Figure 5 shows in solid lines the effects from price changes alone – indicating that scenarios with a stronger price component lead to stronger regressive effects. In Temursho et al. (2020b), we further show how this affects different households also within expenditure groups, i.e. that the CPRICE scenario leads to a wider standard deviation of welfare effects impacts also within income groups.

However, a price-based policy also is able to generate additional revenue that can be distributed back to households – even a lump sum transfer back to households based on household size is able to offset negative effects for the poorest households. As the CPRICE scenario also produces the largest revenue and hence lump-sum reduction, this can be particularly beneficial for poorer households.

**Figure 5. Distributional impacts by expenditure group.** 1=poorest decile, 10=richest decile



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**Appendix A:**

| Occupations – results reporting groups | | CEDEFOP | |
|---|---|---|---|
| | | Code | Label |
| 0 | *Armed forces* | 1 | *Armed forces* |
| 1 | *Managers* | 2 | *Chief executives, senior officials and legislators* |
| | | 3 | *Administrative and commercial managers* |
| | | 4 | *Production and specialised services managers* |
| | | 5 | *Hospitality, retail and other services managers* |
| 2 | *Professionals* | 6 | *Science and engineering professionals* |
| | | 7 | *Health professionals* |
| | | 8 | *Teaching professionals* |
| | | 9 | *Business and administration professionals* |
| | | 10 | *Information and communications technology professionals* |
| | | 11 | *Legal, social and cultural professionals* |
| 3 | *Technicians and associate professionals* | 12 | *Science and engineering associate professionals* |
| | | 13 | *Health associate professionals* |
| | | 14 | *Business and administration associate professionals* |
| | | 15 | *Legal, social, cultural and related associate professionals* |
| | | 16 | *Information and communications technicians* |
| 4 | *Clerks* | 17 | *General and keyboard clerks* |
| | | 18 | *Customer services clerks* |
| | | 19 | *Numerical and material recording clerks* |
| | | 20 | *Other clerical support workers* |
| 5 | *Service and sales workers* | 21 | *Personal service workers* |
| | | 22 | *Sales workers* |
| | | 23 | *Personal care workers* |
| | | 24 | *Protective services workers* |
| 6 | *Skilled agricultural workers* | 25 | *Market-oriented skilled agricultural workers* |
| | | 26 | *Market-oriented skilled forestry, fishery and hunting workers* |
| | | 27 | *Subsistence farmers, fishers, hunters and gatherers* |
| 7 | *Craft and related trades workers* | 28 | *Building and related trades workers, excluding electricians* |
| | | 29 | *Metal, machinery and related trades workers* |
| | | 30 | *Handicraft and printing workers* |
| | | 31 | *Electrical and electronic trades workers* |
| | | 32 | *Food processing, wood working, garment and other craft and related trades* |
| 8 | *Plant and machine operators and assemblers* | 33 | *Stationary plant and machine operators* |
| | | 34 | *Assemblers* |
| | | 35 | *Drivers and mobile plant operators* |
| 9 | *Elementary occupations* | 36 | *Cleaners and helpers* |
| | | 37 | *Agricultural, forestry and fishery labourers* |
| | | 38 | *Labourers in mining, construction, manufacturing and transport* |

| | | | |
|---|---|---|---|
| | | 39 | *Food preparation assistants* |
| | | 40 | *Street and related sales and service workers* |
| | | 41 | *Refuse workers and other elementary workers* |