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Modelling the decarbonisation of energy intensive industries in the EU: The potential effects of a carbon border mechanism

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European Trade Union Institute

Prepared by Cambridge Econometrics as part of the project 'Decarbonisation of energy intensive industries in Germany' commissioned by ETUI-ECF.

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Introduction

As part of a wider research project initiated by the European Trade Union Institute and the European Climate Foundation, the objective of this study is to map the current situation of energy intensive industries (EII) in the EU27. The main aim of the analysis is to provide evidence on the labour market and economic impacts of different decarbonisation pathways for the basic metals, chemicals and minerals sector, as a part of EII, and for the wider economy, considering also the expected effects of a carbon border adjustment mechanism (CBAM).

The E3ME macroeconomic model maintained by Cambridge Econometrics was used to simulate the direct and indirect effects of transition in this sector as well as to give insights into the induced effects such as: the impact on the economy of supply chain effects and changing energy demand from EII sectors; the spillover effects in other sectors from potential lay-offs or sectoral transformation; and the socioeconomic impacts that arise from changing Emissions Trading System (ETS) revenues.

Three scenarios were designed, representing alternative decarbonisation pathways for each industry based on different assumptions; namely, the type and share of technologies adopted and the time profile and costs of emissions abatement. The study also analysed the proposed CBAM and its effects in interaction with the different decarbonisation pathways.

This paper summarises the EU27 results from the E3ME modelling exercise which analyses the impacts of the sectoral decarbonisation scenarios for energy intensive industries. These scenarios are defined on top of a reference scenario that is already aiming to reach economy-wide net zero emissions by 2050, therefore limiting global warming to 1.5C by the end of the century. The sectoral pathways aim to contribute to this by eliminating emissions from EII by 2050.

After a brief overview of the scenarios under the E3ME model, a discussion of the results follows. This focuses on employment at EU27 level as well as on the differences between the Member States.

1. Methodology

This modelling uses the E3ME model (www.e3me.com) owned and maintained by Cambridge Econometrics. E3ME is a global, macroeconomic model that is designed to address the major economic, social and environmental challenges of the coming decades. Developed over the last 25 years, it is one of the most advanced models of its type.

The model was developed to analyse the impacts of policies or technological developments on selected sectors, including the sector most relevant from the viewpoint of the current study: the production of metals, mineral products and chemicals. By using the model we can quantify the direct employment and economic impacts on industries as well as on the wider economy.

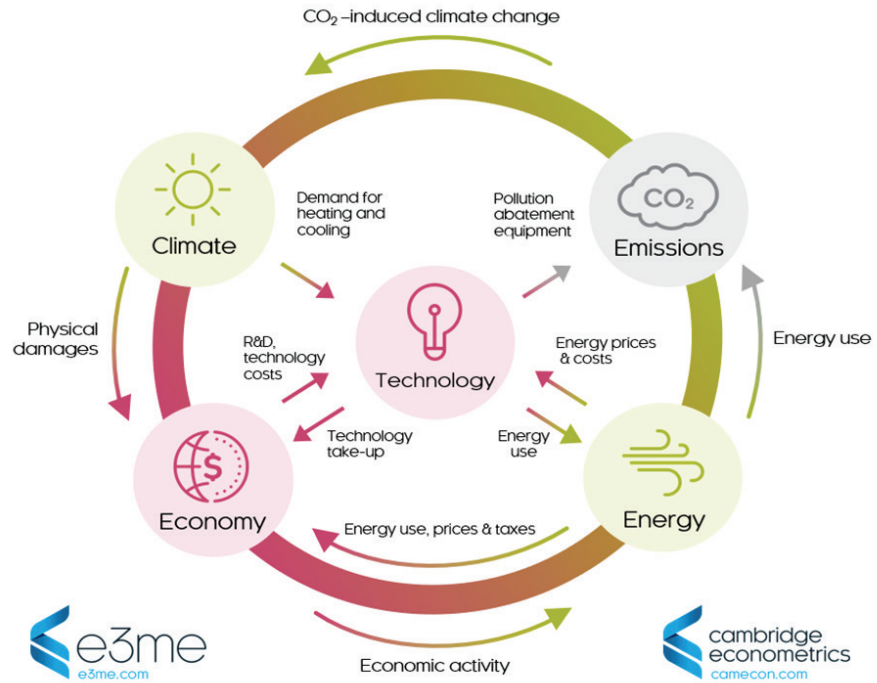
The model is extended with the suite of Future Technology Transformation (FTT) technological models for power generation and steel production to introduce the impacts of technology diffusion and innovation. FTT models are bottom-up diffusion models which simulate imperfect decision making and path dependency in technology adaptation.

The core of E3ME's economic structure rests on econometrically estimated parameters, based on historical data, and is a top-down modelling framework. Input-output relationships determine the linkages across sectors and represent value chains. This is complemented by the FTT sub-models within E3ME which describe the take-up of emerging technologies in the power, transport, heating and steel sectors. The FTT model classes follow a bottom-up logic and integrate the framework of technology diffusion models into E3ME.

Figure 1 shows the basic structure of the E3ME model linking the economy, energy and emissions in a complete framework with two-way feedbacks connecting these pillars.

The model is therefore capable of simulating the direct and indirect effects of sectoral transition as well as giving insight into the induced effects. EII investments targeting abatement can create new investments, while the potential lay-offs resulting from the decarbonisation process can create spillover effects to consumption and other industries.

Figure 1 The structure of the E3ME model



It should be noted that, due to the linked bottom-up modelling, the treatment of the steel industry is somewhat different than the rest of the EII considered here. For the other industries considered within EII targets – chemicals and non-metallic minerals – we do not employ FTT modelling, using instead the industry-level and country-level econometrically estimated parameters of E3ME as well as exogenous assumptions on the development and energy profile of the sectors.

2. Reference scenario

We modelled a reference scenario and compared the three sectoral decarbonisation pathways to this reference case. We also modelled various sensitivities in terms of how the investment needed for such decarbonisation may take place (the different financing options). Finally, we ran simulations on the introduction of the proposed carbon border adjustment mechanism.

In this exercise, the E3ME model was used as an *ex ante* impact assessment from which we could run simulation scenarios as economic-energy-environment outlooks based on assumptions about technology trajectories, adopted policies and other factors. The scenarios are the simulated decarbonisation pathways that are not necessarily based on existing policies but show what socioeconomic impacts may be expected if certain policies shape the development of these sectors in a given way.

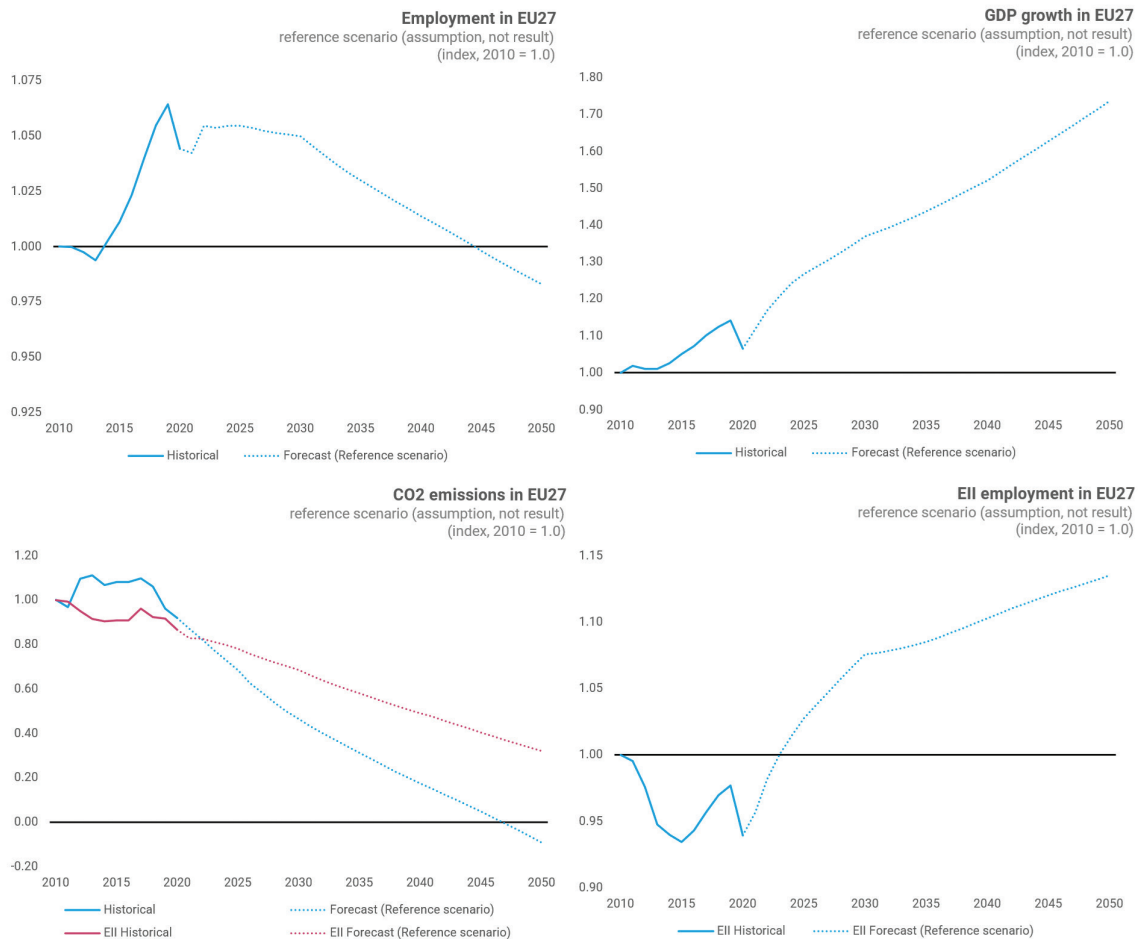
We introduce a naïve decarbonisation pathway (we call this the ‘reference scenario’) which assumes that high-level policy is implemented in the EU (as well as in other countries which already have net zero pledges) with the target of limiting global warming to 1.5C by the end of the century.

This approach is adopted in order to take into account those developments and trends that are already shaping the economy, including decarbonisation and relevant climate policies, even in EII sectors. Therefore, when we discuss results from the different sectoral decarbonisation pathways and talk about differences from the reference scenario, we consider the socioeconomic impacts of the additional effort needed to reach these higher sectoral decarbonisation goals as well as the supplementary impact these pathways have on the overall economy.

Thus, the changes and trends considered in the reference scenario, together with the impacts in the sectoral decarbonisation scenarios, show how the socioeconomic indicators could be affected compared to the situation that we have today. Our reference scenario is built on the EU Reference Scenario, which is one of the European Commission’s key analytical tools in the areas of energy, transport and climate action (EU REF2020 scenario).¹

1. https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en

Figure 2 Overview of the reference scenario EU27 trends (naïve decarbonisation)



When discussing the results, we mostly focus on the supplementary impact of these additional policies that ensure sectoral decarbonisation within the context of the overall decarbonisation of the economy.

Figure 2 shows projections for the key indicators in the reference scenario. We use these projections as a starting point in forming the sector decarbonisation pathways. As shown, total employment is expected to decline in line with the generally declining population (UN projections) unless other factors influence this underlying process. The projections are calculated with an assumed GDP growth of 1-1.4 per cent in the long run and with emissions decreasing to net zero (EU27 total) by 2050. Nevertheless, without sectoral decarbonisation this still means substantial emissions from EII. Employment in EII increases in the reference scenario projection, in line with the trends after 2015 (growth in basic metals is minimal but growth in chemicals and non-metallic minerals amounts to about 15 per cent in the projections).

For some indicators we also provide a comparison with E3ME’s standard baseline scenario (‘standard baseline’), which assumes the continuation of current policies

but no additional climate or energy policy beyond that. That scenario does not assume the attainment of any climate targets by 2100.

3. Scenario design

We consider three different possibilities for sectoral emission abatement:

- **INNO:** focusing on electrification, hydrogen deployment and energy efficiency
- **CIRC:** focusing on alternative design, alternative materials and efficiency
- **CCS:** focusing on the deployment of carbon capture and storage (CCS)

In all of the pathways (scenarios) we consider a mix of several ‘technology levers’, such as electrification, hydrogen use, biomass, alternative materials, energy efficiency, recycling and CCS. We estimate the weighted abatement cost of these options from the literature (see Annex), which we use for calculating the investment required and the operation and maintenance costs. Figure 3 provides a high-level overview of the different actions used and the overall composition of the pathways.

Figure 3 High-level overview of actions used in the decarbonisation pathways

	Innovation led INNO	Circularity and efficiency CIRC	Carbon capture CCS
Electrification			
Hydrogen use			
Biomass use			
Alternative design / materials			
Energy efficiency			
Recycling			
CCS			

It is important to note the financing assumptions of the scenarios:

In all cases:

- we assume that the EU ETS system is kept in place, resulting in government revenues from auctioned allocations and price effects through increasing prices of carbon intensive production
- we also assume (as a high-level assumption) that revenues from the EU ETS are recycled towards decreasing general taxation, including labour, income and sales taxes

In the separate financing sensitivities:

- in the main case we assume that sectoral decarbonisation is financed from new sources; that is, there is no ‘crowding-out’. This is in line with the assumptions of endogenous money theory (Pollitt and Mercure 2018)
- in the ‘crowding-out’ scenarios, we adopt the assumption that targeted EII sectors have to repurpose current and planned investments for abatement, thereby crowding-out the investment that they would otherwise undertake. It needs to be noted that, due to the FTT-based modelling, crowding-out is only applied in a limited fashion in the steel sector
- in the public financing scenarios we assume that sectoral abatement is paid out of the public purse, with a revenue recycling mechanism that increases general taxation in order to maintain budget neutrality

We further consider the effects of the proposed carbon border adjustment mechanism (CBAM) on the scenarios; however, we employ a simplified methodology to represent the effects of the mechanism which might fail to cover all aspects of the policy. Our method applies the carbon border tax to goods purchased from countries outside the EU (or exception countries such as Switzerland), deducting any carbon taxes that the exporter has already paid in the country of production. Revenues from the CBAM are recycled into decreasing general taxation, as with other policies. However, E3ME has a broader industrial classification than the definition of products falling under the CBAM regulation, which means we are applying CBAM to a broader scope of products but with lower average carbon intensity. We also need to note that our current CBAM treatment excludes any coverage for electricity trading as this would need a much more complex modelling exercise.

4. Modelling results

This Paper primarily focuses on discussing the EU27 employment results arising from the main scenarios, with an outlook on emission impacts. Different financing scenarios are briefly discussed at the end.

Employment in EII

First, Figure 4 presents the potential direct employment impacts in EII sectors. The actual effects differ between Member States but there are similar patterns.

As regards EII sectors by decarbonisation pathways, the CIRC scenario shows that EII employment is substantially lower than in the reference scenario. However, it needs to be considered that this is a result only for those EII sectors where we expect decreases due to lower demand (from the use of alternative materials and efficiency gains) and the application of more efficient solutions. These employment changes might therefore not represent losses at the level of the wider economy but, rather, distinct shifts in the economic structure. Germany, Spain and Italy drive this impact in both absolute and relative terms with chemicals in Italy and Spain and non-metallic minerals production in Germany and in Poland contributing substantially to the difference.

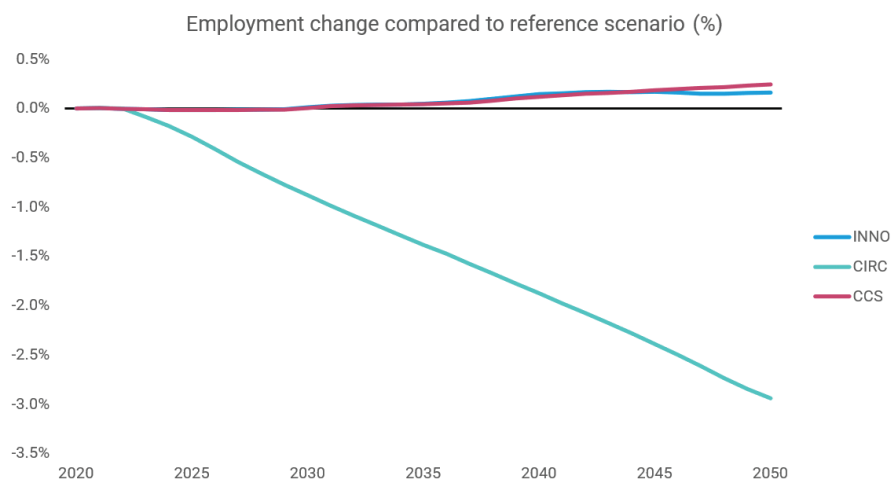
In comparison, the INNO scenario shows somewhat rising employment than in the reference scenario. This coincides with overall growth in sectoral output (0.2-0.3 per cent compared to the baseline) although its magnitude is smaller (about half of the output effect of around 0.1-0.15 per cent). The effect here is driven by increasing demand for EII products, a result of a decreasing industry price due to lower energy and carbon costs. As decarbonisation is happening, the industry has to pay less in environmental taxes (decreasing carbon intensity) and pays less (compared to the reference scenario) for energy. This leads to a decrease in consumer prices (including intermediate consumption), raising demand, output and therefore employment in the sector. This does not apply to iron and steel production where a somewhat increasing unit cost produces opposing effects. All this can be seen in Figure 5. Nevertheless, we have to consider that modelling responses in the steel sector has been done using FTT and, therefore, that somewhat different results were expected.

Finally, in the CCS scenario there are two competing effects: first, the modelling indicates that, in the steel industry, the deployment of CCS might increase costs more than it decreases unit costs through the elimination of carbon price costs

and decreasing energy prices. In the non-metallics industry, CCS costs might be lower than carbon costs, meaning that the deployment of CCS could result in unit cost (and therefore price) decreases which would further mean increased output (due to positive demand elasticity) and employment in the industry. These two competing effects, on an EU27 level, result in slightly increased employment numbers in aggregate EII employment. It needs to be noted that this increase is also helped by the outcome that, while for most Member States the employment effect is negative, the job effect is positive in some economies like Germany, Belgium and Croatia, pushing net EU-wide effects into the positive domain.

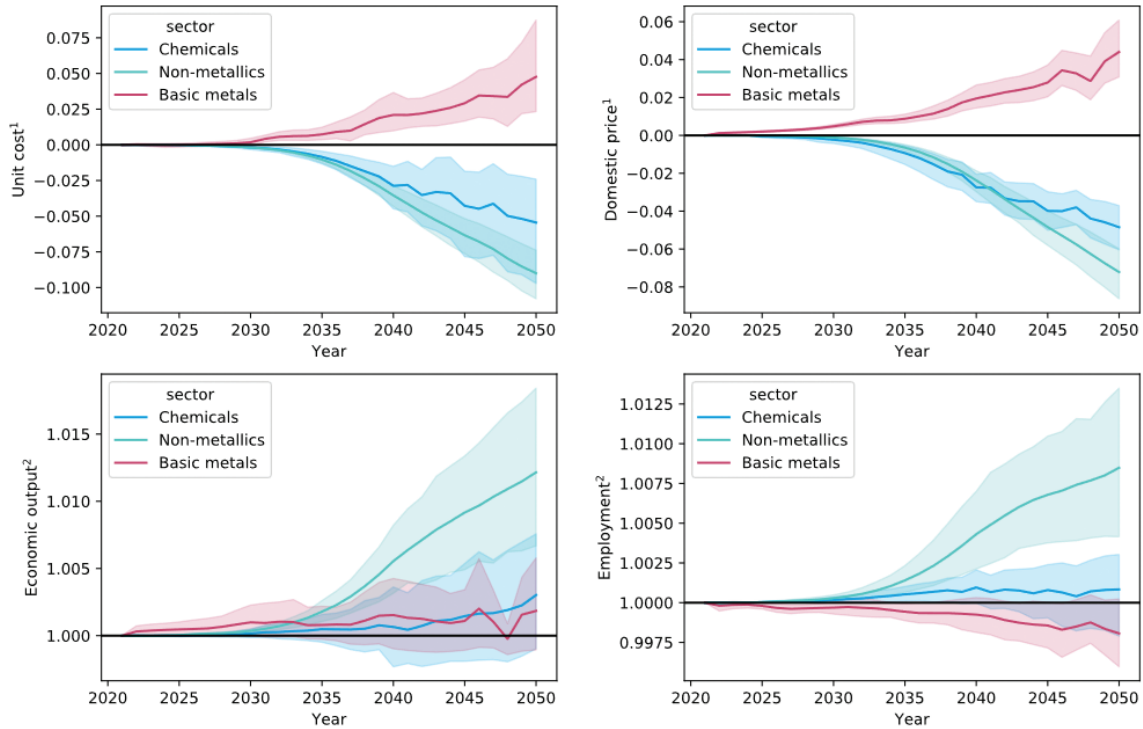
Overall, the results indicate that the CIRC scenario decreases EII sectoral employment – as expected – since this is really a scenario of economic transformation with decreasing spending (due to efficiency) on EII goods and production. But it also shows (and this is discussed later) that, in this pathway, the gains are there, just that they are realised outside EII sectors. The INNO and CCS pathways show different outcomes: in both cases unit costs are major drivers. In the INNO case we see that decarbonisation mostly results in cost decreases (carbon cost and energy cost), driving consumption and production in these sectors and therefore creating employment in them. In the CCS case we see something similar although the costs and avoided costs are different here, leading to differing outcomes at Member State level. However, the important difference between the two cases, even though their net EII employment impact is similar, is the magnitude of the sectoral employment transition (through re-skilling, re-training, labour market transformation, etc.) which is required: this is about 8 per cent higher² in the CCS case.

Figure 4 EII employment change in the scenarios, EU27 (compared to reference scenario)



2. Measured as total employment impact across sectors and Member States.

Figure 5 Unit cost and price effects in EII sectors in the INNO scenario, EU27 average³



Notes:

- 1 – Percentage point difference from the reference case, unit is price index, with 2010=1.0
- 2 – % difference from the reference case, unit for output is million EUR constant 2010 prices, employment is in '000 people
- 3 – Greece, Luxembourg, Cyprus and Malta are excluded because of model instability

Further figures about the CIRC and CCS pathways are available in the Annex (Figures 15 and 16).

Economy-wide employment

The economy-wide employment effects can differ from the EII employment effects as there could be substitution effects (i.e. spending in other areas of the economy arising from lower spending on EII goods) as well as the spillover effects (employment change also leads to changes in income).

Figure 6 shows these overall employment effects at EU27 level building on the combination of (aggregate) direct (EII) and indirect (via spillover and substitution) effects to indicate the overall net impact. This net impact is largely positive by the end of the modelling period (2050) in the CIRC scenario but negative for the other two pathways, although in the INNO scenario the effect is actually positive for most of the modelling period.

Figure 7 gives further insight into these impacts by indicating the magnitude of these changes.

The CIRC scenario demonstrates what we have discussed in earlier sections: in this pathway, EII sectors lose employment as consumers spend less in EII but they spend much of that 'freed-up' money on other goods and services, increasing employment in other areas. The net impact of +19 thousand jobs is comprised of a net growth of 129 thousand jobs in non-EII sectors and a net loss of 110 thousand in EII sectors. This means that, even though the CIRC pathway has the most positive employment outcomes at EU27 economy-wide level, there is a substantial structural and employment shift involved in such an outcome.

In the CCS scenario there are major impacts in non-EII sectors in employment terms. At EU27 level, overall employment by 2050 is about 80 thousand lower than in the reference scenario. The CCS pathway impacts are a result of multiple forces acting at the same time: due to decarbonisation, revenues from ETS and carbon pricing are declining, thereby lowering the revenues that the government can use (consequently increasing taxes through revenue recycling). At the same time, the deployment of CCS means that many of the investments otherwise necessary for decarbonisation (electrification, energy efficiency, etc.) do not happen in this pathway. The combined impact of these forces is that, while EII employment might not decrease severely, employment in other sectors does (due to lower investment and less available government revenues).

The INNO scenario is somewhat similar to the CCS one but with much more limited impacts, even though the same forces are at play here as well. But, in this case, the innovation needs (e.g. electrification, hydrogen production) also require substantial investments which offset the negative effects of the processes described above.

Taken together, the scenario results show how, in the CIRC pathway, a large-scale transformation of the labour market is necessary but in the context of an overall positive net effect on employment. The results also show how CCS deployment can lead to some unfavourable outcomes: lost carbon revenues bundled together with weaker incentives for investment might mean jobs are retained in EII but lost in other areas. Finally, the INNO pathway shows that these adverse effects can be offset as a result of innovation investments.

Figure 6 Economy-wide employment impacts, EU27, compared to reference scenario

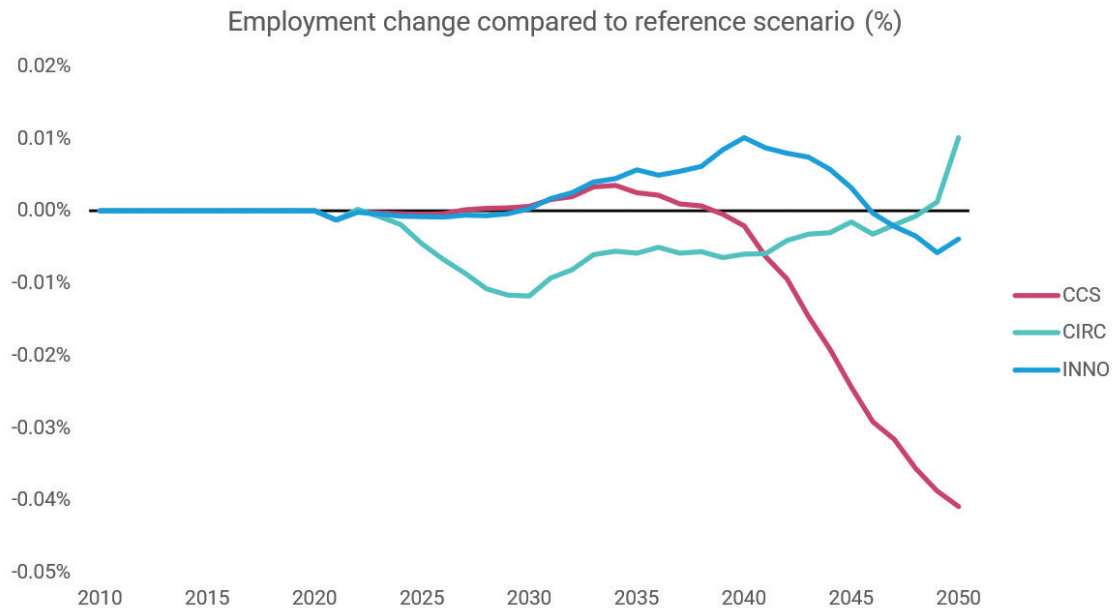
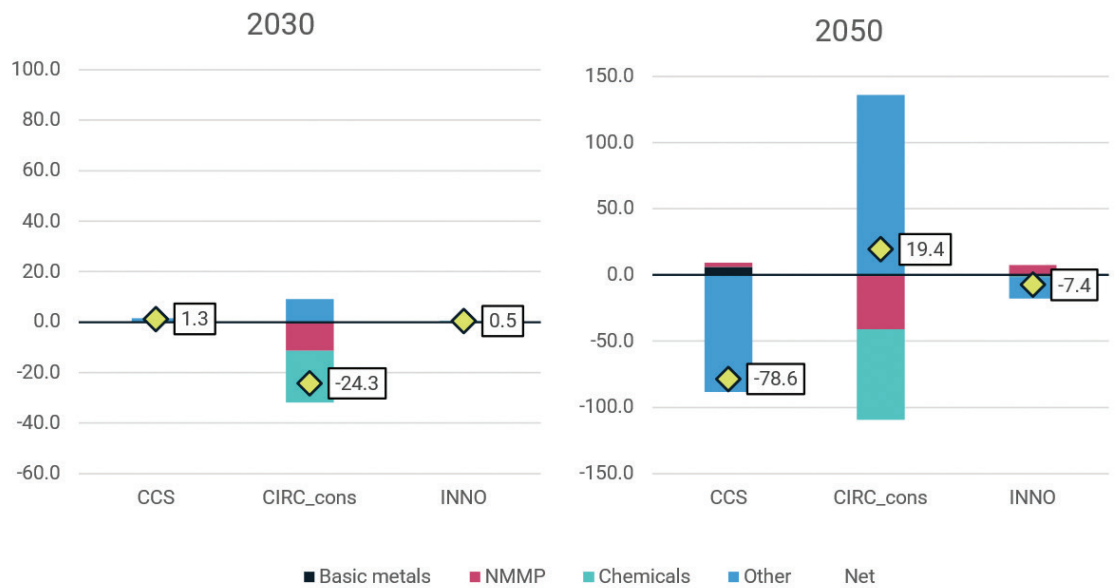


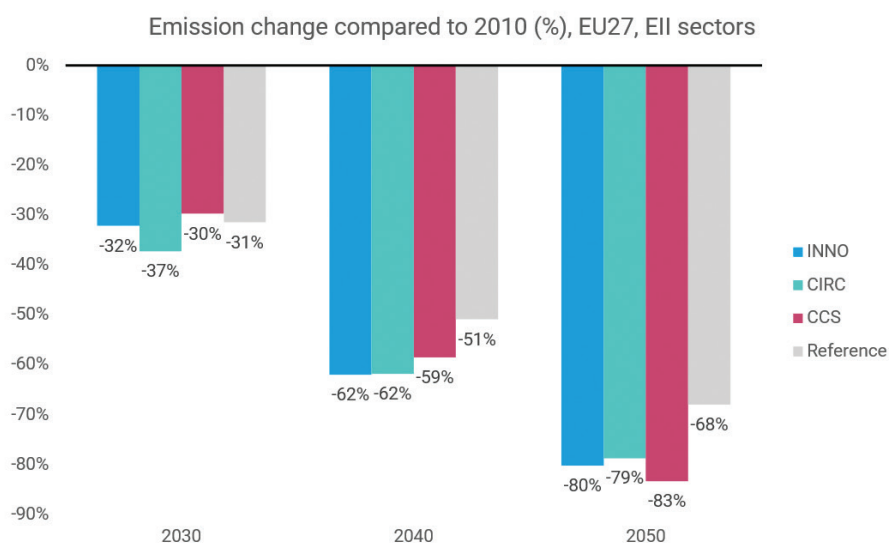
Figure 7 Economy-wide employment impacts, EU27, compared to reference scenario, sectoral breakdown



Emission impacts

Figure 8 shows the emission impacts of the simulated scenarios. The reference scenario already achieves substantial emission reductions in EII sectors, an effect driven by its assumption of a naïve decarbonisation pathway. Increasing carbon pricing, high-level policies and energy efficiency measures all contribute to this reduction.

Figure 8 EII sector emission impacts, EU27, compared to 2010 emissions



The sectoral decarbonisation pathways, however, are designed to push EII decarbonisation even further, reaching a reduction of about 80 per cent by 2050 compared to 2010 emission levels. All three pathways are able to reach this goal, but with very different employment and sectoral outcomes (as discussed previously), as well as with different emission reductions within the sector. The emission results by industry are shown in the Annex; in the steel industry these targeted decarbonisation scenarios might even lead to small increases in emissions arising from the high-level policies within the reference scenario already having important consequences for steel decarbonisation.

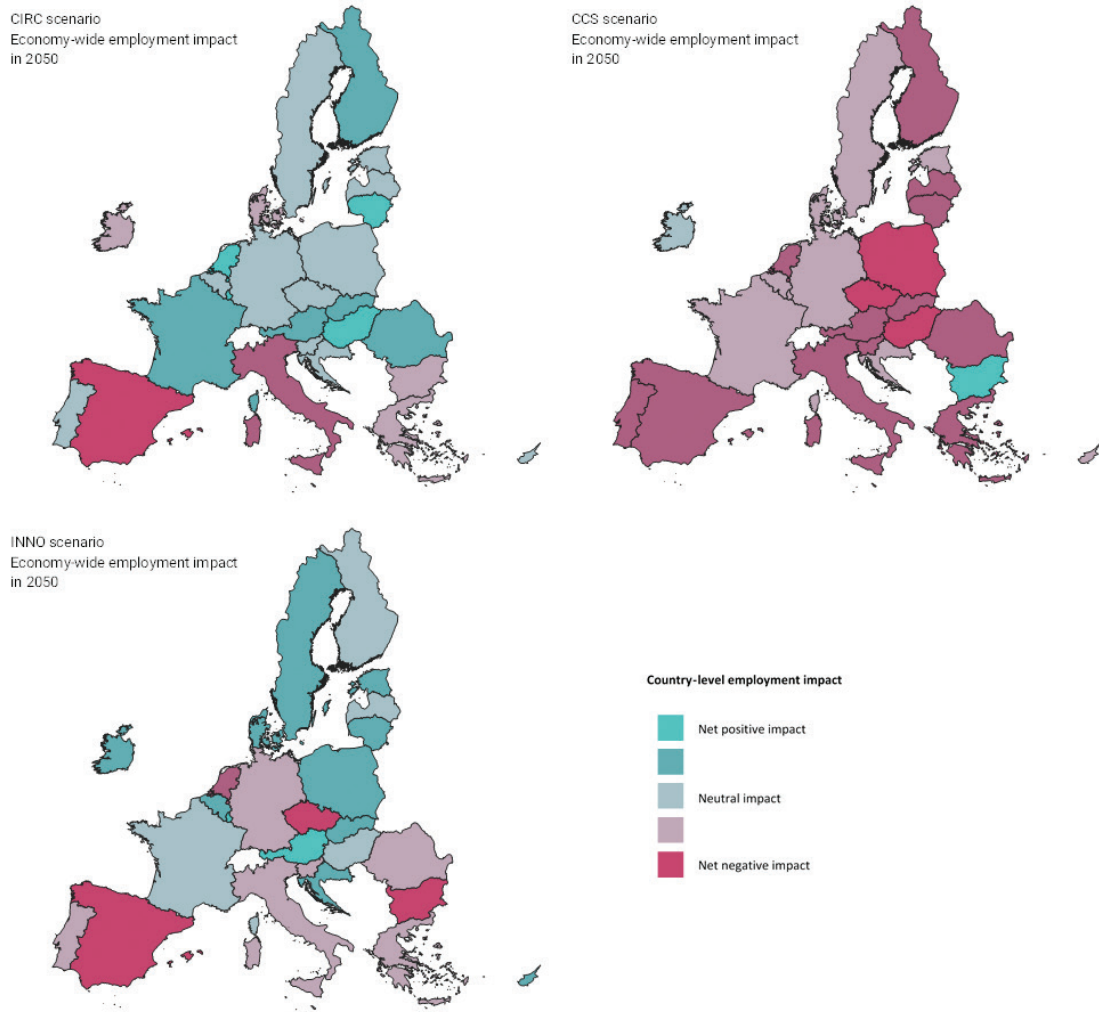
Differences across Member States

Given that E3ME is a multi-regional model, in which the EU27 is represented by 27 regions, one can investigate the differences across Member States in the results. Figure 9 therefore presents the economy-wide employment differences in the pathways at Member State level. The overall EU27 result of the scenarios was discussed earlier; the maps below present a more granular picture.

In the case of the CCS scenario we can observe that the effect is indeed negative in most countries, albeit perhaps less substantial in France, Germany and Sweden, while it could be positive in Bulgaria, driven by employment in the coal industry

which, in contrast to the reference scenario, continues to supply 4-5 thousand jobs in the Bulgarian economy.

Figure 9 Employment impacts (economy-wide) across Europe by 2050, EU27, compared to reference scenario, calculated as % difference from the reference scenario



In the CIRC pathway, there is a division between most northern and southern Member States. Most northern and central European states see positive impacts while some southern ones (Italy, Spain, Greece and Bulgaria) see negative impacts. This is to do with sectoral structure and dynamics in these countries: in central and northern states, increasing non-EII consumption easily offsets the losses in EII. But the results are dependent on several factors: how much money is ‘freed up’ by decreasing EII costs; how that is spent by households; and how employment in those sectors reacts when additional consumption creates demand.

Spain and Italy are two Member States in which the negative impacts (the loss of EII-related jobs) are much stronger than the positive impact resulting from increasing consumption. The model results indicate that, in Italy, as much as

29 thousand jobs can be lost in EII while the jobs gained in other sectors would amount to about 13 thousand;³ in Spain, a net 29 thousand loss can be observed, without non-EII adding much in terms of employment. Meanwhile, in northern and central countries consumption can largely offset the losses: in Germany, about 22 thousand jobs are calculated to be potentially lost in EII while over 26 thousand can be gained in other sectors. The case is similar in Hungary, where two thousand jobs can be lost in EII while the gains in other sectors amount to over seven thousand jobs.

Finally, in the INNO scenario the division is less clear-cut but, as discussed, the results here are also dependent on other factors. Investments towards innovation, power generation and hydrogen production drive some of the impacts but, at the same time, we have the loss of government revenues (carbon tax revenues) while there are also EII price impacts coming through.

In Spain, for example, there are employment losses in EII partially offset by investment in power generation, but the magnitude is insufficient to offset the adverse impacts in full. Meanwhile, in Austria the losses in EII (especially in steel) are countered by investment and resulting employment in power generation. But Poland might be the most prolific case: employment in the gas and coal industries drop, but there are major increases in chemicals and non-metallics (price effect), coupled with employment in hydrogen production (as industries switch fuel) and increased employment in electricity production (both because of electrification and increasing electricity demand because of hydrogen production).

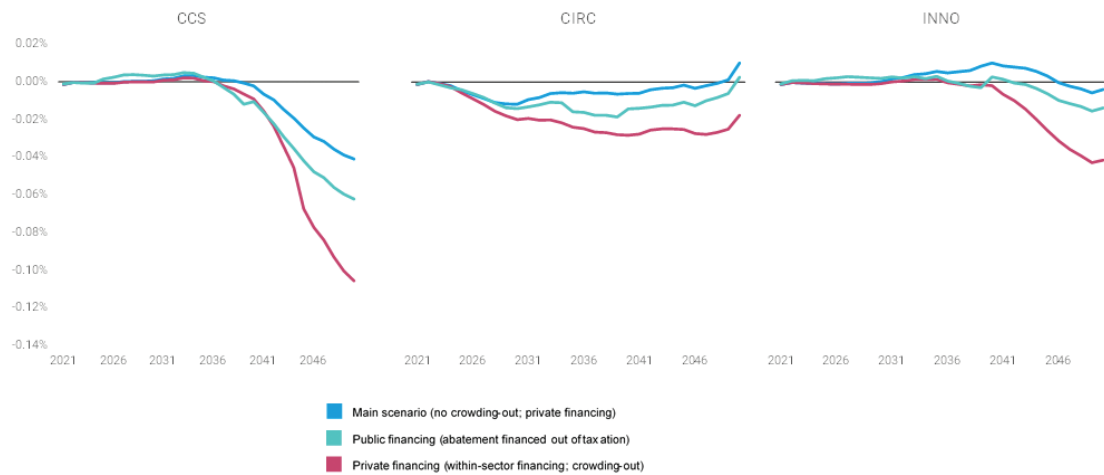
Cases of financing

Modelling establishes that the means of abatement financing does have an impact on the results. In the modelling we tested three scenarios of abatement financing. The main scenario (whose results we have discussed so far) assumes that ‘new’ financing is available for the implementation of targeted sectoral abatement in EII. Green financing sources, such as sustainable investment and/or green bonds, can be one such source, bringing in ‘new’ money for financing these projects. This approach is also in line with endogenous money theory (Mercure et al. 2019) and does not assume any investment crowding-out effects. Nevertheless, we have also tested two other financing options: (a) within industry financing with full crowding-out; and (b) public financing with taxation.

Figure 10 shows the economy-wide employment outcomes of all these scenarios. Both alternative financing scenarios lead to worse labour outcomes than the main scenario; this is as expected since, in the main scenario, new sources of financing are being brought in whereas, in the other two cases, ‘existing’ financing sources are redistributed towards these goals.

3. Both by 2050.

Figure 10 Impacts of financing options on economy-wide employment impacts, EU27, compared to reference case



Public financing leads to a slightly worse employment outcome than the main scenario. Here, the costs of sectoral abatement are paid by out of the public purse via government revenues; to maintain budget neutrality, taxes (labour, sales, income) are slightly increased which results in a reduction of consumption. This, in turn, means lower production and acts as a drag on employment.

In the case of private financing with crowding-out, we take an extreme approach and assume that EII sectoral abatement is fully financed from internal resources and that there is no ‘new’ money supporting abatement. Therefore, in this case abatement investments completely ‘crowd-out’ other productive investments in EII sectors. This leads to substantially worse employment outcomes: the investment need is concentrated in a small number of EII industries which forfeit some of their other investments in order to carry out the necessary abatement. Demand as a result of these lost investment activities is therefore lower, leading to decreased output in sectors supplying the capital goods purchased by these industries.

It is notable, however, that the type of financing generally has the lowest impact in the case of the CIRC pathway and the highest in the case of the CCS one. This is explained by the abatement cost differences between the scenarios. The CCS scenario has the highest per emission unit abatement cost while CIRC – mostly built on efficiency, changes in consumption and design choices – has the lowest.

5. Effects of a carbon border adjustment mechanism (CBAM)

The carbon border adjustment mechanism (CBAM), as proposed by the European Commission (EC) as part of its Fit-for-55 agenda, is a tool that is primarily aiming to limit carbon leakage. The goal of the CBAM is to ensure the competitiveness of European industry, which faces higher environmental regulations than third-party countries, while limiting carbon-leakage stemming either from offshore production or the import of goods from countries with inadequate environmental regulations.

Current EC plans aim to establish a fully operational CBAM from 2026 alongside the phasing-out of the current system of free allocations given to emitters. Nevertheless, there are still various questions surrounding the implementation and introduction of the CBAM system. These include possible legal challenges and unilateral responses from trade partners as well as questions about the feasibility of implementation (e.g. the reliable measurement of carbon intensity and acknowledging third-party emission permits).

In the modelling, we consider a simplified CBAM version, introduced from 2026 and covering the target EII sectors. Crucially, we exclude any electricity trade in order to be able to carry out the modelling on this basis.

Modelling CBAM impacts

The modelling considers the introduction of a CBAM system from 2026 onwards. The simulated CBAM covers the three industries that are considered to be EII decarbonisation targets: iron and steel; non-metallic minerals (cement); and chemicals.

Technically, the CBAM is modelled as a tax on import prices for EU countries, with exceptions for announced third-party countries and with decreased rates for those countries which have adopted a net zero carbon pledge. If a country exporting to the EU belongs to none of these categories, then a tax, equivalent to the ETS price, is applied to its products. The total amount of the tax is calculated from the estimated carbon intensity of the exporting sector in its home country and the EU ETS price.

It needs to be noted that this modelling approach is a simplification of how the CBAM will be implemented in reality.

First, CBAM will, based on the current proposal, include electricity imports but, due to the nature of electricity interconnections and the high volatility and high variability of electricity trade pricing, we do not take electricity imports into account here.

Second, it is likely that CBAM coverage will be specified at CN product code level and levied on certain products. NACE sectors (and their E3ME equivalents) are broader categories that necessarily include more than just the selected products (Table 1 shows the degree of correspondence). In the modelling we apply the CBAM to these broader categories. This leads simultaneously both to over- and under-estimation. On the one hand, due to applying the CBAM to a larger sector, we might over-estimate its effects but, on the other, we are applying the CBAM to a carbon intensity that is calculated based on the entire sector which is, therefore, likely to be much lower than if we took emission intensity at product level. Thus, these two effects act in opposite directions and might cancel each other out, leading to a less biased estimation.

Table 1 CBAM coverage (CN codes) and E3ME/NACE sectors

Products	Relevant E3ME sector / NACE sector	EU imports of products covered by CBAM (billion €, 2020 prices)	EU imports of products in E3ME sector (billion €, 2020 prices)	Share of CBAM product trade in the broader E3ME sector
<ul style="list-style-type: none"> • Iron and steel • Iron and steel articles • Aluminium 	Basic metals	89.2	114.9	77.6%
<ul style="list-style-type: none"> • Fertilisers • Inorganic chemicals 	Other chemicals	17.9	152.1	11.8%
<ul style="list-style-type: none"> • Cement 	Non-metallic mineral products	0.2	21.8	1.1%
<ul style="list-style-type: none"> • Electrical energy 	Electricity	3.6	4.2	85.4%

Concerning the introduction of CBAM, free ETS allocations also need to be considered. It has been suggested that the introduction of a CBAM system will be followed by the complete phasing-out of free allocations from the ETS. Crucially, in the modelling we assume that firms take an ‘opportunity cost’ approach to the costs of the ETS. This means that, regardless of them obtaining the necessary permits through auctioning or free allocations from the government, they factor permit costs into their prices. The underlying assumption is the opportunity cost treatment of the free allocations on the firms’ side: as they are able to trade permits they should be able to sell free allocations if there was an overallocation in the system; hence, by emitting and then surrendering permits for their own emissions, there are opportunity costs – the forfeited revenues from the sale of the permits.

Nevertheless, our understanding is that the opportunity cost approach might not cover all sectoral behaviours. There are two factors that need to be considered: (1) the low ETS price over the last decade due to overallocations; (2) higher corporate profits through the sale of free permits and cost pass-throughs. Together, these might lead to expectations of higher baseline profit levels and low or no ETS

awareness on the corporate side. Therefore, we posit that the phasing-out of free allocations might act as a shock to the system which may lead to ETS price hikes. To test the effect of this we also report simulation results from a scenario in which the ETS price increases above the expected level due to the joint introduction of CBAM and the phasing-out of free allocations.

Results

Figure 11 shows an overview of the GDP impacts of CBAM for each scenario for the EU27. GDP outcomes are about 0.45 percentage points higher in all cases with the CBAM introduction than without it. The impacts are consistent across pathways and across time (i.e. they are around 0.27 points in 2040, increasing to 0.43-0.45 points by 2050). Imports (and exports) of the EII sectors shrink but, due to revenue recycling (collected CBAM revenues are used to decrease labour and consumption taxes), consumer sectors boost their sales, production and even their trade activity. This is explained by increasing import prices combined with the opportunity cost approach treatment of ETS costs which, together, cause the relative prices of domestically produced EII goods to decrease. This is further complemented with a growth in domestic investment as steel producers shift away from scrap metal importing and recycling due to increasing costs, favouring instead other types of production.

Figure 11 Impacts of introduction of CBAM on economic activity (GDP) compared to reference scenario, EU27

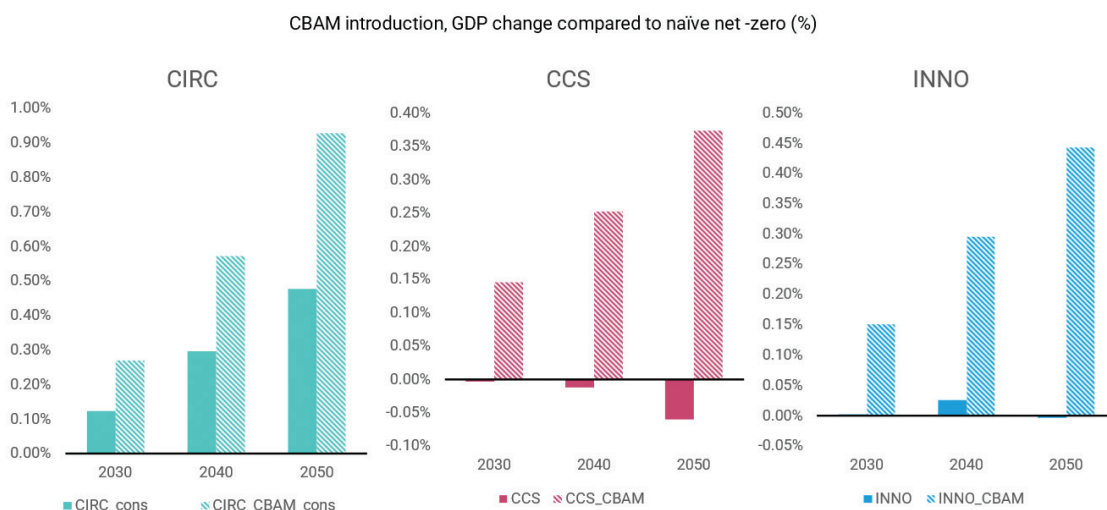
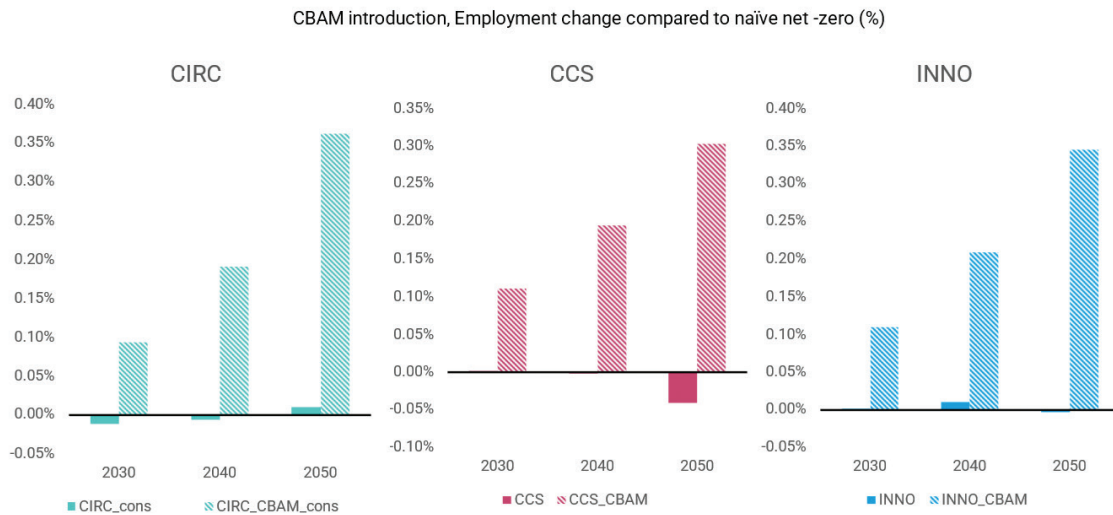


Figure 12 Impacts of introduction of CBAM on employment compared to reference scenario, EU27



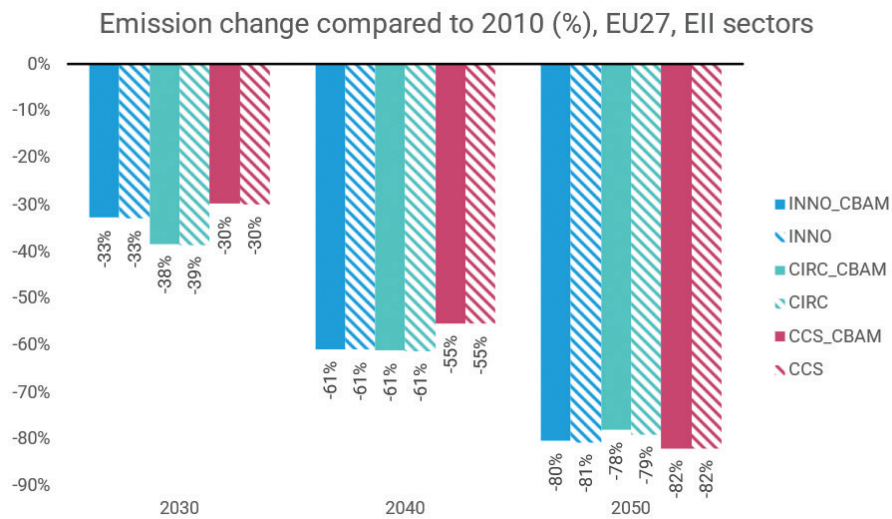
The employment impacts at macroeconomic level, shown in Figure 12, again demonstrate the substantial positive impacts of the introduction of CBAM across the EU27. Most of the realised employment gains appear, however, outside the EII sector due to the revenue recycling mechanism. Revenues collected at the level of the Member States from CBAM are recycled towards tax decreases which substantially boost production; this again is complemented with the effects stated above.

Environmental impacts

It is crucial to understand that these figures compare the simulation outcomes to a baseline scenario, in which ETS prices have already been increased compared to the levels observed today. Therefore, the scenarios capture the marginal effect of the introduction of CBAM, but do not assess the effect of increased carbon prices (i.e. ETS price increases and the phasing-out of free allocations) on industry: those effects are already included in the baseline as well.

Nevertheless, these developments also have environmental impacts. These are mostly due to the rebound effects of revenue recycling result in more consumption. Domestic emissions might increase as production is shifted from global to local and consumption increases as a result of that.

Figure 13 Impacts of the introduction of CBAM on emissions compared to 2010 emissions, EU27, EII sectors



As Figure 13 shows, this might result in slightly lower emission reductions in the case of the CIRC and INNO pathways by 2050 than in the case of no CBAM implementation.

6. Conclusions

Figure 14 shows an overview of some of the highlighted impacts and aspects of the results stemming from a consideration of the pathways featured in this Paper.

The INNO pathway produces slightly negative employment impacts at the level of the wider economy (EU27 aggregate), but EII employment stays positive compared to the reference case. Transformation need is limited – new energy sources and the deployment of innovative technologies that can decarbonise energy use in EII are expected to follow on from increased investment (power generation, new processes, hydrogen production, etc.), balancing out the negative employment impacts of losing government revenues (due to shrinking carbon taxation revenues). Decreasing prices in EII sectors (due to energy cost and carbon cost decreases) raise demand for the sector's products which keeps EII employment high. Country differences are substantial in this case, because the impact is dependent on a number of factors: price impacts and elasticity for EII products; employment changes in energy supply; the overall effect of EII fuel switching; and, finally, the changes in government revenues.

Compared to this, the CCS pathway comes with a more negative economy-wide employment outcome, although EII employment is highly positive in this case. This is explained in that the expected deployment of CCS renders a sectoral transformation unnecessary in this scenario. Nevertheless, it also means that, while government revenues decline (since carbon tax revenues shrink), there is no investment effect (as in the case of INNO) to offset this. While abatement costs are high (stemming from investment into CCS), it is not enough to balance these other forces. Thus the result is an overall decrease in consumption, resulting in employment losses in non-EII sectors. Country-level impacts are rather uniform in this case; however, coal producing and using countries (such as Bulgaria) might respond better.

Figure 14 Overview of modelling results (EU27) for the highlighted impacts of the pathways, compared to the reference scenario

	Innovation led INNO	Carbon capture CCS	Circularity and efficiency CIRC
Net labour outcome	Slightly negative	Negative	Slightly positive
EII employment	Slightly positive	Positive	Negative
Labour transformation need	Some transformation	No transformation	High / major transformation
Tax increase / government revenues	Decreasing revenues / slight increase in taxes	Decreasing revenues / slight increase in taxes	Limited change
Gross investment needs	High investment	Limited change	Limited change
Abatement costs	High	Highest	Limited
Country differences	High regional differences	Mostly similar impacts	Some regional differences

The CIRC pathway produces results that are somewhat different from the above two, although our assumptions behind what is happening are rather different as well. Net labour outcomes are slightly positive in this case, but this is an outcome of a large-scale labour market transformation. EII employment shrinks in this scenario but employment in other areas – such as wood-based products, consumption goods and services – increases. This is explained by household savings resulting from the efficiency, consumption and design choices implicit in the scenario. Traditional EII products are assumed to be more long-standing and consumed less, which can release money for consumption in other areas. Due to this type of effect, the changes to government revenues and the investment and abatement costs themselves are rather limited. The country-level impacts are dependent on the strength of the losses in EII sectors and the employment dynamics of those sectors to which consumption is shifting.

All in all, the results of the modelling indicate that high emissions reductions in EII (at close to or above 80 per cent compared to 2010 levels) is possible in multiple ways. However, different pathways yield very different labour and economic outcomes and need different conditions to be fulfilled. In all cases there are major questions regarding their feasibility. Can CCS be deployed on the scale that would be necessary? Is the large-scale labour and sectoral transformation necessary for the CIRC pathway actually possible? Can innovation provide us with technologies to employ hydrogen, increase electrification and introduce new, more carbon-friendly processes in EII? These are questions where further research is necessary to map out the possibilities, costs and opportunities. Meanwhile, attention also needs to be paid to the cross-country differences: while a certain country might

be better suited for a given way of decarbonising, the same pathway might create unintended consequences in another.

This study also modelled a simplified version of the CBAM system proposed by the Commission. The simulation assumes that the CBAM is introduced from 2026 and that it covers EII sectors, increasing import prices for third-country goods. It also assumes that revenues, captured through the CBAM, are recycled towards tax measures to maintain budget neutrality.

The simulation results show that, given these assumptions, the CBAM can result in substantial economic and employment gains as it decreases relative prices for domestic production and therefore shifts demand from imports to local production. Meanwhile, the collected and recycled revenues create excess consumption, thus driving the economy and employment, mostly in the services sector. Nevertheless, the results also show that, this increased (rebound) consumption can decrease the impacts of the environmental measures via an increase in local emissions.

In the current landscape, against the background of new geopolitical and energy policy developments, such as the war between Ukraine and Russia and the resulting REPowerEU package, there are some likely directions on the horizon when thinking about the future of industry. One of these notions is that decarbonisation is becoming a necessity rather than an opportunity, not only because of climate change mitigation but also because energy security concerns make fossil-dependency a heavy burden for EU economies. Therefore fossil-fuelled processes might become simply less realistic and/or more expensive in the future. This could decrease the feasibility of a CCS-focused pathway.

But this does not necessarily mean that these developments favour other pathways. Supply-chain and logistics issues, as well as sanctions against Russia and the disruption of production in Ukraine, might also make it more costly to supply raw materials for European EII. For example, steel production, given that the CIRC pathway employs production from scrap metal, might see limited opportunities if the availability of imported materials shrinks.

REPowerEU proposes a speeded-up low-carbon transformation through energy efficiency, renewable deployment and the diversification of import sources. Importantly, for EII this would entail replacing a substantial part of fossil fuels (especially natural gas) with renewable energy and green hydrogen. This resembles our INNO pathway but, as is highlighted there, uncertainties about innovation outcomes and questions about technological feasibility are still outstanding. However, the modelling indicates that, if the necessary investment is raised, then not only might the expected decarbonisation be possible but we might additionally see acceptable labour outcomes across the EU economy as a whole. This is so not least as a result of renewable energy and hydrogen creating extraordinary economic and employment opportunities.

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Annex

Employment in EII

Figure 15 Unit cost and price effects in EII sectors in the CIRC scenario, EU27 average³

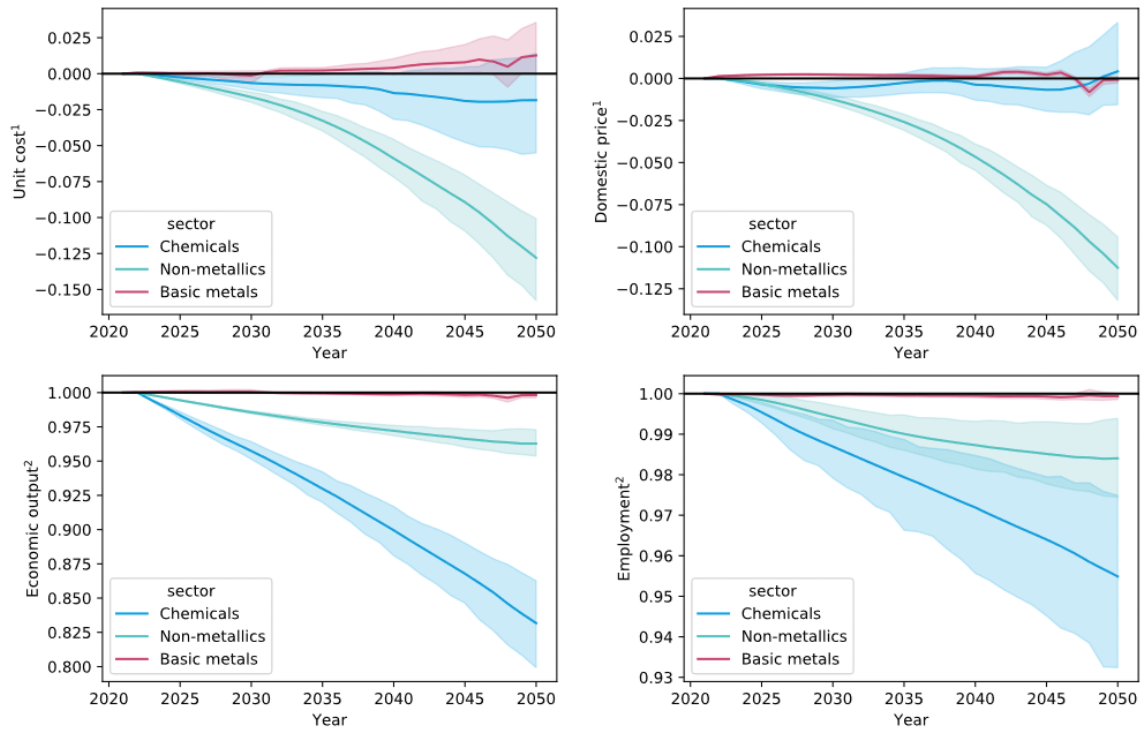
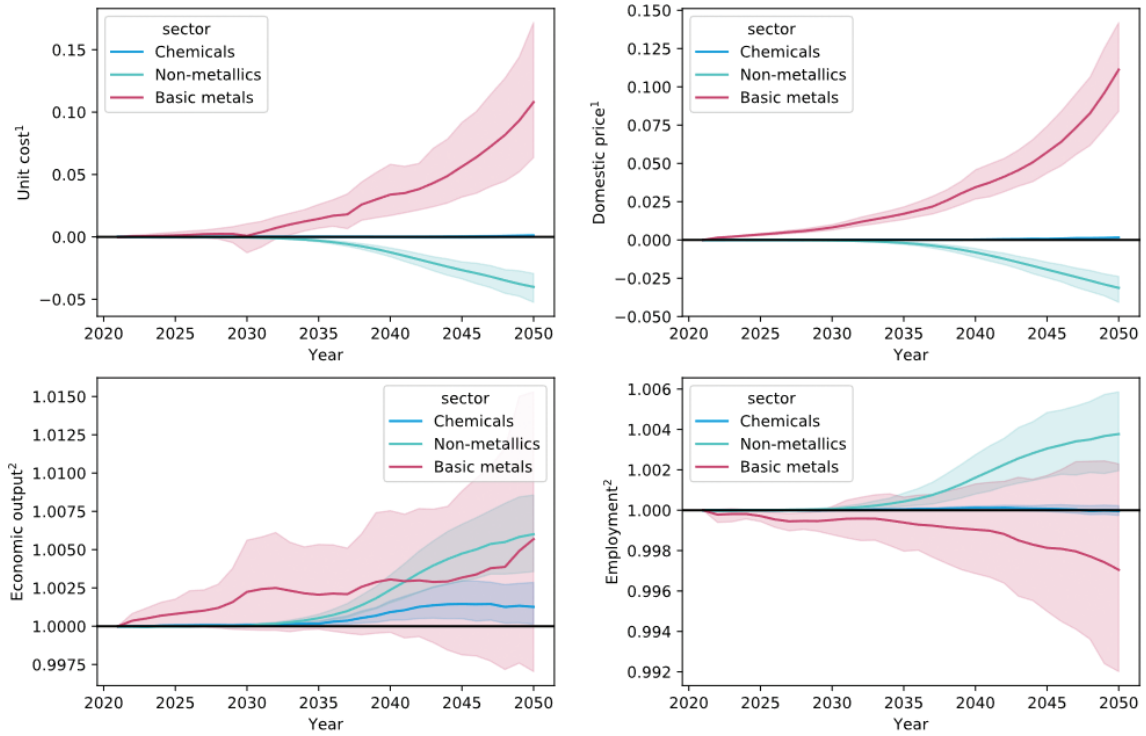


Figure 16 Unit cost and price effects in EII sectors in the CCS scenario, EU27 average³

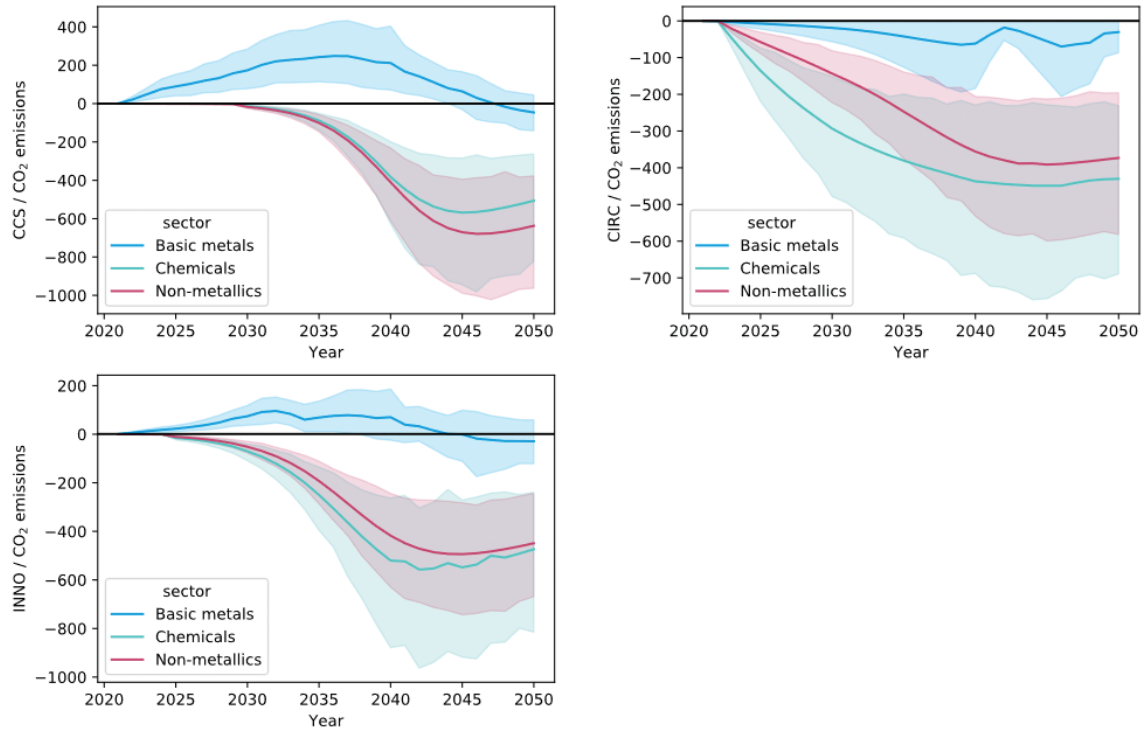


Notes:

- 1 – Percentage point difference from the reference case, unit is price index, with 2010=1.0
- 2 – % difference from the reference case, for output, unit is million EUR constant 2010 prices, employment is in '000 people
- 3 – Greece, Luxembourg, Cyprus and Malta are excluded because of model instability

Emissions in EII

Figure 17 Emission changes (CO2) in EII sectors in the scenarios, EU27 average¹



Notes:

1 – Greece, Luxembourg, Cyprus and Malta are excluded because of model instability

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