Agora Energiewende

STUDY

EU climate policy between economic opportunities and fiscal risks

Assessing the macroeconomic impacts of Europe's transition to climate neutrality

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Preface

Dear reader,

The reforms adopted since 2019 under the European Green Deal initiative will reshape the European economy, while being just part of the regulatory changes that will be needed to reach climate neutrality in the European Union by 2050. Rising carbon prices, stronger regulatory measures and the energy price crunch in 2021–2022 have sparked a broad debate on how Europe's transition to climate neutrality will affect our standards of living and the distribution of income across Europe.

At the moment, there is a large climate investment gap that Europe needs to close in a challenging geopolitical, fiscal and macroeconomic environment: for the rapid scaling of clean energy infrastructure such as power grids, to make clean heating or mobility solutions affordable to low-income households with little savings or to leverage the private investments into the transition. It is clear that the transition poses a huge challenge to public budgets.

Based on an analysis by Oxford Economics, this report offers new insights on the macroeconomic and fiscal implications of reaching climate neutrality in Europe. We put special emphasis on how national government revenues and debt levels are projected to change as fossil fuels are gradually phased out, and what this implies for the EU economic governance and financial framework.

I hope you enjoy the read.

Matthias Buck
Director Europe, Agora Energiewende

Key findings at a glance

1 **Europe can both reach an ambitious 2040 climate target and grow its economy.** The EU will likely aim for a 90 percent greenhouse gas emission cut by 2040. The related green investments would help increase the EU GDP by around two percent, strengthen demand for EU manufacturing, and foster economic convergence between Western and Eastern Europe. The 2024–2029 EU legislative cycle will be crucial for setting the necessary financial and regulatory conditions for the EU to exploit the positive economic potential of the transition.

2 **Most EU governments cannot rely on carbon pricing revenues alone to finance their climate investment programmes.** The net amount available to EU governments from carbon pricing is expected to be on average 27.5 billion euros annually from 2030 to 2035. It turns negative after 2037, while EU-wide public spending needs exceed 200 billion euros per year in the 2030s. This finding calls for more flexibility for climate spending in fiscal rules and the examination of new revenue sources to complement carbon pricing.

3 **Italy and Spain – among the five countries analysed – will need additional fiscal consolidation for them to deliver both on their climate and debt reduction goals over the long term.** Despite the positive economic effect, these two countries' debt stocks will tend to build up unless governments carry out additional fiscal adjustments. EU member states should start to assess and address transition-related fiscal risks in debt sustainability analyses and national budget plans.

4 **Europe should ensure continued EU-level funding after 2026 when the Recovery and Resilience Facility ends to help safeguard climate action, especially in Southern Europe.** The social and political costs of additional fiscal adjustments pose risks to the implementation of climate policy. EU co-financing would bring substantial benefits for Europe as a whole, as those member states required to cut their public debt stock under the reformed EU fiscal rules account for 40 percent of Europe's greenhouse gas emissions.

Content

Executive Summary

The European Green Deal represented a paradigm shift in climate policy. However, it is just the beginning of a long policy journey that will lead the European Union (EU) to become climate-neutral by 2050. A new EU legislative cycle will begin in late 2024; a phase that will be crucial for setting financial and regulatory frameworks that can close the green investment gaps and properly support the private sector in the transition to climate neutrality. The EU greenhouse gas emissions reduction target for 2040 has yet to be agreed on, but it will likely be set around 90 percent, based on 1990 levels. While the technical feasibility of various 2040 target ambition levels has been assessed (ESABCC 2024 for example), there is only a limited number of independent studies on the economic and fiscal implications of reaching deep emission cuts by 2040.

Current and future climate policy will have profound macroeconomic implications, with effects rippling across sectors, influencing investment patterns and industrial structures, job markets, trade relationships and government budgets. The 2030s are expected to be the decade in which green investment reaches cruising speed, greenhouse gas emissions are tightly priced and regulated and the loss in fuel tax revenues begins to materialise in national budgets. Global industrial supply chains are in the midst of a deep transformation, with electric vehicles taking over the global automotive industry and energy-intensive industries increasingly switching to clean energy. Reaching deep emission cuts by 2040 will also require large investment by households and some degrees of lifestyle changes.

In order to better understand these effects, we commissioned Oxford Economics, an economic consultancy, to model the economic and fiscal implications of Agora Energiewende's EU Gas Exit Pathway, a techno-economic roadmap to the EU's 2050 climate neutrality goal (Agora Energiewende 2023) that reaches an 89 percent reduction in domestic greenhouse gas emissions by 2040. The analysis is carried out for the EU as a whole and it offers deep-dives on five member states, namely France, Germany, Italy, Poland and Spain, using Oxford Economics' Global Economic Model (GEM) and the Global Industry Model (GIM). While the EU Gas Exit Pathway determines the least-cost technology mix that can deliver the full decarbonisation of the EU energy system by 2050, the Oxford Economics models assess the effects that changes in energy costs, climate investment and energy-related tax revenues have on key macroeconomic and fiscal outcomes like GDP or public debt levels.

Drawing on Oxford Economics' analysis, this report offers new insights on the macroeconomic and sectoral effects of setting an ambitious EU climate target for 2040. It also contributes to the debate on the fiscal implications of reaching climate neutrality in Europe, which is still in its early stages. This report identifies future challenges that the EU fiscal and financial architecture will face during the transition to climate neutrality and thereby seeks to support expert discussions on these issues.

A reduction of EU greenhouse gas emissions by around 90 percent by 2040 compared to 1990 levels can be achieved with broadly positive macroeconomic outcomes.

Oxford Economics' models capture the multiple effects of climate policy using a theoretical framework where the economy is stimulated by green investment in the short to medium term, but only structural factors like productivity and the capital stock determine the long-run policy effects. At the same time, carbon pricing and emission standards raise the economy-wide cost of using energy as long as fossil fuels make a large share of the energy mix. The economic impact is determined by these two drivers, namely emission regulation and green investment.

The Oxford Economics' modelling of the assumptions provided by Agora Energiewende finds the EU's real GDP in 2040 to be around two percent higher than in a Baseline scenario that is not compatible with climate neutrality in 2050. The Western countries (Germany, France, Italy and Spain) should see a smaller gain, whereas Poland's real GDP is projected to increase by around five percent compared to baseline levels in 2040. These results contrast with the common view that decarbonising the European economy will come at a cost in terms of economic growth, and that countries like Poland would be impacted the most. In fact, several studies consider carbon pricing as a cost factor only, while our modelling approach also allows for assessing the additional investment wave that is triggered by carbon pricing. The resulting investment wave stimulates the economy, manufacturing activity, and productivity growth in the long-run.

The positive macroeconomic projections, especially for the short-term horizon, rest on the assumption that there are no substantial barriers to the ramp-up of climate investment. While green skill shortages and financial constraints for households and firms currently exist, the analysis considers that these issues are promptly addressed. If the climate-related regulatory and fiscal frameworks are set up in a timely and credible manner, workers will more likely be attracted to those sectors which are necessary for the rapid uptake of clean technologies. Financial barriers will have to be addressed with de-risking measures that expand the access to credit and reduce financing costs for green investors. If policymakers fail to address these framework conditions, higher carbon prices and tighter emission regulation will be needed to achieve the climate target. That worsens the economic outcomes.

By the mid-2030s, the erosion of fossil fuel tax revenues will dominate carbon pricing revenues and governments will have to find alternative ways of financing their climate policies.

The taxation of fossil fuels, notably gasoline and diesel for motor vehicles, generates substantial income for public budgets. The revenues from excise taxes alone were worth around 1.5 percent of GDP between 2015 and 2021 in the EU,[1] while those from value added taxes applied on these products should be added on top. In Slovenia and Greece, over the same period, fuel excise tax revenues reached up to 3.2 percent and 2.2 percent of GDP, respectively. Europe's transition to climate neutrality will see a gradual erosion of these tax revenue streams. The consumption of motor fuels and other fossil-based products will be reduced to marginal amounts, if not to zero.

According to our analysis, it should not be assumed that the energy transition will be *budget neutral*, meaning that carbon revenues will pay for the public climate spending needs. Even at their peak in the mid-2030s, a large fraction of the carbon revenues will be offset by the loss in energy tax revenues in most cases. Therefore, the financing of public programmes for climate investment will require governments to make room in their budget planning for this spending, which is between 0.7 percent and 0.9 percent of the EU's GDP in the first two decades. In the absence of fiscal adjustments through new taxes and spending cuts, the increase in the stock of public debt will be significant. The removal of (explicit) fossil fuel subsidies, a no-regret option, can temporarily ease the budgetary pressures but won't solve the problem in the longer term.

Nevertheless, when the positive growth effects of green investment are accounted for, the impact on public debt ratios – as percentage of GDP – will be significantly mitigated. Higher non-energy tax revenues and nominal GDP should keep the average debt-to-GDP ratio in the EU close to the baseline

1 OECD's *Environmentally related tax revenues* database (accessed on 5 December 2023).

levels over the long run. Not all countries will share this outcome, especially if the policy mix is tilted towards more subsidies and less carbon pricing. As the growth effect eases and carbon pricing revenues start declining in the mid-2030s, climate policies will push public debt levels higher in Italy, and to a lesser extent in Spain. In Italy, reaching climate neutrality will add between 25 and 33 percentage points to its debt-to-GDP ratio by 2050, relative to the Baseline scenario. However, these results are more optimistic than other studies assessing the public finance implications of the transition to climate neutrality, which expect a significant debt increase for the average advanced economy and not only for the most fiscally fragile countries.

The conclusion that climate policy will increase governments' financing needs, and possibly public debt stocks, should also not be misunderstood as an argument against taking action to make the European economy climate neutral. While not explicitly modelled for this analysis, failure to mitigate climate change means more climate-related damages to property and infrastructures and larger investments into adaptation measures, which both carry high public costs. Instead, understanding the fiscal risks related to the energy transition is useful for two reasons. Firstly, it creates the urgency to fully integrate both climate transition and physical risks into debt sustainability analyses and national budget plans. Secondly, it allows us to assess which fiscal frameworks are the most supportive of the energy transition.

Whereas the positive growth effect of the energy transition helps reducing the average public debt ratio in the EU, there are exceptions. Italy and Spain will find it harder to keep their debt levels on a declining path, as required by the EU fiscal rules.

The recently reformed EU fiscal rules, that is the common rulebook for national fiscal policy, require high-debt member states to reduce their debt-to-GDP ratio gradually but steadily, with the ultimate goal of reaching 60 percent of GDP. For countries like Italy and Spain, significant fiscal consolidation will be needed to comply with rules on deficits and debt levels, even in the absence of climate spending needs.[2] Our analysis shows that the transition to climate neutrality will tend to push high-debt countries out of their debt reduction path starting from the early 2030s, in spite of the positive economic backdrop.[3]

Additional austerity measures can lead to a more efficient use of public funds. However, they may also harm long-run growth and will raise the risk of political backlash and social unrest. This risk increases when the cause of the fiscal adjustments can be easily identified and when the adjustment period is very long. By weighing on budget balances, the energy transition will also force less indebted governments using public deficit limits (such as Germany's *Schuldenbremse*) to undergo fiscal adjustments that lead to similar political complications. This adds to the already existing challenges that governments will face with the implementation of carbon pricing and other kinds of emission regulation. Therefore, as climate change mitigation will mostly benefit future generations, it is warranted to introduce more flexibility for climate investment in EU and national fiscal rules.

National fiscal constraints affecting climate investment can also be eased with a higher share of EU financial contributions. As the reduction of greenhouse gas emissions benefits all EU member states, and considering that the EU's 2050 climate target can be reached only if all countries deliver, joint EU-level financing of climate investment also using EU debt is justified. In fact, the energy transition is one of the main pillars of the Next Generation EU, the debt-funded post-pandemic recovery instrument. In addition, a more centralised funding of EU public goods such as climate investment can improve allocation

2 For an assessment of the fiscal adjustments required by the Council's agreement, see https://www.bruegel.org/first-glance/assessing-ecofin-compromise-fiscal-rules-reform

3 In cases when the EU fiscal rules require debt reduction, the exclusion of co-financing of EU programmes from the net expenditure indicator is of limited help in taking climate expenditures out of national fiscal constraints.

efficiency and enable the most important spending needs in a context of fiscal constraints. Expanding the financial resources available for EU public goods in the next EU Budget period 2028–2034, following the conditionality-based mechanism of the Recovery and Resilience Facility, could create much-needed additional fiscal space for member states, which they can use to comply with strict EU rules on national fiscal policies and debt reduction plans.

1 Introduction

To meet its commitment under the Paris Agreement, the European Union (EU) has set the legally binding targets of becoming climate neutral by 2050 and reducing net greenhouse gas emissions by at least 55 percent by 2030, compared to 1990 levels. To achieve this 2030 target and lay the foundations for successfully making the European economy environmentally sustainable, the von der Leyen Commission put forward a comprehensive regulatory package named the European Green Deal. The European Green Deal has strengthened the existing emission trading system and established a new one covering road transport, buildings and small polluting plants, putting carbon pricing at the core of EU's climate action.

How will the transition to climate neutrality affect the economy? As carbon prices rise and emission regulation is tightened over time, energy will become increasingly expensive for households and firms. However, this classic effect is only part of the story. In response to environmental regulation, carbon emissions are reduced mostly through the adoption of clean technologies. The investment to switch away from fossil fuels generates demand for a wide range of capital goods, which has an impact on aggregate and industry demand. Emissions must be cut within a limited time horizon, which means the transition will, in several cases, accelerate the replacement of existing assets. Over time, the inflationary effects of emission regulations will fade away as renewables and energy efficiency help cutting costs. In the meantime, higher production costs and faster capital replacement will have spurred innovation and productivity improvements across industries, with a positive influence on potential output. The location of new global value chains of green technologies and critical materials will also determine the economic outcomes of the energy transition for the EU.

We commissioned Oxford Economics, an economic consultancy, to produce an assessment of the economic and fiscal implications of the energy transition up to 2050. The analysis is carried out for the EU and five member states, namely France, Germany, Italy, Poland and Spain, using Oxford Economics' Global Economic Model (GEM) and the Global Industry Model (GIM). The macroeconomic analysis takes the investment needs and energy mix dynamics from Agora Energiewende's EU Gas Exit Pathway, a techno-economic roadmap to the EU's 2050 climate neutrality goal. This energy system scenario is characterised by an accelerated fossil gas phaseout in the EU industry, buildings and power sectors. The focus is on climate change mitigation, hence adaptation and other environmental policy areas like biodiversity and natural resources preservation are not covered in this report.

Oxford Economics' GEM captures the multiple effects of climate policy using a theoretical framework where the economy is stimulated by green investment in the short to medium term, but only structural factors like productivity and the capital stock determine the long run effects of the transition to climate neutrality. Based on the assumed green investment and financing assumption, the GEM projects significant economic dividends from the energy transition, that are added on top of the avoided damages from climate change if the rest of the world follows suit.

2 Methodology

2.1 The macroeconomic modelling framework

The analysis is carried out with a suite of Oxford Economics' models: the Global Economic Model (GEM) and the Global Industry Model (GIM). Figure 1 depicts the role of each model, with the GEM simulating the macroeconomic outcomes that feed into the industry-level GIM. Infobox 1 offers a brief overview and presents the main features of each model.

The main idea is to feed a technological roadmap (that is, a scenario) describing the EU's energy system transition towards climate neutrality into Oxford Economics' economic models. The integration of energy scenarios into macroeconomic models is a standard practice in the assessment of climate and energy policies (see EIA 2020, Hallegatte et al 2023). The technological roadmap used here is the EU Gas Exit Pathway scenario of Agora Energiewende (2023), which is constructed with bottom-up

The Oxford Economics modelling suite

The GEM is a global macroeconometric model covering 85 countries, six regional blocks and the Eurozone. The model simulates the trade and financial interlinkages between these countries, creating a fairly detailed representation of the global economy. For Europe, the GEM features several sectors and macroeconomic variables. The financial sector is modelled alongside the public, business, and household sectors. The energy sector is also included in the GEM, modelling demand and supply for oil, fossil gas, coal and electricity in all individual countries and regional blocks. For oil, price is determined in the world market where supply is the aggregate output of all oil producing countries.

The underlying structure is based on economic theory. In the short run, the model has Keynesian features and economic activity is determined by both aggregate demand and supply factors. For instance, public investment raises GDP in GEM, while unemployment and economic activity can deviate temporarily from the long-term equilibrium values determined by structural factors. Over the long term however, a country's GDP is determined only by productivity, the capital stock and effective labour supply (adjusted for the level of education). Productivity is determined by a series of drivers including R&D investment and the distance to the technology frontier (growing faster in lagging countries), institutional quality, financial development, trade openness, and commodity prices. Unit labour costs and foreign demand drive industry competitiveness and exports.

The industry-level model GIM quantifies the dynamics of sectoral gross value added at two to three digits level. In each sector, product demand is determined by macroeconomic conditions, as computed by the GEM, economic activity in other industries and input costs, productivity and other factors influencing trade competitiveness. The GEM computes values for individual components of final demand, namely consumption, investment and exports (foreign demand), which are disaggregated into demand for narrow sectors based on input-output data. In turn, production in one sector generates demand for intermediate goods from others, and these network effects are also modelled. Changes in input costs, like labour and energy, affect sectoral output as demand shifts away to other products or to foreign competitors if sectoral costs rise excessively.

techno-economic energy models for the power, industry, and building sectors, and off-the-shelf scenarios for the transport, agriculture, waste, and land use sectors.[4] The technological roadmap sets the path for the GEM's energy mix, aggregate fuel intensities and energy-related capital expenditures up to 2050.

This bottom-up approach produces decarbonisation pathways that are robust from a technology standpoint. For instance, the deployment of renewables in the EU power sector is simulated with Artelys' state-of-the-art power sector model, accounting for the multiple technical constraints associated with intermittent renewables. These models are able to estimate quite accurately the investment needs required to meet predetermined emission targets, selecting the least-cost technology mix. While they are not able to factor in the general equilibrium effects that influence these investment decisions – through product, labour or commodity markets – their representation of the technology options is more robust than stylised functions used in macroeconomic models, often calibrated with scarce empirical evidence.

4 The energy modelling was carried out by Artelys (power sector), TEP Energy (buildings and district heating) and Wuppertal Institute (industry and refining). For the other sectors, the transition pathways follow the analysis of Transport & Environment (transport) and the European Commission (agriculture, waste, LULUCF). Agora Energiewende (2023) provides the full details of the methodology.

The modelling framework has other advantages over the use of standard macroeconomic models featuring simplified representations of the energy sector. Firstly, the modular approach allows the combination of the macro model GEM with a highly disaggregated industry model, which offers additional insights on the distributional impacts that complement the macroeconomic results. Secondly, the GEM offers a detailed representation of government budgets without requiring these budgets to balance in every period – as it is common in computable general equilibrium models (that is CGE) used for energy policy analysis. This setup allows us to explore alternative fiscal stances associated with climate policy, and to understand their implications for debt sustainability and economic growth.

A few characteristics of the methodology must be kept in mind when interpreting the model results.

→ The GEM assumes that output in the short term can be expanded using spare capacity and that there are no significant labour constraints, including skill shortages, that can hinder this expansion. However, increased demand may lead to higher inflation and interest rates, without fully crowding out green investment.
→ Here, the output of the energy modelling of Agora Energiewende (2023) is taken as input into Oxford Economics' models in one iteration, and the models

Modelling framework → Fig. 1

Agora Energiewende (2024)

are not solved recursively. As a result, our analysis does not account for the feedback effects that changes in economic activity and industrial production costs have on technology deployment. These effects can lead to higher or lower climate investment needs compared to the levels estimated in the sectoral energy models.

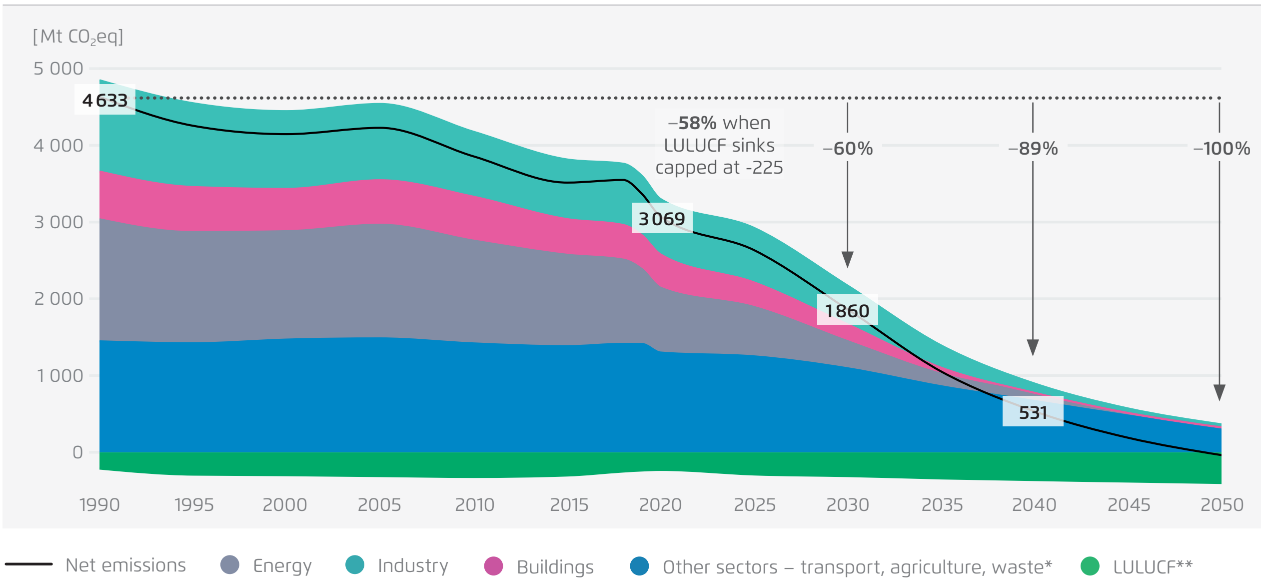
2.2 Sectoral technology roadmaps

The EU Gas Exit Pathway is a scenario of transition to climate neutrality by 2050 with a reduction in total fossil gas consumption by roughly a half versus 2018 levels by 2030. Fossil gas does not act as a *bridge fuel* from coal, and its consumption in the EU declines steadily after 2030 with a 90 percent reduction in 2040 and a complete phase-out of fossil gas by 2050. This is achieved through investment in clean energy and energy efficiency across sectors, especially in power generation, buildings and industry. Net EU greenhouse gas emissions fall by 60 percent compared to 1990 levels by 2030, and by 89 percent by 2040, before reaching zero in 2050 (Figure 2).

The energy sector undergoes a deep transformation with a fast upscaling of solar and wind power generation (Figure 3), which replaces existing fuel-based plants and accommodates for the rising electricity demand. The total capacity for solar and wind power in the EU quadruples between 2018 and 2030, reaching 1050 GW. This level is slightly lower than what is expected in the European Commission's RePowerEU plan. The fast penetration of renewable energy leads to a stark reduction in fossil fuel use in power generation, with fossil gas use down 76 percent by 2030 (relative to 2018) and oil almost phased out by 2025. Coal power generation is completely phased out in 2035, but it is already sharply reduced by 2030.

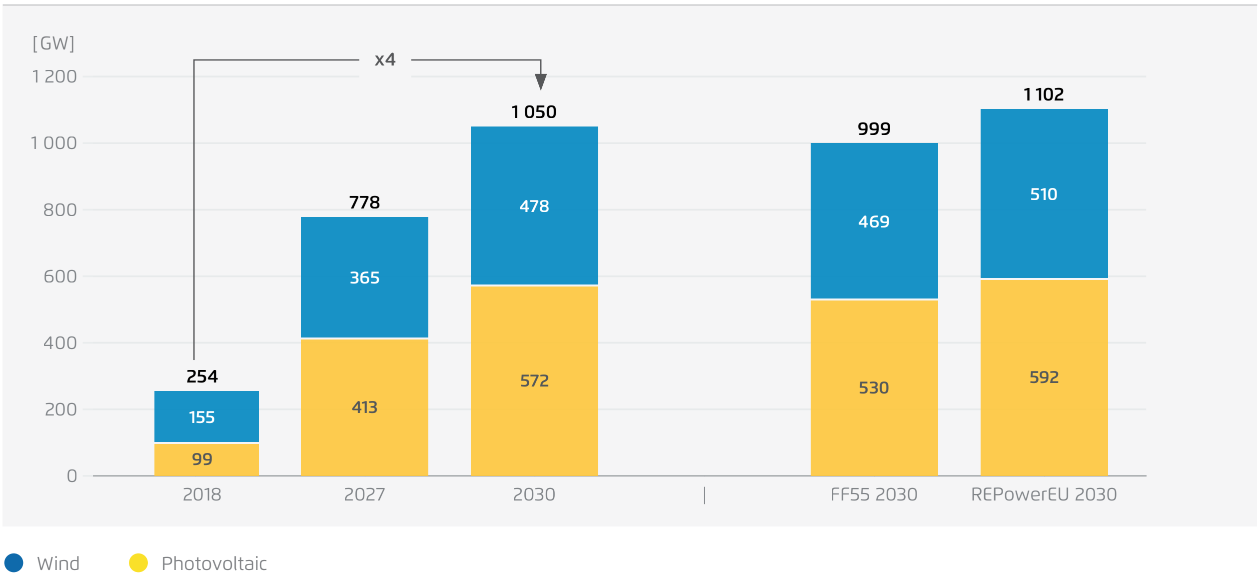
The building sector is one of the largest consumers of fossil gas in Europe and its accelerated phase-out of this fuel is a key element of the EU Gas Exit Pathway, which was created in the context of Russia's invasion of Ukraine and the RePowerEU plan. The sector decarbonises almost completely by 2040 through energy efficiency investment, the deployment of air-source and ground-source heat pumps and the expansion of district heating. Heat networks play a prominent role in the EU Gas Exit Pathway, especially

EU Gas Exit Pathway – GHG emissions by sector, EU → Fig. 2



Agora Energiewende (2023). Eurostat; Artelys modelling (2023) *Based on scenarios by Transport & Environment (transport) and the European Commission (agriculture, waste) **Based on the LULUCF+ scenario from the EC Climate Target Plan impact assessment (assumes a five-year delay)

Installed capacity for photovoltaic and wind power in the EU Gas Exit Pathway, Fit for 55 package and REPowerEU plan until 2030 → Fig. 3



Agora Energiewende (2023) and Artelys modelling (2023), Commission staff working document accompanying the REPowerEU plan (2022)

in EU member states where these technologies are already widely utilised. The EU floor area served by district heating more than doubles by 2040 and the network expansion comes along with the decarbonisation of existing heat plants, currently highly reliant on coal and fossil gas. The deployment rate of heat pumps in homes not connected to heat grids is of more than six million units per year in the EU in 2030 and the installed amount reaches 80 million by 2040 and 82 million units by 2050.

Industrial activities are decarbonised through a variety of technologies, depending on the sector and the specific process. The technology mix includes industrial heat pumps, electric boilers, hydrogen, biomass, thermal insulation, waste heat, and carbon capture and storage (CCS). Solutions fostering circularity in use of materials also contribute to the decarbonisation of the sector. Industrial fossil gas consumption in 2040 is 90 percent below the 2018 level, and coal is phased out almost completely by that date. Electrification and energy conservation substantially reduce the primary energy consumption of manufacturing, which contributes to shrinking the economy-wide use of fossil fuels and release of emissions.

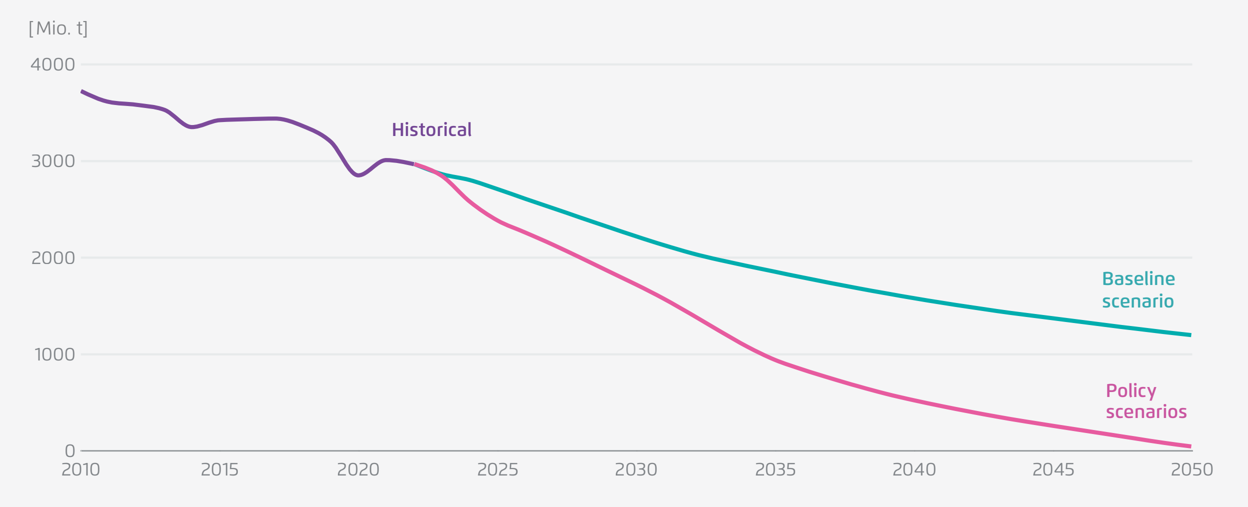
2.3 Economic policy scenarios

The same pathway of emission reduction and clean technology deployment foreseen in the EU Gas Exit Pathway can be achieved with different policy mixes, such as different combinations of carbon pricing, regulation, and investment subsidies. Therefore, we have constructed three *policy scenarios* that explore alternative approaches in setting the incentives to abate emissions, which are expected to have diverse economic and fiscal outcomes. These outcomes are assessed against a Baseline scenario; a standard procedure in economic analyses of climate policies. Figure 4 shows the emission trajectories corresponding to the different scenarios in Oxford Economics' modelling, which only covers CO_2 emissions.

Baseline scenario

The Baseline scenario is the reference scenario describing how the European and global economy will evolve up to 2050 without new major climate policy measures. It includes the implementation of adopted regulation while leaving the energy system to develop without additional regulatory constraints.

Carbon dioxide emissions by scenario → Fig. 4



Oxford Economics (2024)

The baseline plays an important role in the analysis because it allows us to distinguish, in the policy scenarios, the effects induced by tighter emission regulations from the outcomes of underlying structural changes in the economy (that is, demographics, general technological progress and economic development). Moreover, the Baseline scenario sets the framework for non-EU countries in the policy scenarios.

Oxford Economics' baseline forecast up to 2050 acts as a reference. It entails a slow diffusion of green technologies, leaving the global energy mix dominated by coal, oil and gas. Countries that have pledged to become climate neutral by mid-century fail to achieve this goal. Carbon capture technologies are not developed sufficiently, and average global temperatures keep rising, reaching 2°C above pre-industrial levels by 2050. The EU keeps reducing its carbon emissions, but not at the pace required to meet the 2050 net zero emissions target (Figure 4). Within the EU, CEE (Central and Eastern European) countries remain dependent on fossil fuels while Germany and Northern Europe invest in clean energy and energy efficiency at scale.

The baseline should not be interpreted as a no-policy scenario but rather as a *muddle-through* case. Most of the EU's Fit for 55 package and related legislative proposals has been agreed between the European Commission, Council and Parliament, and they introduce a significant amount of policy stringency over the next few years. For instance, the Baseline scenario accounts for the introduction of the new emission trading scheme covering road transport, buildings and small industrial plants. Nevertheless, in this scenario there will be a lax implementation of the new regulations – with interventions to cap the price of carbon in emission trading, for instance – and the setting of loose emission caps in trading schemes beyond 2030.

Policy scenarios: the Core scenario

The Core scenario represents a balanced mix of policies that deliver the transition to climate neutrality in all EU countries by 2050, with an accelerated phase-out of fossil gas. It starts from the implementation of the EU's Fit for 55 package and develops it further with additional measures over the next three decades up to 2050, both at the EU and national levels. The policy mix is composed of:

- → a second EU-wide emission trading scheme covering road transport and buildings;
- → sectoral regulation to limit end-use and process emissions, not only in sectors covered by carbon pricing but also in other sectors like agriculture;
- → public investment in energy and transport infrastructures;

→ subsidies to private investment in clean energy, energy efficiency, sustainable mobility and clean technology manufacturing.

Climate policy outside of the EU remains the same as in the Baseline scenario. That is, the US, UK and China, as well as the rest of the world, will not achieve climate neutrality by mid-century. Fossil fuels remain dominant in the global energy system and oil demand stays elevated, with coal-to-gas switching contributing to strong fossil gas demand outside of the EU. When climate policy is unilateral, as in this case for the EU in the policy scenarios, carbon intensive and trade exposed sectors are expected to see their cost competitiveness deteriorate. In the absence of carbon tariffs or similar measures, this effect weighs on economic activity and leads to more negative policy outcomes.

Carbon pricing

The main carbon pricing policies will be the two EU-wide emission trading schemes (ETS). The ETS 1 (power, large industry), already in place, will be accompanied by the separate ETS 2 covering road transport, buildings and small industrial emitters from 2027. The latter will significantly extend the carbon pricing coverage in the EU, as most member states do not have a national carbon pricing for those sectors. While both ETS are foreseen in the Baseline scenario, only the Core scenario remains in line with the EU's 2050 climate neutrality target and, therefore, has a tighter management of the emission caps through 2050. The result is a much steeper increase in the prices of emission allowances compared to the Baseline scenario.

The development of the price of emission allowances in the ETS 1 follows the forecast of BloombergNEF (2023) up to 2030. The nominal carbon price in the ETS 1 reaches 160 euros (EUR) per ton of CO_2 equivalent (tCO_2eq) in 2030, which is equivalent to about EUR 110/tCO_2eq in constant 2015 euro prices. This value is within the range of forecasts of prominent European carbon market models.[5] After 2030, the allowance price grows over time and reaches, in constant 2015 euro prices, EUR 396/tCO_2eq in 2040 and EUR 700/tCO_2eq in 2050. As for the latest EU-level agreement, free allowances to industry are gradually phased out by 2034 and full auctioning will apply to aviation as of 2026.

The carbon price in the ETS 2 starts in 2027 at EUR 55/tCO_2eq, reaches EUR 100/tCO_2eq in 2030 and then climbs to EUR 260/tCO_2 in 2040 and to EUR 440/tCO_2 in 2050, all values being in constant 2015 euro prices. As this emission trading scheme covers the energy use of households and small businesses, we envisage more moderate price dynamics through 2050 compared to the ETS 1, as policymakers will directly or indirectly intervene to moderate this price.[6] Indeed, the ETS 2 regulation foresees the release of allowances from the Market Stability Reserve to keep the allowance price below EUR 45/tCO_2eq (in 2015 euro prices) in the first years of operation. Our assessment is that the foreseen price stabilisation mechanism is unlikely to contain the strong market imbalances that would exist at such a low price.[7] Therefore, the analysis considers a real allowance price growing above the limit, even if at a relatively moderate pace.

Part of the carbon revenues is redistributed to households to mitigate the distributional effects. In the Core scenario, one third of all carbon revenues is recycled.[8] This is the average rate of recycling across different carbon revenue streams, from both EU and national ETS. Transferring carbon revenues back to households also reduces the negative impact that carbon pricing has on private consumption, as the results below show.

Carbon revenues not redistributed to households feed into public budgets. The assumption is not in violation of the EU's ETS regulation requiring member

5 See Pahle et al. (2022). That report refers to a previous vintage of BloombergNEF's carbon market outlooks.

6 Indirect intervention includes subsidies for building renovations and zero-emission vehicle purchases, which reduces the net cost of abatement and therefore the emission trading market price.

7 For a more detailed discussion, see Agora Energiewende und Agora Verkehrswende (2023).

8 Berry (2019) finds that, for the case of France, redistributing one third of the carbon revenues can be sufficient to offset the distributional effects and reduce energy poverty.

states to use carbon pricing revenues only for climate action. In the model, public climate investment is funded by the government budget and the only additional public spending taking place in the policy scenarios is related to climate policy. There is no compensation of carbon costs to firms.

Because of technical constraints, the modelling does not include a Carbon Border Adjustment Mechanism (CBAM). This is the case even if the scenarios assume a unilateral move by the EU, and that the rest of the world does not follow the EU in the more ambitious policy path. The CBAM could mitigate the negative effects of carbon pricing and emission regulation on external competitiveness (substitution effect), but it also makes goods for EU consumers and producers more expensive because imports are more costly (income effect). These effects also differ depending on whether only upstream or also downstream sectors are covered by the CBAM. Therefore, the net effect of such trade measures on GDP and exports is unclear,[9] relative to our scenarios, and it would require a dedicated analysis.

No changes in energy taxation are envisaged here, and the current fuel and electricity tax structure remains at baseline levels. Carbon pricing is therefore the only market-based policy instrument considered in this study. This approach may appear reductive. The removal of fossil fuel subsidies is one way to align incentives towards decarbonisation while raising public revenues. The same result can however be obtained by carbon pricing, even if a higher carbon price is needed compared to a situation without explicit fossil fuel subsidies. Most estimated fossil fuel subsidies are implicit,[10] meaning that the price misalignment is due to the lack of carbon pricing rather than to the presence of explicit subsidies to fossil fuels. Moreover, it could be argued that cutting energy taxes while carbon prices rise would help alleviate the impact on the most vulnerable consumers. Targeted support can be done similarly by using carbon pricing revenues.

Finally, a caveat must be highlighted. Carbon prices and the real price of green investment goods are exogenous in each scenario, and they do not respond to changing macroeconomic conditions. If climate policy brings about economic activity, then carbon prices in emission trading would fall as a reaction. Such second round effects are not accounted for in the analysis.

Other climate and energy regulations

The model takes regulatory measures that complement carbon pricing at EU and national level into account. Sectoral regulation is modelled in detail in the techno-economic sectoral modelling underlying the EU Gas Exit Pathway scenario, while the macro model GEM tracks broad trends in the stringency of environmental regulation. This stringency is measured by a shadow carbon price, affecting production and consumption costs but not generating revenues for governments. The Core scenario assumes that emission regulation tightens over time, and that it plays a dominant role in sectors not covered by carbon pricing, like agriculture. Together with the explicit carbon pricing, shadow carbon pricing makes the **effective carbon price**, a synthetic indicator of emission-related regulation, which is often used in integrated assessment models and macroeconomic applications. Figure 5 shows the evolution of the effective carbon rates in each scenario, with the pace of policy tightening accelerating in the early 2030s as the economy must deal with more expensive abatement options.

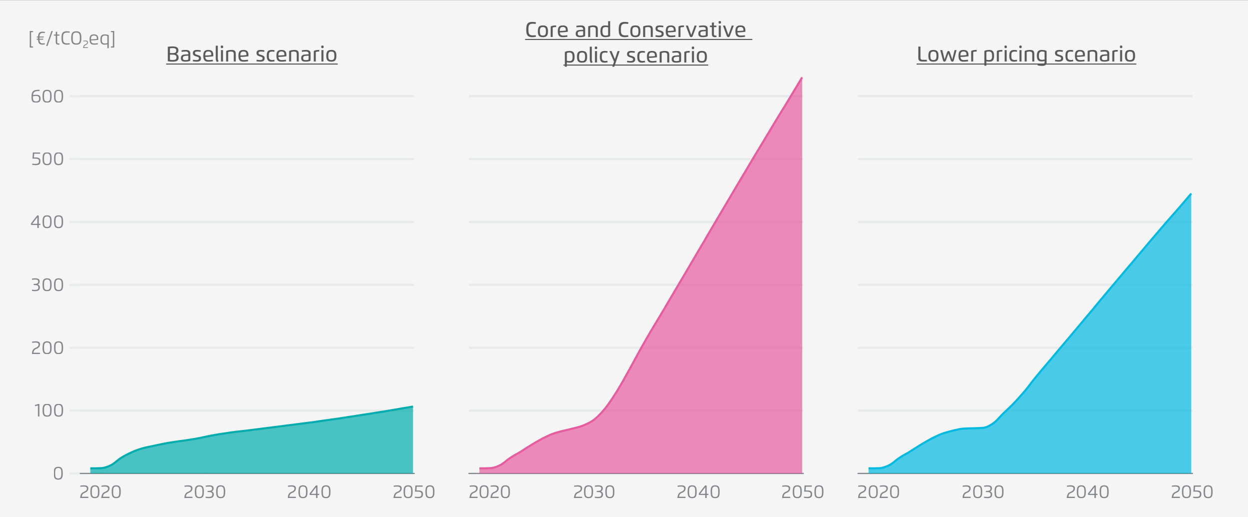
Green investment: needs and policy support

Carbon pricing and other regulatory and fiscal measures make clean technologies more attractive and lead to an increase in green investment across sectors. The build-up in green capital expenditures is a cost for households and firms, but this also brings demand for goods and services through the economy. In order to take this effect into account, the GEM takes the flow of climate investment spending as an input from the EU Gas Exit Pathway and

9 See for instance the quantitative modelling of the EU CBAM in ADB (2024) and Bellora and Fontagné (2023).

10 See https://www.imf.org/en/Blogs/Articles/2023/08/24/fossil-fuel-subsidies-surged-to-record-7-trillion

Effective carbon price by scenario, EU → Fig. 5



Agora Energiewende and Oxford Economics (2024). Note: All prices are in constant 2010 euros per ton of CO_2 equivalent.

complementary estimates. While the bulk of the investment needs come from the sectoral techno-economic modelling of Agora Energiewende (2023), other sources are used to extend these results to more countries and sectors.[11] These figures do not include investment in adaptation to climate change and other sustainability objectives related to biodiversity and natural resources.

These green investments are introduced in the GEM as a shock to the baseline investment levels in the residential, business and public sectors, while second-round effects (for example, through prices and interest rates) ultimately determine the final outcome for aggregate (that is, country-wide) and sectoral investments. Figure 6 illustrates the change in aggregate investment in each country in the Core scenario. The increase with respect to the Baseline scenario is sizable in the first phase of the transition, gradually rising to 3.3 percent GDP of additional investment in early 2030s in the EU, softening in the later years. These figures include the second round (general equilibrium) effects on total investment across sectors after the initial increase in energy and climate investment.

In a recent study, I4CE (2024) estimates that the EU needs to double the levels of climate investment recorded in 2022 in order to meet its 2030 emission reduction target. This investment gap is 2.6 percent of the EU GDP per year until 2030, a figure that underestimates the real gap because this study does not cover investments needed to decarbonise industry, hydrogen supply, district heating and urban public transport. Overall, the magnitude of the investment gap estimated in that study is similar to the additional climate investment needs we feed into the Oxford Economics models, at least for the EU until 2030. These EU-wide additional climate investments reach 2.7 percent of GDP in 2030, rise slightly above three percent of GDP until 2035, and then gradually decline until 2050.

The additional energy and transport investment is not only induced by carbon pricing and regulation, but also by grants offered to the private sector to cover part of the capital expenditures related to green technology adoption. The support rates differ across sectors and depend on factors such as technological maturity of zero-emission solutions and equity considerations. The shares range from 10 percent in

11 Agora Energiewende (2023) provides investment needs for power generation and interconnectors, residential and non-residential buildings, district heating, manufacturing and hydrogen production. The investment needs for other sectors, namely power grids and transport sector, are produced from own analysis and a review of existing studies on the topic.

power generation to more than 50 percent for home renovations in Italy. In reality, investment subsidies are also provided in the form of opex support, especially in industry or power generation. However, for modelling purposes, all support is translated in the same unit of capex grants. More financial support is needed in the 2020s to scale up the deployment of key technologies such as heat pumps and electric vehicles, and it is gradually reduced through 2050.

The amount of available EU funding remains at baseline levels in all scenarios, and the higher public climate spending is financed by national budgets in the modelling. The Recovery and Resilience Facility (RRF) is discontinued in 2026 as this is a one-off instrument created during the Coronavirus pandemic in 2020. The RRF grants, which (as opposed to loans) are not entering national budget balances, currently cover around 10 percent of the EU-wide public climate spending needs in 2021–2027.[12] The Social Climate Fund, following the RRF until 2032, is much smaller in size. Not modelling future developments in the EU budget and other financial instruments means that one important source of cross-country redistribution is not explored.

12 A detailed comparison of EU funding instruments and climate public spending needs is available online at https://www.agora-energiewende.org/data-tools/eu-climate-funding-tracker

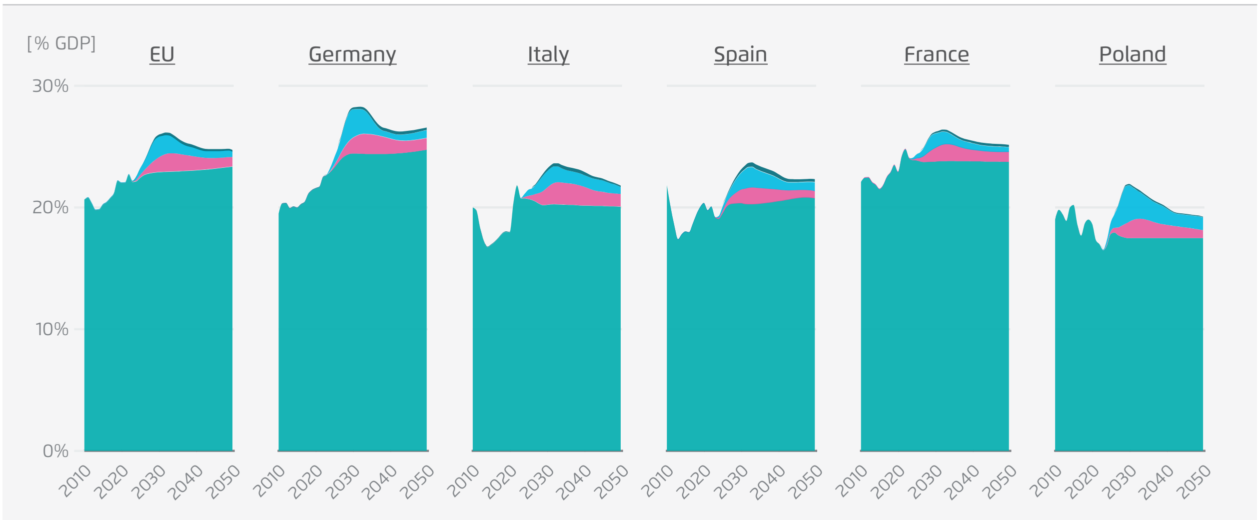
However, one exception is made with respect to EU funding in the policy scenarios. As the Modernisation Fund is an important source of funding for Poland, the analysis attempts to project an extension through 2035, financed with a smaller number of allowances. This contribution differs across scenarios as it depends on the realised ETS 1 price. It is assumed that this line of financial support to Poland is discontinued after 2035, as the country's real GDP has grown 40 percent relative to 2023, and its real GDP per capita passes the mark of 80 percent of the EU average.

Energy prices

Energy prices for households and businesses are affected by the policies through two channels. The European energy transition lowers global demand for oil and gas, which leads to lower spot prices over

Additional energy and transport investment by institutional sector in Core scenario

→ Fig. 6



Agora Energiewende (2024) based on Oxford Economics' modelling.

time. However, the cost of fossil fuels for downstream sectors and households will increase because of carbon pricing and other climate regulations.

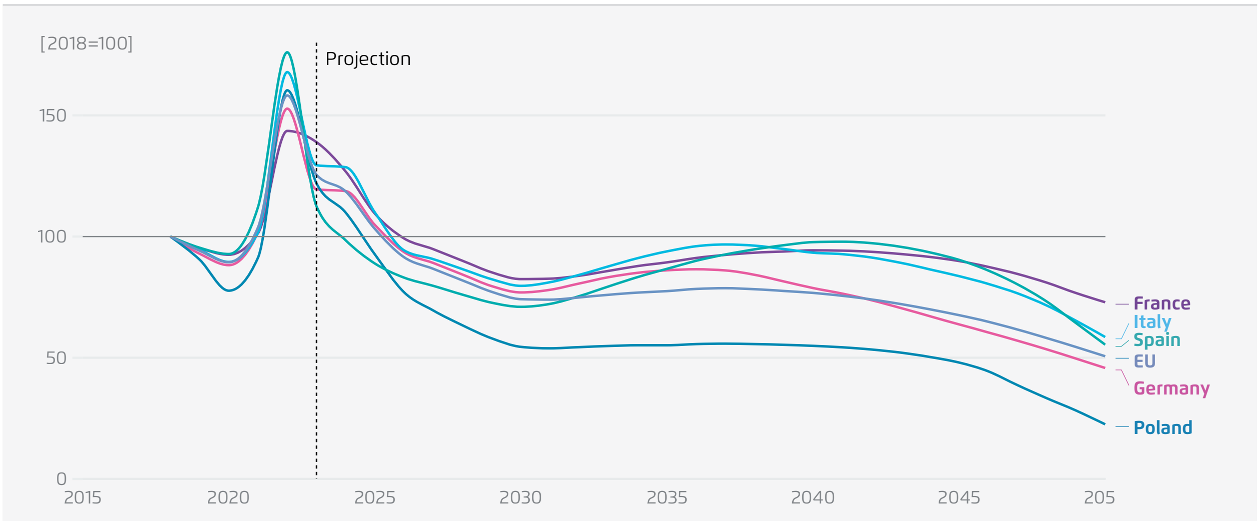
As EU member states start with a heavy reliance on fossil fuels in their energy mix, fast-rising carbon pricing close to 2030 translate into an increase in the overall cost of energy. Fossil fuels become increasingly expensive, which pushes electricity prices up. However, the energy cost shock is gradual and temporary in nature. The diffusion of renewable energy counteracts this effect and its deflationary impact prevails later on once fossil fuels take a minority share of total energy consumption. Moreover, improved energy efficiency makes energy costs a lower burden for the economy. Differently from the fossil gas crisis of 2021–2022 in Europe, the increase in energy costs will be slower and come alongside green investment and economic growth. As a result, the ratio of energy costs to GDP will decline through 2050 and show only a moderate upward trend during the phase of rising carbon costs in the 2030s (Figure 7).

The global demand for oil peaks in 2033 in the Baseline scenario and in 2031 in the policy scenarios. The complete phasing out of oil consumption by 2050 in Europe has only a relatively small change in global markets, because of its small share compared to Asia and North America. Oil prices steadily rise through 2050 in the Baseline scenario, after a short period of decline before 2025. In the policy scenarios, European climate policies do not bend this upward trajectory, but rather slow the growth down. The Baseline scenario still foresees a global curb in oil usage, both due to regulation and the diffusion of electric mobility, which negatively affects the upstream investment in the oil sector.

Monetary policy

Interest rates are an important factor in determining the cost of financing private and public investment in climate change mitigation. As climate regulation affects consumer prices and economic activity, central banks may react by adjusting their key interest rates, for instance by increasing borrowing costs to cool down inflationary pressures. Higher financing costs can have significant effects on aggregate investment and government budgets. However, a few empirical studies have found that, in the past, carbon pricing has affected headline but not core inflation in advanced economies (see *Moessner 2022*). As a result, it could be argued that central banks will focus on core measures of inflation, which exclude the more volatile energy component, and therefore won't react to the temporary increase in the overall price index.

Energy cost as a share of GDP in Core scenario → Fig. 7



Agora Energiewende (2024) based on Oxford Economics' modelling.

Scenarios description → Table 1

Area/Scenario	Core	Lower pricing	Conservative policy
CO_2 pricing revenue use	Redistributed to households: 33 percent	Redistributed to households: 100 percent	Redistributed to households: 33 percent
Green investment support	Medium: Values vary by country and sectors, declining over time.	Medium-high: grants cover 10 percentage points of capex more than in other scenarios. Values vary by country and sectors, declining over time.	Medium: Values vary by country and sectors, declining over time.
Fiscal policy	No budget adjustment in response to climate policy.	No budget adjustment in response to climate policy.	When budget deficits worsen, they are kept at baseline levels by cutting non-climate government spending.
Monetary policy	Look-through: Central banks consider policy-induced inflation as transitory and do not react by changing interest rates.	Look-through: Central banks consider policy-induced inflation as transitory and do not react by changing interest rates.	Taylor rule: Central banks respond to the policy-induced inflation.

Agora Energiewende (2024)

By default, the GEM features a Taylor rule, which is a standard equation linking policy rates to the gap between the core inflation rate and the target rate (that is, two percent in the Euro Area) and the output gap. However, this rule is deactivated in the Core and the Lower pricing scenarios. In these scenarios, monetary policy *looks-through* the effects that transitioning to net-zero emissions has on inflation and, therefore, it does not react to the policy-induced inflationary pressures. This view assumes that central banks will focus on core inflation measures and that they will not be significantly impacted by climate policy. As discussed below, the third scenario offers sensitivity to these results by adopting a different monetary policy stance.

Policy scenarios: Sensitivities

Two additional scenarios are added to explore sensitivities on key assumptions regarding the policy mix. The Lower pricing scenario foresees a more progressive policy stance with lower carbon prices in emission trading. The Conservative policy scenario depicts the case in which policymakers react to fiscal and inflationary pressures.

The Core scenario assumes that the average investment grant covers between one third and half of private costs for green technology adoption. In Lower pricing scenario, higher support rates are assumed across sectors and the average rises by 10 percentage points. Given the higher share of private investment costs paid by the government, lower carbon prices are needed to trigger the same amount of emission reduction. Effective carbon prices are then around 30 percent lower than in the other policy scenarios. At the same time, more extensive transfers are provided to households as a compensation for their carbon costs. All carbon revenues are returned to households, which increases their disposable income but eliminates a source of revenues for governments.

In the Conservative policy scenario, central banks do not *look through* the inflationary pressures generated by climate policy but instead react by raising interest rates to cool these effects off. It could be argued that, in fact, the transition to climate neutrality is too long to be considered a temporary phenomenon. Once monetary policy responds to the effects of climate policy, borrowing costs for the private and public sectors are affected. Moreover, in this scenario the fiscal policy approach is also different. Governments are, in this scenario, unwilling to increase their borrowing to finance the energy transition, and instead pursue budget neutrality by offsetting any additional financing needs through cutting existing public expenditures, either consumption or investment. When budget balances tend to worsen in the Core scenario, the fiscal adjustment brings them back to Baseline scenario levels. This scenario is particularly useful to assess the growth effects of containing inflation and fiscal deficits.

3 An ambitious 2040 climate target can be achieved with broadly positive economic outcomes

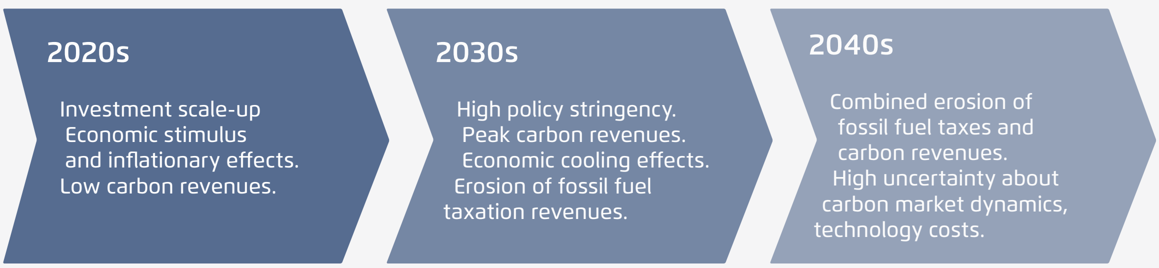
The EU Gas Exit Pathway features a reduction in carbon emissions in 2040 of around 90 percent compared to 1990. This level of abatement, along the lines of what is currently suggested as the official EU target for 2040, can be met with broadly positive macroeconomic outcomes, with real GDP in the EU being two percent higher than in the baseline in 2040 and 2.3 percent higher in 2050 (Figure 9).

The simulations show three phases in the transition (Figure 8). In the first phase, the 2020s, the investh ment scale-up occurs while environmental regulation tightens, with carbon prices gradually rising. The low carbon prices during the 2020s – low compared to the later periods - are enough to trigger green investment in areas with the lowest abatement costs. The initial Keynesian effect is particularly strong, with green investment reaching sizable amounts in the early 2030s and total fixed capital expenditures in the EU peaking at 3.3 percent of GDP above baseline levels in 2032. This lifts aggregate demand and output by utilizing spare production capacity and boosting production in capital goods sectors like manufacturing and construction. In GEM, wages and prices are assumed to be sticky in the short term, and the higher labour demand from the investment drive pushes real wages and inflation up only gradually over time.

In the second phase, starting from the early 2030s, these wage costs rise as the employment expansion and inflationary pressures persist. The rise in carbon prices starts to push energy costs up significantly, as European economies are still mid-way through phasing out fossil fuels. These factors have a cooling effect on the economy. Finally, the last phase from 2040 up to 2050 sees the energy system dominated by clean energy, and the economy being less and less affected by the tightening of climate regulation, which is still necessary to abate the residual amount of carbon emissions.

The policy has inflationary effects, not only because of carbon pricing and emission regulation, but also because of the ramp-up of green investment. The sizable rise in capital expenditures in all sectors puts pressure on prices because green investment raises demand for a wide range of goods and services, including imported ones. The pressure on production capacity leads to higher inflation, adding up to 0.8 percentage points to the annual inflation rate in the EU through the mid of the 2030s. In Convervative policy scenario, monetary policy reacts to the inflationary pressures by raising interest rates which has a cooling effect on inflation. The monetary policy intervention in this scenario reduces inflation only

Key features of the transition, by decade → Fig. 8



Agora Energiewende (2024)

slightly, but just enough to lower the cumulative impact on prices in 2050 by 1.5 percentage points compared to the Core scenario.

Over the long term, the initial stimulus effect fades and national income is determined by structural factors such as the stock of capital, labour force and aggregate productivity. The green investment wave has a positive effect on the effective capital stock of firms. Decarbonisation is not simply the replacement of fossil-based equipment with a cleaner version. Instead, reducing corporate emissions often entails the widespread modernisation of production processes and building structures. The energy transition also has a positive effect on productivity through R&D and innovation. The investment boom and higher energy prices stimulate firms' spending in energy-related R&D, patenting activity, and the adoption of energy-saving technologies.[13] Spillover effects from R&D can positively impact knowledge creation and innovation more broadly. Moreover, the adoption of energy- and resource-saving technologies improves production efficiency and profitability.[14] This channel alone adds around half percent to GDP levels in 2050 compared to the baseline. In the macro model, this positive effect of innovation activity has only long-term effects and works alongside other channels that have negative impacts on economic performance instead, that is short-term trade competitiveness and prices.

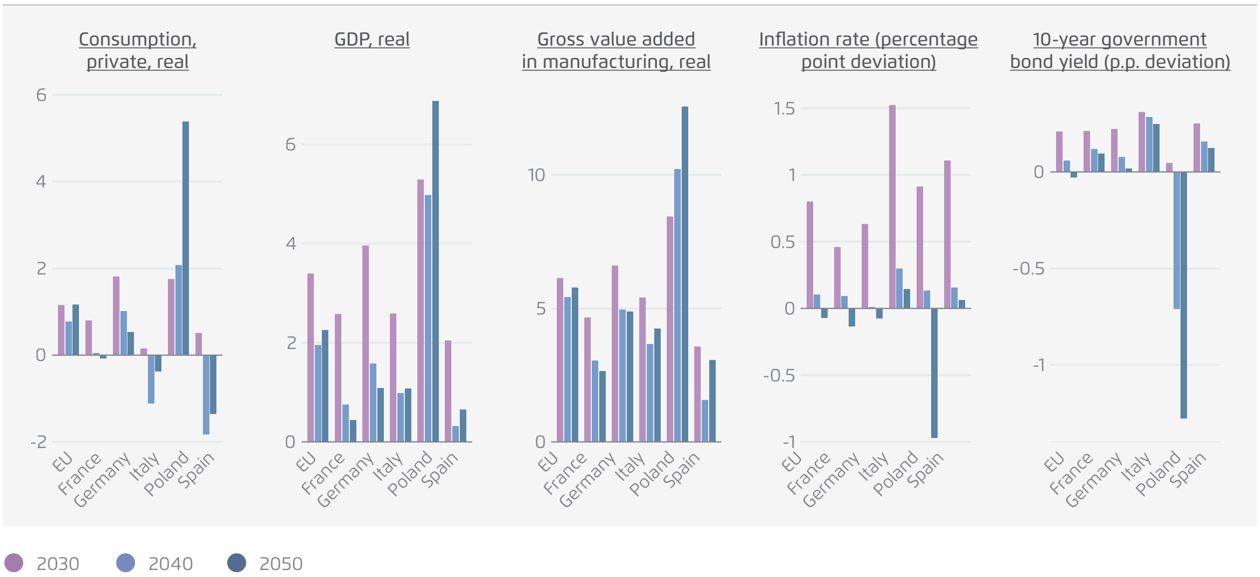
The major differences between the three policy scenarios for the EU lie in the outcomes for private consumption, interest rates, and inflation. In the Lower pricing scenario, the economy benefits from lower carbon prices, and aggregate consumption and output grow more strongly, as a larger part of the transition cost is absorbed by the public sector. The fiscal implications are discussed in Section *Fiscal risks* below. By comparison, the Conservative policy scenario shows slightly weaker economic outcomes from conservative fiscal and monetary policies. Higher interest rates and public budget consolidations reduce the investment-driven economic expansion, even if only by a small amount.

13 For a comprehensive review of the literature on induced innovation on energy technologies we refer to Grubb et al (2021).

14 On the impact environmental regulation and innovation can have on firms' profitability, see Rexhäuser and Rammer (2014).

Key macroeconomic outcomes in Core scenario – percent deviation from baseline

→ Fig. 9



Agora Energiewende (2024) based on Oxford Economics' modelling.

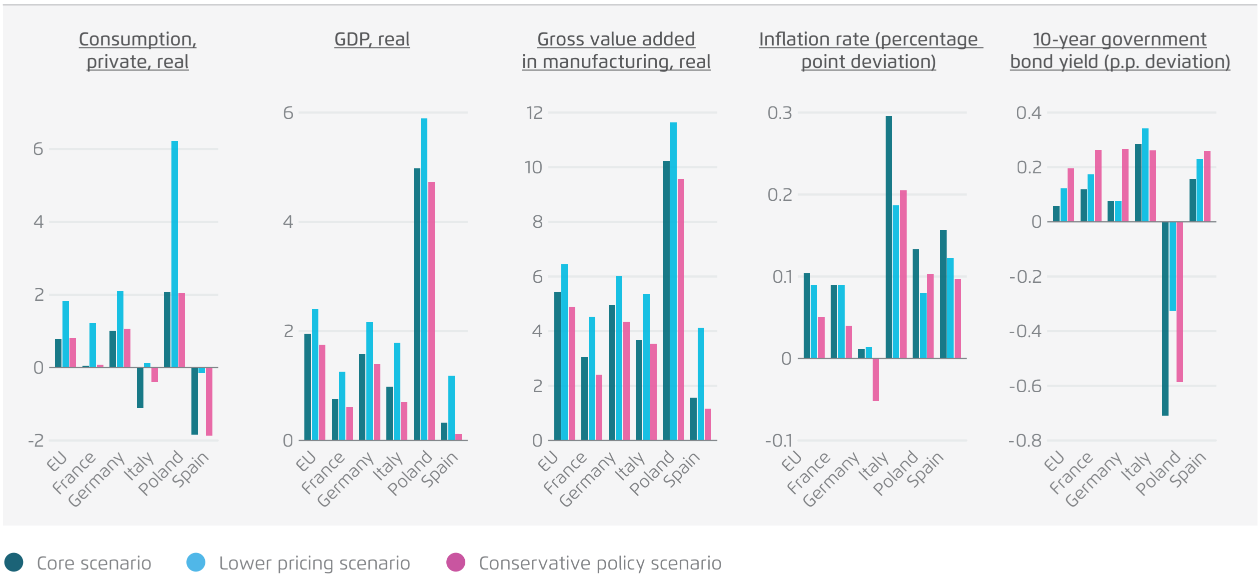
Below the EU average, individual member states have quite different outcomes (Figure 10). All selected countries benefit from a positive economic backdrop during the transition, with GDP rising across the board. Similarly to the EU results, the economic expansion slows down during the 2030s and GDP settles slightly higher than in the baseline in 2050, with the exception of Poland. The country enjoys a more persistent economic momentum instead, leading to much higher GDP at the end of the energy transition. In spite of its high carbon intensity, Poland is projected to experience a strong economic performance mostly thanks to the investment-driven expansion of its manufacturing sector.

While private consumption at EU level still rises despite higher energy prices and residential investment needs, this is not the case in France, Italy and Spain. In these countries, consumption contracts (Italy and Spain) or stagnates (France) by the end of the energy transition. In Italy and Spain, household consumption suffers from the combination of weaker income growth and higher inflation (Figure 10). These results can be partly explained by differing baseline assumptions. The policy scenarios feature a slightly larger regulatory shock for the three countries compared to Germany, since the Baseline scenario projects a tighter regulatory framework in Germany with a more extensive use of carbon pricing. This effect is combined with a slower phase-out of oil use in the policy scenarios for France, Spain and Italy, in particular in the transport sector. As a result of the more persistent use of fossil fuels by households, the decline in energy costs is slower to occur in the three countries, (cf. Figure 7) which affects private consumption. The Lower pricing scenario shows a better outcome instead, given the lower carbon prices and larger carbon cost compensation to households (Figure 10).

The positive effect on economic activity comes with strong job creation initially (Figure 11). Aggregate employment rises above the baseline levels in the EU and in the individual countries until the mid-2030s, when the positive effect fades away. Over the long run, employment returns to baseline because of the cooling economic boost and the role productivity gains will have in reducing labour demand. The GEM assumes that the higher value added comes with production efficiency gains over the long term, as a response to rising wages for instance.

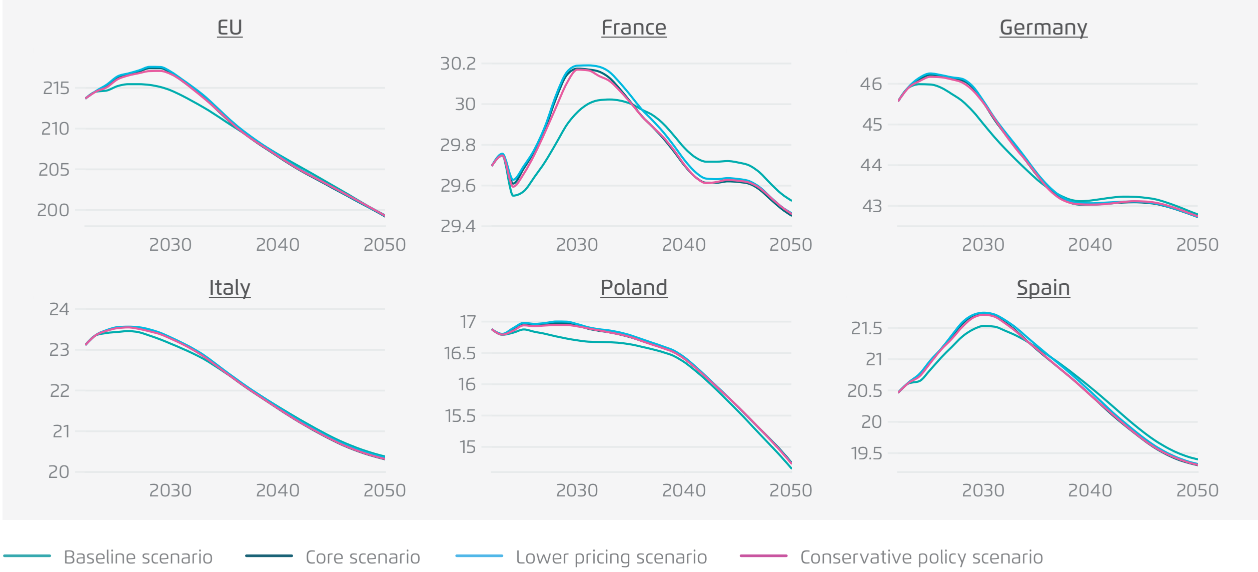
Key macroeconomic outcomes in 2040 by scenario – percent deviation from baseline

→ Fig. 10



Agora Energiewende (2024) based on Oxford Economics' modelling.

Total employment by scenario – million persons → Fig. 11



Agora Energiewende (2024) based on Oxford Economics' modelling.

The risks of delayed action

While a scenario of delayed action is not modelled, we can argue that postponing the implementation of climate policy makes reaching the 2050 target more costly. When climate policy is not adjusted today to the new targets, but rather in a few years from now, much tighter regulation and higher carbon prices are necessary to return to a path compatible with the target. The sudden policy adjustment occurs in an economy that is still using fossil fuels intensively, which generates a stronger shock on energy costs. Decarbonizing in a shorter timeframe would require more output reduction in a de-growth fashion, as there is more limited scope for green investment and innovation in this case. Therefore, the set of scenarios analysed in this report should be interpreted as a best case, assuming policy developments proceed without delays and setbacks. The economic implications of delayed policy action have been extensively discussed in other studies, such as OBR (2021), IMF (2022, 2023).

External sector

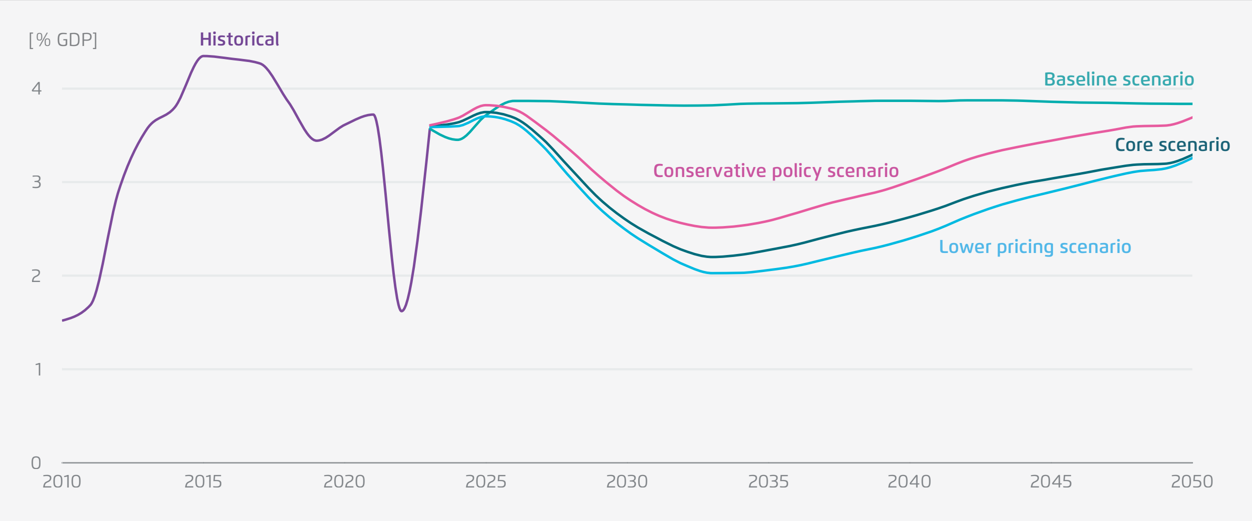
The transition to an energy system based on renewable energy eliminates the need for expensive fossil fuel imports, yet this does not necessarily translate into an improvement in the EU trade balance (Figure 12). Green investment will demand technologies and materials from third countries, and the stimulus effect will raise imports more broadly as GDP increases. Extra-EU exports are also affected by rising carbon and energy costs until the end of the 2030s, as all policy scenarios assume that the rest of the world does not follow suit and that there is no comprehensive carbon border adjustment mechanism protecting European manufacturers. The deterioration in the EU trade balance due to climate policy looks modest, however, in light of previous oil and gas price shocks in 2010 and 2022, but the effect is more persistent than these shocks.

The phase out of fossil fuel trade is one of the major advantages of Europe's transition to a climate neutral economy. Most fossil fuels consumed today are imported and net imports exceeded 3 percent GDP in 2022, as the EU is heavily dependent on foreign producers for the supply of oil and gas. The decline in EU oil and gas imports will erode a significant amount of revenues of the EU's main suppliers, namely Norway, the United States and OPEC countries. Part of this spending will be absorbed by EU governments through carbon pricing. Figure 13 compares the two types of expenditures and offers a few insights. Firstly, a *muddle-through* scenario like the Baseline scenario has higher costs, as neither fuel imports nor carbon pricing expenditures seriously decline. By comparison, policy intervention eventually brings both fuel consumption and emissions to zero by 2050 in the Core scenario. Secondly, the decarbonisation through carbon pricing is preferable to an alternative case with high global oil and gas prices. Carbon pricing has a similar effect on carbon abatement incentives to high energy commodity prices, but it has the advantage of providing revenues to EU governments instead of foreign oil and gas producers.[15]

15 Future spikes in global fuel prices are not modelled here. The UK Office for Budget Responsibility has shown that the volatility of oil and gas prices in a status quo scenario can have sizable fiscal costs (July 2023 Fiscal risks and sustainability report).

External sector: EU trade balance

→ Fig. 12



Agora Energiewende (2024) based on Oxford Economics' modelling.

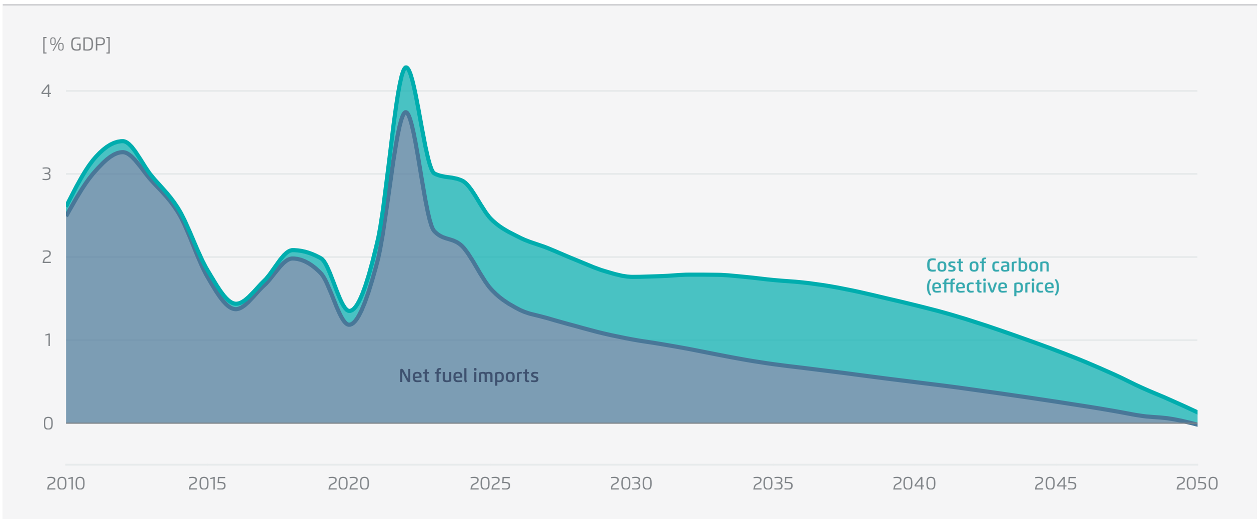
4 Sectoral effects

The EU Gas Exit Pathway has uneven effects on gross value added and employment across sectors. Besides the classic shrinkage of fossil fuel industries, the modelling projects a relative gain for sectors producing capital goods compared to those manufacturing consumption goods and consumer services. Figure 14 shows for the EU that, during the 2020s, almost all sectors grow their employment and gross value added faster than in the baseline. The post-2030 contraction in aggregate consumption as discussed in the previous section, together with the fading investment-led stimulus, reverts the expansion in most sectors, especially services. Therefore, total employment results to be slightly lower than in the baseline in 2040, with a significant sectoral divergence. The transition through 2040 will come with a reallocation of labour from services to sectors producing capital goods, namely manufacturing and construction. The change in sectoral value added is more positive, however, with an increase in value across the board in 2040 compared to the baseline.

The sectoral reallocation predicted by the model may appear as counterintuitive, since manufacturing and construction are more carbon intensive than most service sectors and they should suffer more strongly from the costs associated with emission regulation. The demand-pull effect of green investment on industrial production is nevertheless large enough to offset the impact of carbon costs in these sectors. The results for industrial value added shown in Figure 15 are from the GIM, the model taking into account of the input-output relationships between narrowly defined sectors. Most industries should increase their value added above baseline over the long term, benefiting from the enduring investment in clean technologies and infrastructures during the transition.

Industries will have significant growth opportunities despite the challenges from international competition. The policy scenarios do not feature any sort of carbon tariff, and manufacturers are therefore exposed to a cost disadvantage in markets of traded goods. Even the most energy-intensive sectors, such as basic metals and chemicals, can yet overcome this challenge due to the fast-growing demand for industrial goods. The large-scale investment in energy and transport infrastructures, energy efficient equipment

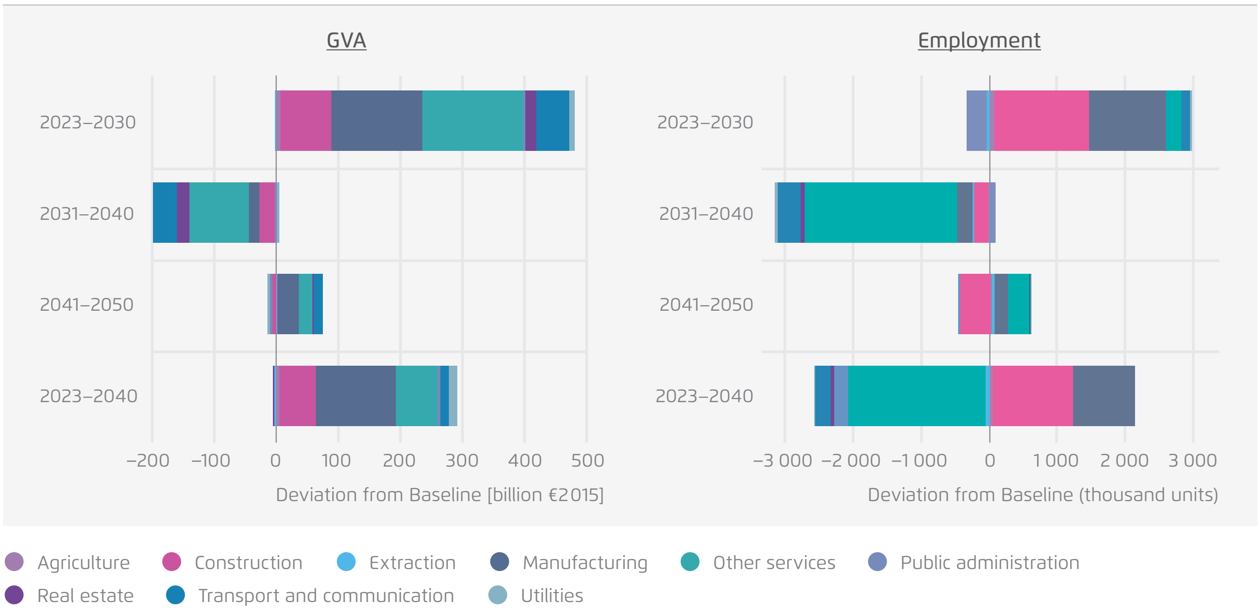
Total expenditures on carbon pricing and net fuel imports in Core scenario → Fig. 13



Agora Energiewende (2024) based on Oxford Economics' modelling.

Composition of gross value added and employment changes in the EU compared to the Baseline scenario

→ Fig. 14

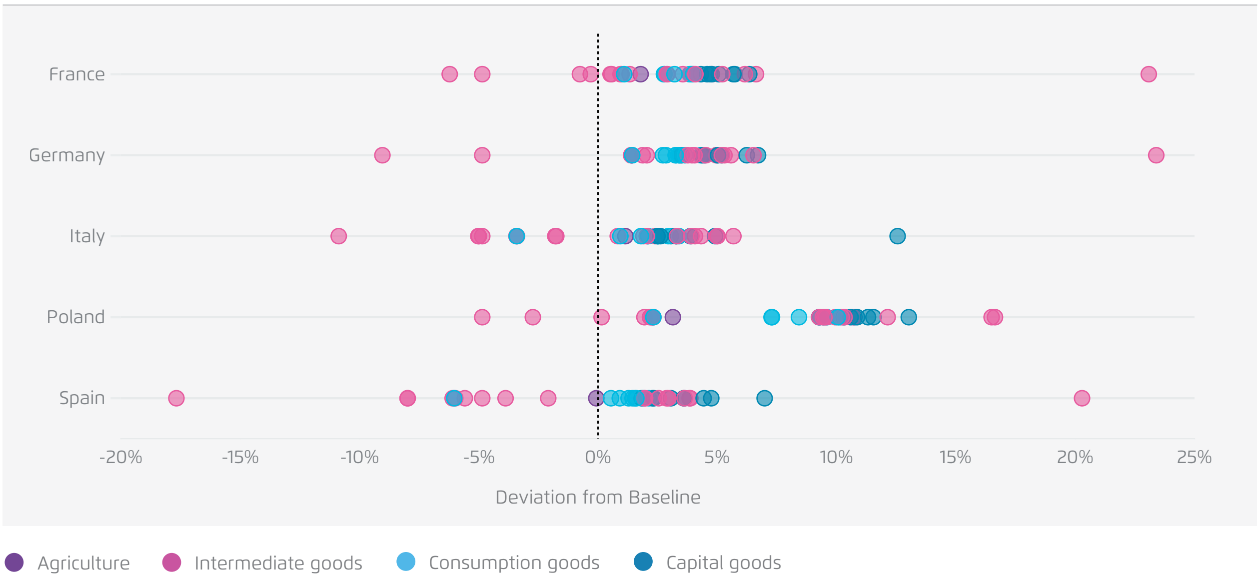


Agora Energiewende (2024) based on Oxford Economics' modelling.

and machinery, and clean vehicles gives the opportunity to European manufacturers to hold, or even expand, their production levels in spite of the cost pressures. It must be noted that the model does not fully represent the risks from technological foreign rivalry in key sectors, which can erase part of the gains in high-tech sectors like automotive. Therefore, the model assumes that European manufacturers will keep up with the technological development of Asian or other foreign competitors.

Gross value added by sector and product type in 2040 in the Core scenario

→ Fig. 15



Agora Energiewende (2024) based on Oxford Economics' modelling. Note: Coal mining and gas manufacture and distribution are excluded because their decline exceeds 60 percent.

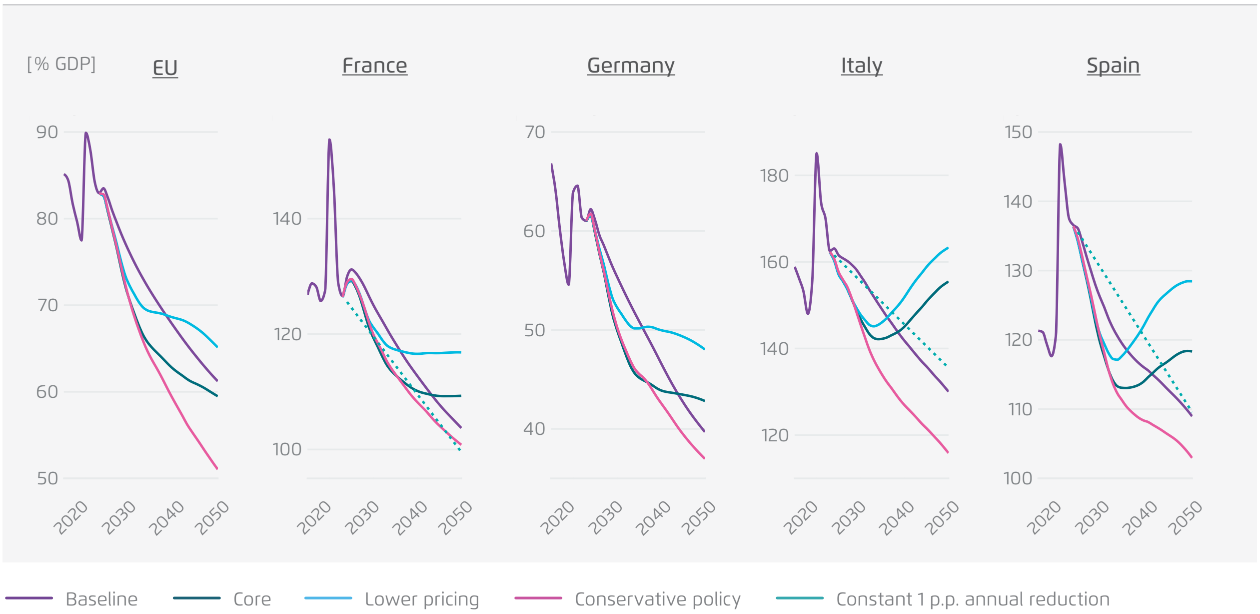
5 Fiscal risks

The fiscal implications of the transition to climate neutrality are multifaceted, and only a quantitative analysis can shed light on the overall impact on public budgets and its dynamics over time. There are in fact several factors at play. The positive growth effect of green investment improves the sustainability of national debt, while the phase-down of fossil fuels erodes what is an important source of tax revenues in several EU member states. Moreover, carbon pricing generates additional income for national budgets, but at the same time this comes along with commitments to provide compensations to those households most affected by the higher energy costs and investment grants for technology adoption and innovation.

The simulation results suggest that the transition will have limited impacts on the average debt level in the EU, while having more mixed effects on high-debt Euro Area countries like Italy and Spain (Figure 16). In the Core scenario, in which there is a balanced mix of carbon pricing and subsidies, debt levels decline steadily until the mid-2030s. At this point, the materialisation of a series of risk factors put pressure on national budgets and the debt dynamic reverts. In Italy and Spain, debt levels rise in the later phase of the transition, a pattern that is even more pronounced in the Lower pricing scenario. In this case, the combination of lower carbon revenues and higher spending for investment grants increases the borrowing needs.

When financing needs are reduced through budget adjustments, namely higher taxes or spending cuts, the policy-induced risks for debt sustainability are potentially eliminated. In the Conservative Policy scenario, public debt stocks steadily decline because fiscal adjustments are carried out to keep budget balances at baseline levels. In particular, net financing needs are offset by cuts in other areas of public spending. The negative growth effects of fiscal consolidation (Figure 10) are small enough so that the GDP outcome is similar to the one in the Core

Government debt by scenario: EU average and Euro Area countries → Fig. 16



Agora Energiewende (2024) based on Oxford Economics' modelling.

scenario. As a result, the budget neutral approach leads to lower debt levels compared to the Baseline scenario.

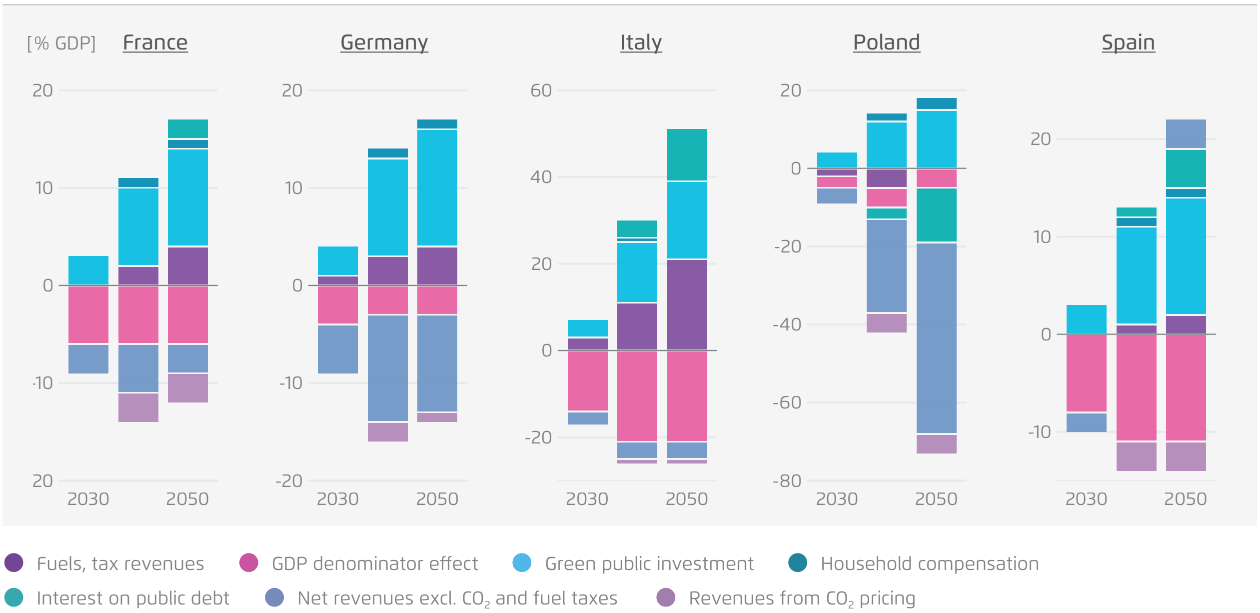
The results about the role of fiscal consolidation must be interpreted with caution; the long-lasting series of budget cuts should be added on top of fiscal consolidations already embedded in the Baseline scenario (namely Italy). These budget cuts are expected to have significant social costs, and their long-term growth impacts, for instance through labour productivity if health spending is reduced, are not fully accounted for by the model. The takeaway should be that fiscal risks that originated from the climate policy can be mitigated through tax increases or spending cuts, but the feasibility depends on the individual country circumstances.

What if high-debt countries had to comply with a debt reduction rule? Let's consider the target of a one percentage point reduction per year in the debt-to-GDP ratio by member states with ratios above 90 percent. The trajectory implied by such a rule is shown in Figure 16. In the EU Gas Exit Pathway, the policy-induced acceleration in GDP helps member states to meet the target in 2030. However, the debt dynamics in the following years are much less favourable in the Core and Lower pricing scenarios, and complying with the debt reduction rule would require significant budgetary adjustments, like those in the Conservative policy scenario. Therefore, fiscal rules that want to achieve a constant reduction in debt levels are likely to introduce strong trade-offs in national fiscal policies, especially if unexpected factors reduce the positive growth effect of climate policy.

The expansionary effect of the green investment scale-up through 2030 is the key driver of major declines in the debt-to-GDP ratios across member states (Figure 17). The stronger growth in nominal GDP comes with higher tax revenues that improve the government budget balance. Higher employment not only generates more labour income taxes, but it also reduces expenditures like unemployment benefits. Moreover, the debt-to-GDP ratio declines because of the higher denominator (the *GDP denominator effect*). In this phase, debt levels decline faster than in the baseline in all policy scenarios, as most of

Determinants of cumulative changes in public debt in Core scenario – deviation from baseline

→ Fig. 17



Agora Energiewende (2024) based on Oxford Economics' modelling. Note: Positive values indicate that the factor increases the debt level.

the differences between scenarios materialise only after 2030. The baseline already projects falling debt ratios in part because of the application of European and national fiscal rules, aiming at limiting fiscal deficits and reducing debt levels.

While the debt-to-GDP ratios are lower than in the Baseline scenario initially, the debt dynamics start to change in the early 2030s because of rising head-winds. Green investment programmes will be running at full speed and carbon revenues, net of household compensations, will not match those outlays in general.[16] At the same time, fossil fuel tax revenues will start to shrink as the demand for oil products and fossil gas falls with transport electrification and the deployment of heat pumps (Figure 17). Among the countries analysed, this effect is the strongest in Italy, due to the higher weight of fuel taxes in the government budget and the relatively lower degree of fossil fuel demand reduction in the Baseline scenario.

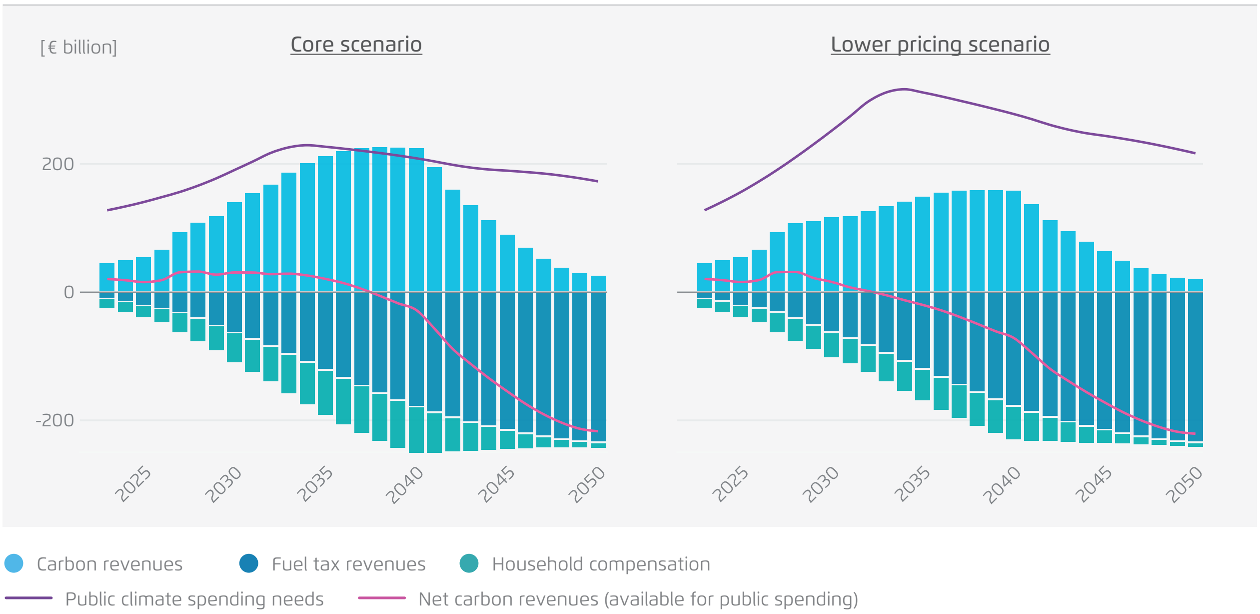
In high-debt countries, rising government bond yields increase refinancing costs and add to the financing needs. Bond yields rise in the policy scenarios because of inflationary and growth effects and, in the Conservative policy scenario, the tightening of monetary policy. The effect of higher interest rates is the most notable in Italy and Spain, where the debt stock is initially large as a percentage of GDP and the dynamics are less favourable in the policy scenarios. In Italy, higher borrowing costs increase debt levels by 12 percentage points of GDP cumulatively by 2050, whereas this effect is much smaller in other countries.

Poland is a special case, with most factors contributing to a rapid reduction of its debt level. Poland's public debt currently stands at 44 percent of GDP and the country is not part of the Euro area. The country is the one, among those analysed, gaining the most in terms of GDP (Figure 9), and the economic stimulus

16 Figure 17 shows the deviations from the Baseline scenario. The difference in carbon pricing revenues between the Core and Baseline scenario scenarios may not be so stark, because the higher price level in the Core scenario is compensated by a much lower amount of emissions, as they are reduced rapidly over time.

Public spending needs and net carbon revenues in the EU by scenario – deviations from 2015–2019 period

→ Fig. 18



Agora Energiewende (2024) based on Oxford Economics' modelling.

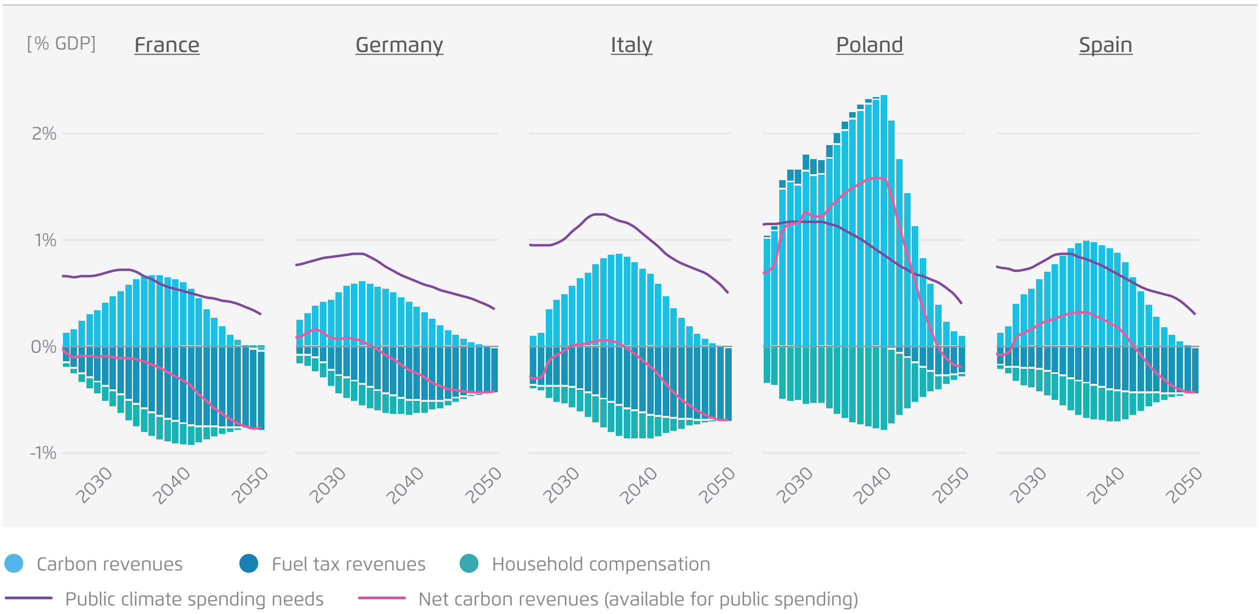
works in improving the budget balance and the debt-to-GDP ratio. As bond yields fall together with the debt level (Figure 9), interest payments contribute to the deleveraging process. Most importantly, Poland experiences a combination of high carbon revenues and limited dependency on fuel excise revenues. Net carbon revenues are high enough to cover the expenses for public green investment programs (Figure 19).

The impact of the erosion of fossil fuel tax revenues on national budgets will materialise slowly over time, but it will reach sizable amounts already in the mid-2030s. Figure 18 and Figure 19 compare the evolution in fuel excise revenues and carbon revenues, showing the net change in revenues of the transition, that is net carbon revenues. This measure illustrates the amount of carbon revenues remaining available for financing public climate investment once household compensation, necessary to offset the regressive effects of carbon pricing, and the loss in fuel tax revenues are taken into account. Differently from Figure 17, the change is calculated with respect to the pre-crisis period and not the Baseline scenario.

Overall, in the EU, the public climate spending needs can't be financed by net carbon revenues alone. In the Core scenario, the rise in carbon prices through 2040 is followed by the decline in fossil fuel tax revenues and what remains available for public investment is short of the spending needs (Figure 18, left panel). By 2035, total financing needs for EU member states will be higher than 200 billion euros in current prices. After 2040, as carbon revenues rapidly fall, governments will have to find other sources to fill the funding gap left by carbon revenues. In the Lower pricing scenario, the combination of higher subsidies and lower carbon prices leads to even larger financing needs, with net carbon revenues already turning negative in the early 2030s. Finally, it is worth highlighting again that the public climate spending needs can be even higher if the expenditures for climate change adaptation and other environmental goals (for instance, biodiversity) are also included.

However, the projections for the impact on energy-related government revenues are quite diverse across member states. Poland and Spain are exceptions among the countries analysed, as their net carbon

Public spending needs and net carbon revenues in Core scenario, national details – deviations from 2015–2019 period → Fig. 19



Agora Energiewende (2024) based on Oxford Economics' modelling.

revenues remain positive for a much longer period. In France, the faster phase-down of fossil fuel use in the EU Gas Exit Pathway leads to an earlier tax erosion effect that weighs on net revenues. As nominal tax rates are kept constant in the model, the long-run loss in fuel tax revenues shown in Figure 19 is lower than the amounts these revenues make of today's GDP.

The rising electricity consumption could offer additional tax revenues that could compensate for the loss of fuel taxes. However, there is, and there will remain, the necessity for governments to incentivise electrification across sectors. Cutting electricity tax rates is one of the most discussed solutions in this respect. At least during the initial phase of the transition, not doing so may increase the need of larger grants for the purchase of heat pumps or electric vehicles, shifting the problem elsewhere in the government budget. Electricity taxes could be more likely increased in much later phases of the transition. Alternatively, other fiscal measures could be introduced such as distance-based charges.[17]

The removal of explicit fossil fuel subsidies is not modelled, but this lever could improve the results in some cases, at least initially. Explicit subsidies for coal, oil and fossil gas in the period 2017–2021 were 0.4 percent GDP in Italy, 0.3 percent GDP in France and Poland, and around 0.1 percent GDP in Germany and Spain, per year.[18] They have increased significantly in 2022, but they are expected to return to the pre-crisis levels as the emergency measures are phased out. If such fiscal reform was accounted for, governments would have more revenues in the medium term and the effect would be particularly significant in Italy and France. However, there are two offsetting factors. Firstly, higher energy taxes on fossil fuels will overlap with carbon pricing, making a lower carbon price necessary to achieve the same level of abatement. The estimation of this revenue substitution effect in the presence of multi-sector emission trading is not straightforward. Secondly, the value of these subsidies falls as the consumption of fossil fuels declines. As a result, the revenues generated by the subsidy reform will shrink over time.

Other studies have assessed the impact of the transition to climate neutrality on public debt and revenues, even if for different geographies. IMF (2023) project debt levels in advanced economies to increase between 10 percent and 45 percent GDP by 2050, depending on how much governments rely on subsidies or carbon pricing. For France, Pisani-Ferry and Mafouz (2023) estimate that the public debt stock would rise by 25 percentage points of GDP by 2040, assuming that the erosion of fuel tax receipts is completely offset by new taxes (that is, the debt would increase more without this offsetting intervention). The UK Office for Budget Responsibility (OBR 2021) finds that the transition will increase the UK's public debt by 20 percentage points of GDP by 2050, an effect that is mostly driven by the erosion in the fuel tax base. Contrary to our results, in these studies the higher debt levels are also the result of a negative impact on real GDP, even if the effect tends to be small compared to other factors.

The UK Office for Budget Responsibility (OBR 2021) estimates that, in the UK, the loss of the fuel tax base will become larger than the receipts from carbon pricing already from the mid-2030s, eventually reducing government revenues by 1.6 percent of GDP in 2050. OECD (2023) evaluates the change in public revenues in a net zero by 2050 scenario and finds a net negative impact on public budget balances across the world, including developing regions. In the EU[19] the effect is negative already in 2030, in spite of carbon revenues of up to three quarter of a percent of GDP, and the reduction in public revenues reaches around 1.3 percent GDP in 2050. The study also highlights that Europe is the most exposed to the erosion of fossil fuel tax revenues among the OECD regions.

17 See OECD (2023) on the topic of distance-based charges.
18 See for instance the IMF and IEA estimates for EU member states available online at fossilfuelsubsidytracker.org
19 The results only cover the EU countries that are members of the OECD.

6 Conclusions

This report offers an overview of the main economic and fiscal effects of the transition to climate neutrality in the EU. The modelling carried out by Oxford Economics reveals that the green investments needed to fully decarbonise the European economy will bring economic dividends that compensate for the higher costs of energy use and production during the transition. The investment wave has the potential to benefit European industry. This demand-pull effect can overcome the higher energy costs, if the right framework conditions are in place for EU companies to become clean tech leaders.

On the other side of the equation, the carbon abatement costs for the private sector will be a key determinant of the macroeconomic impacts in terms of economic growth, employment and cost of living. These abatement costs will be reflected in the price of allowances in the two EU emission trading schemes, which will price around 80 percent of EU emissions going forward, but they also affect the cost of complying with complementary regulations like emission standards and bans of fossil-based technologies. There are three main ways to reduce these costs:

1. Provide subsidies to take over part of the private costs. Grants to households for carrying out home renovations and installing heat pumps or subsidies to industry to switch to clean technologies will reduce the total cost of adopting green technologies. These grants and subsidies will reduce green technologies' payback time and make them more attractive relative to their fossil-based and energy-intensive alternatives. The results of the Lower pricing scenario show that shifting part of the costs from the private to the public sector can improve the economic outcomes, but this benefit must be weighed against the fiscal costs and the implications for public debt sustainability.

2. Improve the framework conditions for green investment, namely red tape, workforce supply, and access to finance. Excessive regulation, the lack of a skilled workforce, necessary energy and transport infrastructures all add to the costs of using green technologies, even making their adoption impossible in some cases. Access to finance can also be a problem, and it can be compounded by poor framework conditions.

3. Invest in R&D to reduce future abatement costs and gain technological leadership in key green industries. From hydrogen to CCS, several key clean technologies are not yet mature and further innovation is necessary to bring the costs down. In cases like batteries, technological disruptions can shift their production away from raw materials that will be in scarce supply or have environmentally harmful extraction and processing activities. R&D can also give the competitive edge to European companies to withstand the international competition in the new markets for clean technologies.

The development of consumer financing for the adoption of clean technologies is very important not only to enable green investment in the residential sector, but also to mitigate the potential crowding out of other consumer spending. Regulatory measures that impose energy renovations and forbid fossil-based boilers from the market, while necessary to meet EU's 2050 targets, are likely to have significant effects on household budgets and consumption if no form of borrowing or lease is available. While consumer financing is well developed for cars, this is not the case for heating equipment and construction services. Policymakers should address the fundamental barriers to the creation of such markets.

On the fiscal side, the transition to climate neutrality can pose risks for debt sustainability. It becomes urgent to integrate these climate-related elements in debt sustainability analyses, the one carried out by the European Commission for instance, and in national budget plans. Our study is not the first one flagging this issue. However, we show that the increase in public debt ratios is limited to a few member states, not affecting the EU average, when climate policy manages to boost economic growth and lift GDP. Among the EU countries analysed here, Italy and Spain are the most vulnerable due to a combination of high legacy debt and dependence on fossil fuel tax revenues, as well as weaker projected economic gains. France has lower vulnerability in this regard, but fiscal adjustments – additional to the Baseline scenario - would be needed if the debt ratio has to be brought to the EU reference value of 60 percent of GDP.

When fiscal rules oblige governments to cover climate spending with new taxes or spending cuts in other areas, the risk of political opposition and social unrest becomes significant over the long horizon of the transition. For the case of countries with debt sustainability issues, these fiscal adjustments would be additional to those already needed in the absence of climate policy. This compounds the pre existing difficulties governments already encounter in implementing carbon pricing and other emission regulations. Introducing flexibility for climate investment[20] in EU and national fiscal rules can allow for more gradual adjustments, balancing the risks for debt sustainability with those of a backlash against environmental policy in the short term. At the end of the day, climate policy is for the benefit of future generations.

Increasing the share of EU co-financing can unlock the way to conciliate the needs of investing in the energy transition and reduce high national debt stocks. The transition is already one of the pillars of the Next Generation EU, a debt-funded instrument for post-pandemic recovery. Centralising funding for EU public goods, such as climate investments, can not only enhance allocation efficiency but also alleviate fiscal space constraints in some member states. As recently proposed by Mario Draghi,[21] issuing more EU debt to finance investment in shared priorities like climate change would justify the adoption of stricter fiscal rules applying to national budgets. High-debt member states will be able to cut their level of indebtedness more easily if the next EU Budget from 2028 to 2034 will be endowed with more resources to co-finance climate-related and other strategic investments.

20 Climate investment needs can be pretty clearly identified, as it was done in the national recovery and resilience plans.

21 In the speech The Next Flight of the Bumblebee: The Path to Common Fiscal Policy in the Eurozone, available online at https://www.nber.org/reporter/2023number3/next-flight-bumblebee-path-common-fiscal-policy-eurozone

7 Annex – Assumptions on carbon pricing and regulation

This section presents a series of assumptions related to carbon pricing and policy stringency indicators used in the analysis. In the GEM, the overall level of climate policy stringency is condensed into one variable, namely the effective carbon pricing rate. The table below reports the national values in 2030 and 2040 for each scenario. The percentage changes relative to the Baseline scenario, shown in the table, are the values of interest. They are more important than the absolute values in determining the policy impacts shown in the rest of the paper.

Effective national carbon prices in 2030 and 2040

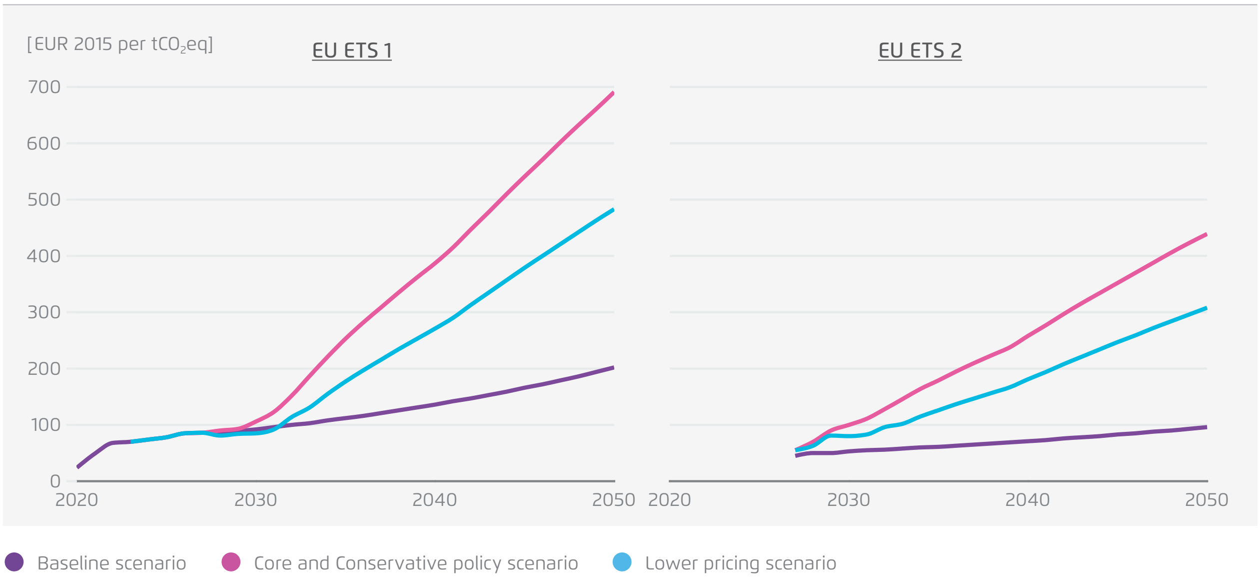
→ Table 2

	2030					2040				
	Baseline scenario	Core & Conservative policy scenario		Lower pricing scenario		Baseline scenario	Core & Conservative policy scenario		Lower pricing scenario	
	Price	Price	Change	Price	Change	Price	Price	Change	Price	Change
France	59	110	87%	92	56%	93	483	418%	337	262%
Germany	75	108	44%	90	20%	103	481	368%	336	227%
Italy	65	101	55%	84	30%	89	475	434%	332	273%
Spain	70	103	47%	87	23%	96	477	399%	333	249%
Poland	69	103	49%	86	25%	99	476	383%	333	238%

Agora Energiewende (2024). All prices are in constant 2010 euros per ton of CO_2 equivalent.

Assumptions on prices in EU emission trading schemes by scenario

→ Fig. 20



Agora Energiewende (2024)

The effective carbon rates capture the presence of national carbon taxes and emission trading schemes. The two European systems, the ETS on power and industry and the future ETS on road transport and buildings, are a major component making the effective rates.

For the Core scenario, the price of allowances in the ETS 1 is constructed from BloombergNEF's forecast up to 2030 in nominal terms.[22] The series is projected forward to 2050 using the growth rate of the EU carbon price in the NGFS' Net Zero 2050 scenario (REMIND-MAgPIE 3.0-4.4 model). The projection for allowance prices in the ETS 2 is based on own analysis, in the absence of available market forecasts. The price growth in real terms is slower compared to the ETS for power and industry, because we assume policymakers will intervene to moderate the price dynamics to protect households.

In the Lower Pricing scenario, the carbon price is set to remain 30% lower than in the other two policy scenarios after 2030. This assumption aims to reflect the presence of higher subsidies provided by the government to adopt clean technologies in this scenario. The 30% adjustment is the result of an increase in the average grant support rate by 10 percentage points and it is derived from Agora Energiewende's economic analysis of technology adoption for key products such as heat pumps.

The EU emission trading scheme finances a series of funds for supporting the energy transition across the continent, namely the Innovation Fund, the Modernisation Fund and, from 2026, the Social Climate Fund. From a fiscal perspective, these funds are relevant because they redistribute carbon revenues between member states. The detailed modelling of these EU-wide financing instruments is complex and therefore it is left out of the analysis. For instance, the Innovation Fund has no predetermined distribution key and the allocation across countries cannot be precisely estimated ex-ante. We focus on the Modernisation Fund, the instrument featuring the strongest redistribution between member states. This fund operates until 2030. Poland is one of the largest beneficiaries among the thirteen countries that will receive funding to invest in the decarbonisation of their energy system from the Modernisation Fund. Between 2031 and 2050, the modelling assumes a continuation of the policy but with a reduction in the number of allowances allocated to this fund for redistribution.

22 1H 2023 EU ETS Market Outlook.

8 Annex – Climate spending needs composition

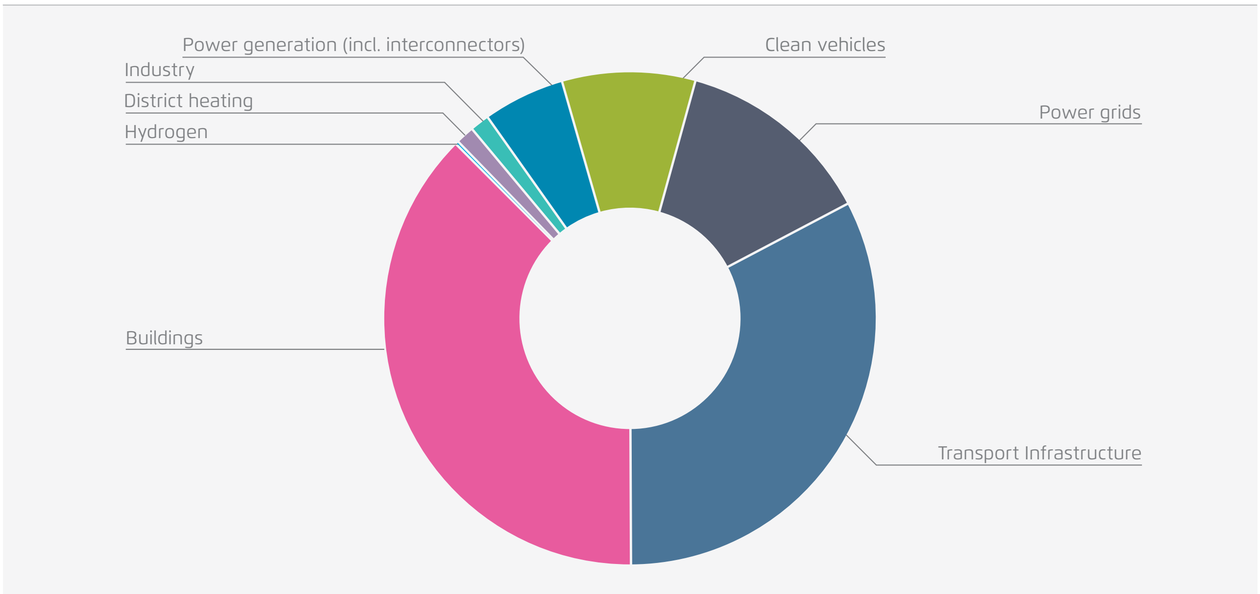
The private and public investments needed to reduce carbon emissions and the public spending associated with investment support programmes and infrastructure build-up are essential inputs to the macroeconomic modelling. In most cases, the climate investment data are from the sectoral modelling of Agora Energiewende (2023). More specifically, it covers power generation and interconnectors, residential and non-residential buildings, district heating, manufacturing and hydrogen production. The investment needs for other sectors, namely power grids and transport sector, are produced from own analysis and a review of existing studies on the topic. For transport infrastructures, the EU-wide investment needs are from the European Commission[23] and, in the absence of country-level estimates, the total is split among individual member states based on their share of the EU transport emissions.

In this study, the public climate spending needs are the fraction of the total climate investment needs that are borne by the public sector. This includes the investment in publicly owned buildings and infrastructures and the subsidies provided to the private sector to adopt clean technologies and invest in infrastructures. The public climate spending needs are calculated by applying coefficients to the sectoral investment gaps, following Baccianti (2022) and Agora Energiewende (2023). These public sector shares are the lowest for power generation and highest for residential and public transport infrastructure investments. The EU (weighted) average of the overall public shares is one third of total capital expenditures, while national values may differ. Fige ure 21 shows the resulting sectoral composition of the EU-wide public climate spending needs over the whole scenario horizon.

23 European Commission's staff working paper accompanying the proposal for the Next Generation EU (SWD (2020) 456 final).

Public climate spending needs in the EU, 2023–2050

→ Fig. 21



Agora Energiewende (2024). Note: Public spending needs include public capex and the share of private capex covered by public grants and other subsidies.

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Agora Energiewende develops scientifically sound, politically feasible ways to ensure the success of the energy transition – in Germany, Europe and the rest of the world. The organisation works independently of economic and partisan interests. Its only commitment is to climate action.

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