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Executive Summary

In the absence of urgent action, global warming could have devastating and irreversible effects on the environment and on the health and living standards of people. The recovery from the current economic crisis provides an opportunity to build consensus on actions to support the transition to a more sustainable economy, including strengthening carbon pricing, prioritizing investment in green infrastructure and innovation, reducing subsidies and tax exemptions for emissions-intensive activities, and promoting green finance.

The European Union remains a global leader in climate change mitigation. The European Green Deal provides a roadmap to transforming the EU into a climate-neutral economy by 2050. Furthermore, the European Commission (EC) is currently conducting a review of climate policy instruments and an assessment of the economic impact of raising the emission reduction target to at least 50 percent by 2030 compared to 1990 levels.

This paper aims to contribute to the debate on the choice of policies to reach the more ambitious 2030 emission reduction goals currently under consideration. It provides an analysis of the macroeconomic and distributional impact of different options to scale up the mitigation effort, and proposes enhancements to the existing EU policies. A key finding is that a well-designed package, consisting of more extensive carbon pricing across EU countries and sectors, combined with cuts in distortionary taxes and targeted green investment support, would allow the EU to reach the emission goals with practically no effects on aggregate income. From a risk-reward perspective, the benefits of reducing the risk of extreme life-threatening climate events and the health benefits from lower air pollution clearly outweigh the costs of mitigation policies. To enhance the social and political acceptance of climate policies, part of the revenue from carbon pricing should be used to compensate the most vulnerable households and to support the transition of workers to greener jobs. In the absence of an international agreement among major emitters, to avoid an increase in emissions outside the EU from higher carbon prices in the EU ("carbon leakage"), a carbon border adjustment mechanism could complement the package although various operational, legal, and political aspects would need to be considered before its introduction.

More robust carbon pricing should be at the core of the new EU climate package as it is the most powerful and efficient tool to cut emissions. Carbon pricing induces consumers and firms to internalize the social cost of their emissions, and steers investment to low-carbon technologies. Moreover, it can generate much needed fiscal revenue. Setting a *uniform* carbon price across the EU would focus efforts on the lowest-cost mitigation opportunities and help avoid carbon leakage between member states. In practice, carbon pricing in the EU could be strengthened by expanding the emission trading system (ETS) to other economic sectors. Alternatively, national-level carbon pricing could be imposed for sectors outside the ETS. While an ETS system provides certainty in emission reduction, the implied carbon price can be volatile. Introducing a carbon price floor in the ETS would provide a predictable price signal for investors, while discontinuing the use of free allowances would allow a more efficient use of public resources. Moreover, subsidies and tax exemptions to fossil fuels in the EU should be discontinued.

With progressively stricter emission reduction goals, the equilibrium carbon price would likely rise from its relatively low current levels, leading to higher energy prices. In fact, some EU countries already have—or are planning to raise—carbon prices well above the ETS price. If increasing carbon prices beyond a certain point proves to be politically difficult, policymakers could consider complementary tools such as feebates, subsidies, or regulations. These instruments reduce the explicit carbon price necessary to achieve climate goals but tend to be less economically efficient as they operate through only a subset of mitigation channels and do not generate fiscal revenue.

The transition to a low-emission world will have multiple benefits but is also likely to have short-term distributional consequences that would need to be addressed in a comprehensive policy package. Fiscal transfers can support the transition in lower-income member states most exposed to higher carbon prices. Within each country, governments should facilitate the transition of workers to growing industries through retraining programs, targeted job-search support, and regional development assistance. The impact of higher energy prices on low-income households could be mitigated through the social support system. Clear communication of the support schemes would help gain broad public support for more robust mitigation policies.

Establishing a carbon price floor across all major emitting countries is necessary to tackle global emissions. Without concomitant global action, carbon leakage to non-EU countries could undermine the EU's effort to curb global warming. The EU currently grants free emission permits to certain firms with the aim to reduce leakage. A more efficient alternative proposed in the Green Deal is a border carbon adjustment (BCA) mechanism to equalize the cost of carbon emissions for domestically produced and imported goods.

The large investments needed to ensure long-term environmental sustainability would also provide an impetus for the recovery from the current COVID-19 crisis. A predictable gradual path to a higher carbon price will already spur investment in green technologies and infrastructure, while generating much needed revenue. However, even under optimal carbon pricing, targeted public support for green investment is needed to address market failures beyond emission externalities. For instance, public investment is warranted to improve infrastructure including public transportation networks and electricity grids, research and development (R&D) support is needed to boost research in low-emission technologies, and the development of a robust green taxonomy would foster green financing. The EU recovery packages, which already have a strong green focus, should integrate these priorities.

CHAPTER

1 Introduction

Global warming looms as a key threat to people's health and living standards in the coming decades. Global temperature has increased by about 1°C above pre-industrial levels so far due mostly to human activities, including burning of fossil fuels. As temperatures keep rising, the risk of deleterious climate events, including heat waves, fires, flooding, and severe storms will increase (Figure 1). The effects are nonlinear: higher temperature increases raise the frequency and severity of these events more than proportionally, risking catastrophic and irreversible outcomes (Intergovernmental Panel on Climate Change 2018; Stern 2006). While the average forecast of the economic cost for the EU of a 2°C global temperature increase is about 3 percent of GDP by 2050, the actual cost could be much higher (DeFries and others 2019; Kahn and others 2019). In the absence of further policy action, scientists predict that temperatures would rise by around 4°C above pre-industrial levels by 2100, well above the 1.5–2°C goal in the Paris agreement.

Global action to date has been inadequate. The long-term goal of the 2015 Paris Agreement is to limit projected global warming to 2°C, with an aspirational (nonbinding) target of 1.5°C. Estimates by the UN Environment Programme (2018) suggest that the voluntary global commitments made under the agreement would limit global warming only to 3°C, so more stringent commitments need to be made by countries over time to meet the goal.

The EU has made significant progress in cutting greenhouse gas emissions (GHG) in recent decades. The 2020 targets were met early: EU GHG emissions fell by 23 percent relative to the 1990 level already by 2017, although many countries have a large gap between consumption- and production-based emissions (Figure 2). Lower emissions intensity was the key driver (emissions per GDP declined by 84 percent over this period). This was mainly due to a shift toward a cleaner energy mix as the share of renewables in energy production increased to 30 percent over the last three decades.

Figure 1. Impact of Climate Change on European Regions

Arctic region
- Temperature rise much larger than global average
- Decrease in Arctic sea ice coverage
- Decrease in Greenland ice sheet
- Decrease in permafrost areas
- Increasing risk of biodiversity loss
- Some new opportunities for the exploitation of natural resources and for sea transportation
- Risks to the livelihoods of indigenous peoples

Coastal zones and regional seas
- Sea level rise
- Increase in sea surface temperatures
- Increase in ocean acidity
- Northward migration of marine species
- Risks and some opportunities for fisheries
- Changes in phytoplankton communities
- Increasing number of marine dead zones
- Increasing risk of water-borne diseases

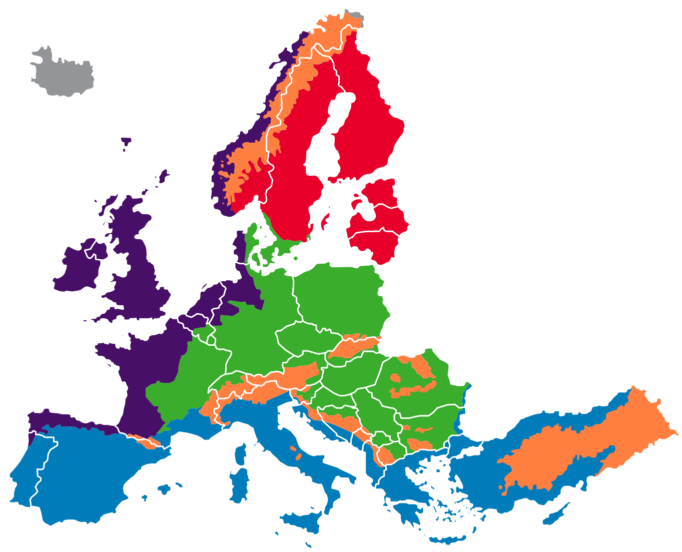
Atlantic region
- Increase in heavy precipitation events
- Increase in river flow
- Increasing risk of river and coastal flooding
- Increasing damage risk from winter storms
- Decrease in energy demand for heating
- Increase in multiple climatic hazards

Boreal region
- Increase in heavy precipitation events
- Decrease in snow, lake and river ice cover
- Increase in precipitation and river flows
- Increasing potential for forest growth and increasing risk of forest pests
- Increasing damage risk from winter storms
- Increase in crop yields
- Decrease in energy demand for heating
- Increase in hydropower potential
- Increase in summer tourism

Mountain regions
- Temperature rise larger than European average
- Decrease in glacier extent and volume
- Upward shift of plant and animal species
- High risk of species extinctions
- Increasing risk of forest pests
- Increasing risk from rock falls and landslides
- Changes in hydropower potential
- Decrease in ski tourism

Continental region
- Increase in heat extremes
- Decrease in summer precipitation
- Increasing risk of river floods
- Increasing risk of forest fires
- Decrease in economic value of forests
- Increase in energy demand for cooling

Mediterranean region
- Large increase in heat extremes
- Decrease in precipitation and river flow
- Increasing risk of droughts
- Increasing risk of biodiversity loss
- Increasing risk of forest fires
- Increased competition between different water users
- Increasing water demand for agriculture
- Decrease in crop yields
- Increasing risks for livestock production
- Increase in mortality from heat waves
- Expansion of habitats for southern disease vectors
- Decreasing potential for energy production
- Increase in energy demand for cooling
- Decrease in summer tourism and potential increase in other seasons
- Increase in multiple climatic hazards
- Most economic sectors negatively affected
- High vulnerability to spillover effects of climate change from outside Europe

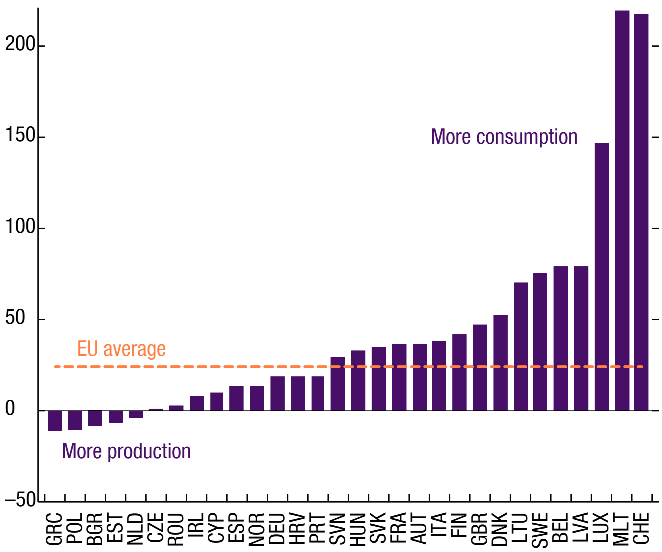


Source: European Environment Agency, https://www.eea.europa.eu/data-and-maps/figures/key-past-and-projected-impacts-and-effects-on-sectors-for-the-main-biogeographic-regions-of-europe-5/map-summary-climate-change-2008.eps/image_large.

Improved industrial processes and lower energy use in manufacturing and construction also helped reduce emissions, while progress in transport and agriculture has been more limited (see Arregui and others, forthcoming).

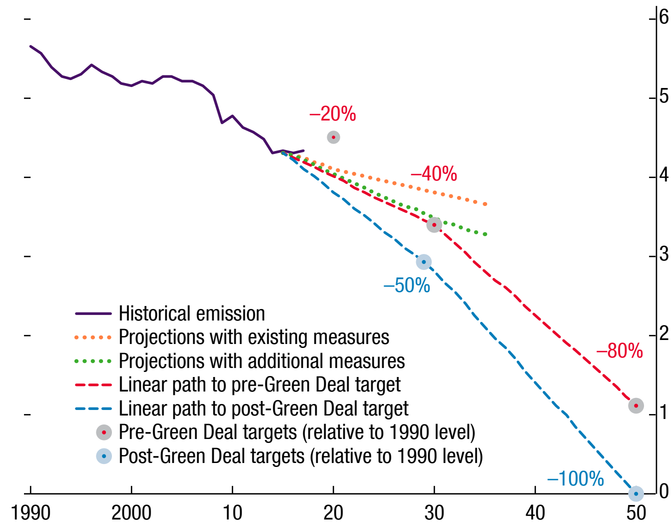
The EU is increasing its ambition in the context of the Green Deal. Its current commitment under the Paris Agreement is to cut emissions by at least 40 percent by 2030 relative to 1990 levels. The European Green Deal,

Figure 2. Difference in CO_2 Emissions from Consumption and Production[1]
(Percent of emissions from production)



Sources: World Bank, *Global Carbon Project*; and authors' calculations.
Note: Data labels in the figure use International Organization for Standardization (ISO) country codes. EU = European Union.
[1]Emissions from fossil fuel-based energy generation and cement. The difference reflects imports and exports of goods and services that involve CO_2 emissions.

Figure 3. EU27+UK: Total GHG Emissions' 2019 Projections and Targets
(Millions of ktCO$_2$e)



Source: European Environment Agency.

presented in December 2019, proposed a European Climate Law enshrining the 2050 climate neutrality objective, and set out a roadmap for developing the required policies. A more stringent intermediate objective of at least 50 percent for 2030 will also be considered. Significant further effort would be needed to reach these more ambitious targets. According to the European Environment Agency, under current policies, EU emission would only fall by 33 percent in 2030 relative to 1990 (Figure 3).[1] The Green Deal also maps out a comprehensive plan to mobilize green investment and to provide financial support for the most affected individuals, businesses, and regions to help with the transition.

This paper provides an overview of the current EU policy framework and discusses economically efficient options to strengthen it. The recommendations are grounded in quantitative analysis using a computable general equilibrium model (Envisage) as well as a broader review of the policy literature. The paper aims to answer the following questions:

[1]https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-6/assessment-3.

- What would be the macroeconomic implications of bringing EU carbon emissions down by 50 percent by 2030 (compared to a path based on unchanged policies and to the current goal of 40 percent)? What are the complementarities and trade-offs between carbon pricing and other policy tools to cut emissions? How to implement more robust carbon pricing in the EU?
- How to use carbon pricing revenues to enhance economic efficiency and the political acceptability of higher carbon pricing? How to address the distributional effects of mitigation policies? What complementary policies are needed to ensure a smooth transition to a low carbon economy? How to reduce carbon leakage?
- What is the role of green investment in the policy package? How should it be integrated in the post-COVID recovery effort? How should projects be selected, and what safeguards need to be in place?

The rest of the paper is organized as follows. Chapter 2 describes current EU policies and future policy plans. Chapter 3 discusses possible enhancement to existing policies, building on a quantitative simulation of the economic impact of different policy packages across EU countries and households. Finally, Chapter 4 concludes with a summary of the main policy recommendations.

CHAPTER

2 The EU Objectives and Policy Framework

The EU remains a global leader of the drive to reduce emissions. In March 2020, the EC proposed a European Climate Law that will enshrine the 2050 climate neutrality objective in legislation. The EC is currently conducting an impact assessment of increasing the EU emission reduction target for 2030 from 40 percent to least 50 percent compared with 1990 levels, to be completed in September 2020. The EC is also reviewing a wide range of policy instruments, including a possible extension of the ETS to new sectors such as road transport, building, and maritime, and is also examining the rationale and possible designs for a carbon border adjustment mechanism. It plans to announce concrete policy proposals by June 2021.[1]

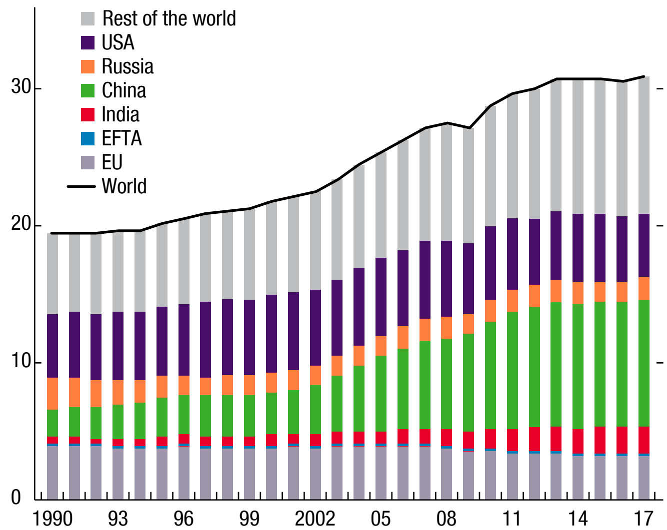
More stringent reduction targets for the EU have been justified by its historical contribution to global emissions. Estimates place the EU at about a quarter of world cumulative emissions, just after the United States, and well ahead of China or Russia. This contrasts with today's emission levels, with the EU accounting for less than 10 percent, and China, India, and the United States having a much higher share of emissions (Figure 4).

Overview of EU Policy Framework

The key elements of the EU mitigation policy framework are the ETS and the Effort Sharing Regulation (ESR) for member states, complemented by other EU directives (Table 1). Emissions from large companies in energy, industry, and aviation (flights within the European Economic Area) are covered by the EU-wide ETS. For other sectors, the ESR defines individual national emission reduction targets. While the ETS covers about 40 percent of total EU emissions, for individual countries the share varies between

[1]See https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf.

Figure 4. World: Total CO_2 Emissions
(Thousand gigatonnes)



Source: IMF, October 2019 *Fiscal Monitor*.
Note: EFTA = European Free Trade Association; EU = European Union.

Table 1. EU Climate Policy Framework

	EU Domestic Legislation				International Commitments
	ETS 2030 Climate and Energy Framework	ESR	Green Deal		The EU's commitment under the Paris Agreement
Target Year of Period	2021–30	2021–30	2021–30	2050	Already in force: covers period post 2020
Emission Reduction Target	−43% in 2030 compared to 2005 for ETS emissions	Annual targets by MS. In 2030 −30% compared to 2005 for non-ETS emissions	Overall target: at least −50% domestic GHG emissions reduction vs. 1990	Net zero	at least −40% in 2030
	Overall target: at least −40% domestic GHG emissions reduction vs. 1990				
Emission Coverage under ETS (share of total)	45%		Up to 85%		
Energy Efficiency	>32.5% improvement relative to the 2007 modelling projections for 2030		>32.5% improvement relative to the 2007 modelling projections for 2030		
Share of Renewables in Energy Consumption	>32%		>32%		
Investment Support	EUR 563bn		EUR 1064bn		
State Aid	Environmental protection, in certain circumstances, may justify the granting of State aid.		Green support is exempted from state aid rules		

Source: Authors' calculations.
Note: ESR = effort-sharing regulation; ETS = emissions trading system; EU = European Union; GHG = greenhouse gas.
[1]Based on available information.

21 and 84 percent. Among sectors not covered by the ETS, transport and housing are the most important (Figure 5).

Emission Trading System (ETS)

The ETS is a cap-and-trade system. It limits the total amount of specified GHG that can be emitted and allows participants to trade emission permits. The cap is reduced annually so that emissions in 2030 would be in line with the current ETS reduction target of 43 percent compared to 2005 levels.[2] The ETS applies to the EU, Iceland, Liechtenstein, Norway, and the United Kingdom (as of 2020).[3] In January 2020, it was also linked with the Swiss ETS.

Free emission allowances are allocated to certain firms in industrial sectors (Figure 6):

- Manufacturing sectors deemed at risk of carbon leakage—as determined by the EU taxonomy—receive free allowances at 100 percent of a benchmark level,[4] that was determined before each trading period, and some small emitters are exempt from the ETS. Manufacturing sectors not at risk of leakage also receive some free allowances, but these are expected to be eliminated by 2030.[5] In addition, electricity intensive industries in some member states are compensated for ETS indirect costs (see Arregui and others, forthcoming).
- Within the aviation sector, 15 percent of allowances are auctioned, and 82 percent are allocated for free based on benchmarks. The remaining 3 percent constitute a special reserve for new entrants and fast-growing airlines.
- In the power generation sector, auctioning applies to all emissions, with optional derogation for the modernization of the electricity sector in certain member states.

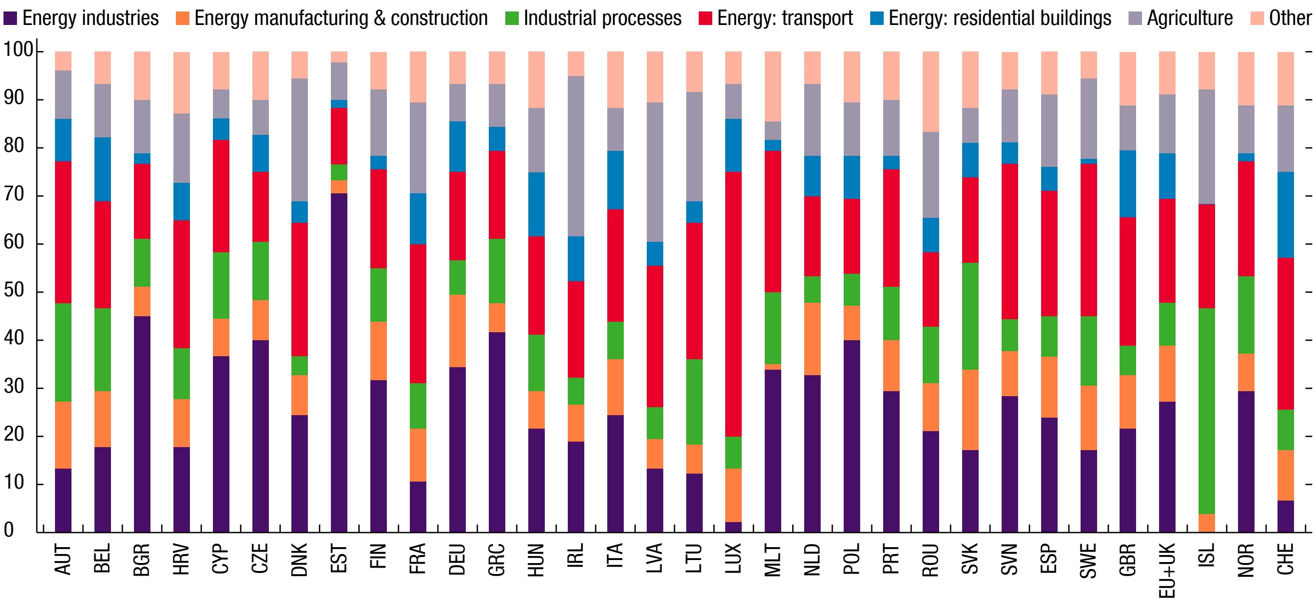
[2]The current annual reduction rate of 1.7 percent will increase to 2.2 percent from 2021 to 2030.

[3]It is currently unclear how the United Kingdom and the EU will collaborate in reducing global emissions after 2021. This paper assumes that the United Kingdom will continue to participate in the EU climate policy until 2030.

[4]Sectors at risk of leakage are defined as those where ETS pricing would increase production costs by at least 5 percent of total gross value added and trade intensity with non-EU countries is above 10 percent. The benchmarks set the amount of free permits for each industrial product. See Delbeke and Vis (2017) for further discussion. Small emitters are allowed to opt out from the EU ETS if they are subject to equivalent measures, in order to minimize administrative costs.

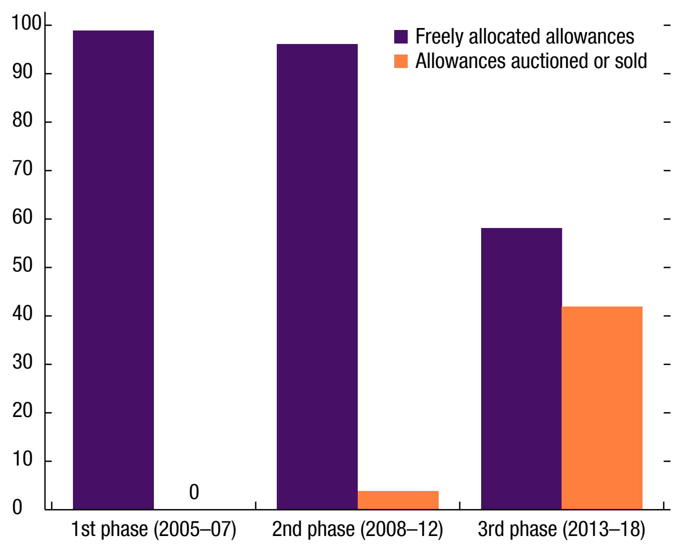
[5]Sectors that are not deemed to be at risk of leakage will receive up to 30 percent free allocations from 2021 to 2026, decreasing linearly to zero from 2026 to 2030. Sectors on the carbon leakage list will continue to receive 100 percent of their allowances up to benchmark levels for free. The benchmark levels will be updated every five years to take technological progress into account.

Figure 5. Total GHG Emissions by Sector
(Percent of total emission without LULUCM & indirect CO_2)



Sources: UNFCCC database; and IMF staff calculations.
Note: Data labels in the figure use International Organization for Standardization (ISO) country codes.

Figure 6. Share of Free Allocation vs. Auction
(Percent, excluding aviation)



Sources: Union registry; and authors' calculations.

- Finally, 5 percent of total allowances are freely allocated to new installations and covered installations whose capacity has significantly increased since their free allocation was determined.

Historically, the ETS carbon price has been volatile and generally low. The ETS fixes the quantity of emissions but leaves the price to clear the market. The implied carbon price collapsed sharply in 2008 as the financial crisis led to a significant reduction in emissions, while the annual allowances volume was not adjusted. Unused permits can be saved to offset future emissions, generating a surplus of allowances. In 2018, total surplus allowances amounted to 1.6 billion allowances, equivalent to all verified emissions that year excluding aviation (EC 2019). Overlapping policies (for example, large-scale subsidies for renewable technologies and infrastructure) and improvements in energy efficiency fueled surpluses by reducing the demand for allowances (Perino, Ritz, and Van Benthem 2019).

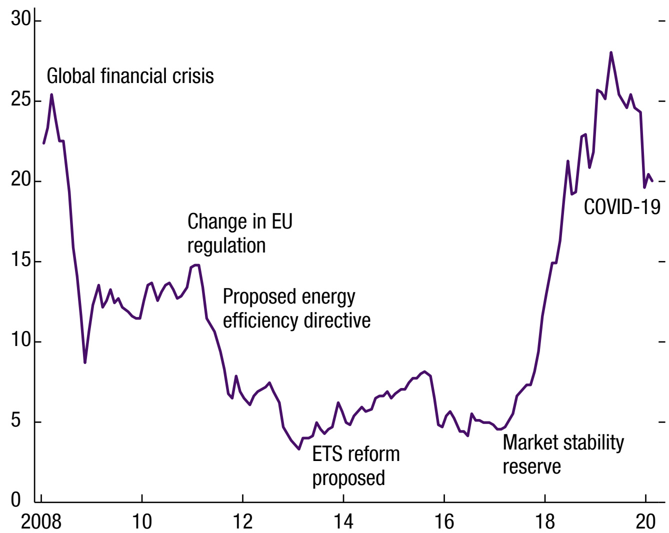
A Market Stability Reserve (MSR) was introduced in January 2019 to reduce the volatility of ETS prices. A large accumulated surplus of allowances weakens the carbon price signal. The MSR puts a fraction of surplus allowances into a reserve when the surplus exceeds a certain threshold. Following the announcement of the MSR, the ETS price has strengthened. However, some academics argue that the MSR in its current form might not be able to absorb all surpluses from policy or cyclical shocks, and that MSR rules are opaque and complex, reducing price predictability (Burtraw, Keyes, and Zetterberg 2018; Quemin and Trotignon 2019; Perino 2018).[6] During the COVID-19 crisis, the ETS price initially dropped but then stabilized at around €20 (Figure 7).

Member states collected €14.1 billion revenue from the ETS in 2018. Revenues are channeled into national budgets mainly based on the countries' historical emissions.[7] The ETS Directive stipulates that at least 50 percent of these proceeds should be used to combat climate change in the EU or third countries. In practice, member states have used over 80 percent of the revenues from 2013 to 2017 for such purposes, though some have devoted a significant share to compensate energy intensive industries (EC 2017, 2018a). More recently, there have been proposals to channel part of the revenue to the EU budget in the future.

[6] Crucial for the pace at which surpluses are reduced is the share which is placed in the MSR. This share is set at 24 percent until 2023 and will be halved after that. Currently, the permits in MSR will be placed back into the ETS if surplus falls below a certain threshold. Starting in 2023, MSR reserves in excess of the previous year's auction volume will be permanently invalidated.

[7] More specifically, 90 percent of allowances to be auctioned will be distributed to member states based on their share of verified emissions. The remaining 10 percent of the auctioning rights are distributed to member states with low per capita income.

Figure 7. EU ETS Carbon Price
(2019 euro)



Sources: Sandbag, Haver and fund staff calculations.
Note: ETS = emission trading system; EU = European Union.

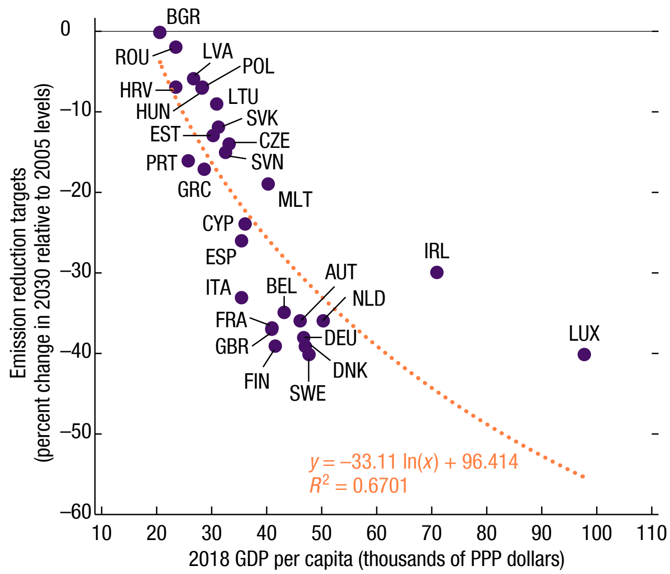
Effort Sharing Regulation

The ESR stipulates country-specific targets for non-ETS sectors. For the EU as a whole, the goal for non-ETS sectors is to reduce emissions by 30 percent by 2030 compared to 2005 levels. Countries with lower GDP per capita have less ambitious targets, with the justification that they have higher projected growth and lower investment capacity (Figure 8).

To achieve the national targets, members states can put in place country-specific polices such as carbon taxes, financial support, and regulations.[8] Each member state publishes a National Energy and Climate Plan that maps out specific policies to achieve the national targets. The 2030 target is the endpoint of a linear reduction trajectory, which defines the annual reduction targets for the years 2021–30. Country authorities have implemented different measures to achieve these targets such as incentives for purchasing clean vehicles and building standards. Some countries have introduced carbon taxes, although the sectoral coverage as well as the level of tax rates vary considerably (Table 2). More countries are planning to adopt carbon pricing at the national level, including Germany and the Netherlands. Some member states are allowed to trade ETS allowances to achieve their annual national

[8]Moreover, France has taken significant steps to integrate environmental goals in the budgetary process.

Figure 8. EU27+UK: GDP per Capita versus GHG Emissions Reduction Targets



Sources: European Commission; and IMF, *World Economic Outlook*.
Note: Data labels in the figure use International Organization for Standardization (ISO) country codes.

Table 2. Selected Carbon Pricing Schemes, 2019

Country/Region	Year Introduced	Price 2019, €/Ton CO_2	Coverage of GHGs 2018: Million Tons	Coverage of GHGs 2018: Percent
Carbon Taxes				
Denmark	1992	20	22	40
Finland	1990	51	25	38
France	2014	39	176	37
Ireland	2010	17	31	48
Norway	1991	46	40	63
Portugal	2015	11	21	29
Sweden	1991	99	26	40
Switzerland	2008	75	18	35
Carbon Price Floors				
United Kingdom	2013	19	136	24

Sources: Stavins 2019; World Bank 2019, 2020; and IMF staff calculations.
Note: GHG = greenhouse gas.

Table 3. European Commission Action Plan on Financing Sustainable Growth, 2018

Areas	Actions Points	Status
Reorient capital flows toward sustainable investment	Establish a **taxonomy** of environmentally sustainability activities.	Ongoing
	Creating **standards (such as the EU Green Bond Standard) and labels** for green financial products (via Ecolabel) to protect integrity and trust of sustainable finance market.	Ongoing
	Fostering **investment** in sustainable projects.	Ongoing
	Disclosing how ESG factors are incorporated when providing investment advice. Enhance transparency to end-investors on how financial market participants consider sustainability.	Ongoing
	Developing sustainability **benchmarks** and ESG disclosures for benchmarks.	Concluded
Mainstreaming sustainability into risk management	Better integrating sustainability in **ratings** and market research.	Concluded
	Clarifying institutional **investors** and asset managers' **duties**.	Ongoing
	Incorporating sustainability in **prudential requirements** (where justified from a risk perspective).	Concluded
Foster transparency and long-termism	Strengthen corporate sustainability **disclosure**.	Ongoing
	Fostering sustainable **corporate governance** and attenuating short-termism.	Ongoing

Source: European Commission.
Note: ESG = environmental, social, and corporate governance.

targets, but this is limited to 2 percent of each country's effort sharing emissions in 2005 (less than 0.5 percent of emissions from non-ETS sectors).[9]

Other EU Directives

Emission targets are complemented by targets for renewables. To facilitate emission reduction, the EU has committed to increase the share of renewables in energy consumption to 20 percent by 2020 and to at least 32 percent by 2030.[10] The directive underpins this effort by specifying national renewable energy targets for each country, taking into account its starting point and overall potential for renewables.

The EU also sets energy efficiency targets and standards for non-ETS sectors. The 2012 Energy Efficiency Directive obliges member states to improve efficiency by 20 percent by 2020 and by at least 32.5 percent by 2030, including through regulation and awareness measures. An example is the Energy Performance Criteria for the building sector, which provides a common energy-efficiency standard for existing and new buildings. Similar EU standards exist for appliances and car emissions.

The EU has led the development of sustainable finance. The European Investment Bank pioneered the issuance of green bonds, targeted to renewable energy and energy efficiency projects. Since 2016, the EC has also developed a series of groundbreaking regulatory measures in the area of sustainable finance. Most of these measures were set out in the EC's Action Plan on Sustainable Finance, which introduced both voluntary market standards and legal obligations (see Table 3). Some of the legislative measures have already been published, including regulations on sustainability-related disclosures in the financial sector. Investment funds offering green portfolios will

[9]Iceland, Luxembourg, and Norway are allowed up to a limit of 4 percent.

be required to use the EU climate adaptation and mitigation criteria from end-2021. However, work on many areas remains to be completed.

The Green Deal Investment Plan

The Green Deal Investment Plan aims to mobilize investment to reach the EU 2030 climate and energy targets. It aims to mobilize at least €1 trillion over the next decade, including both public and the private investment. The five main sources of funding are EU budget funds (€503 billion), EU budget guarantees to the European Investment Bank as well as other development banks and international financial institutions (which is expected to generate €279 billion total investment through the InvestEU program), national co-financing (€114 billion), and ETS revenue (€25 billion or roughly 20 percent of total ETS revenue). The Green Deal also includes the creation of an enabling framework for sustainable investments and support to areas facing challenges from the transition toward the green economy. The Just Transition Mechanism (€143 billion) will focus on the most affected regions, helping to create jobs through job-search and training support, but also help finance projects, including renovation of buildings, renewable energy, district heating networks, and sustainable transport.

The Green Elements of the EU Recovery Plan

The proposed Next Generation EU package focuses on green investment. Recognizing the benefits from investing in the green transition, the package earmarks about a third of the resources for climate change mitigation and adaptation. This applies to funds distributed to EU member states through the Recovery and Resilience Facility (RRF) as well as to the top-ups to the EU budget for the years 2021 to 2027. Additional resources are foreseen for the Just Transition Fund (€10 billion), the European Agriculture Fund for Rural Development (€7.5 billion), the InvestEU program (€5.6 billion, focusing on green infrastructure), and for R&D (€5 billion). Disbursements under the RRF are conditional on the submission of investment plans that ensure consistency with each member state's National Energy and Climate Plans. These resources will be funded by transfers and a new EU-wide tax on nonrecycled plastics, which is scheduled for next year. The EC is also considering extending the ETS to road transport and new sectors and introducing a carbon border adjustment mechanism.

CHAPTER

3 Toward an Enhanced Policy Mix

This section lays out policy recommendations building on a quantitative analysis of various emission reduction tools. The focus is on mitigation policies that would allow the EU to cut GHG emissions by 40 to 50 percent in 2030 relative to 1990 levels, consistent with the Paris Agreement or the new tentative Green Deal targets, respectively. The section evaluates different policy options based on their impact on carbon and energy prices, macroeconomic aggregates, distributional considerations, and spillovers to the rest of the world. The assessment relies on simulations from a highly granular general-equilibrium model (Envisage), as well as on a review of the optimal policy literature. The estimated levels of carbon prices needed to achieve the targets are broadly consistent with estimates from other models (Böhringer and others, forthcoming). The discussion in the paper is focused on the tradeoffs and complementarities between policy options along different dimensions, rather than the absolute price level.[1] Annex 1 describes the model (see van der Mensbrugghe [2019] for a technical guide) and simulation results in more detail.[2]

Introducing EU-Wide Carbon Pricing

Introducing EU-wide uniform carbon pricing should be a key component of the policy package. Carbon pricing is the most efficient tool to address the negative externalities from GHG emissions as it aligns the marginal abatement costs across all agents, minimizing the economic efficiency loss (EC 2014a; IMF 2019a; Parry 2020). Carbon pricing also directs investment and

[1]The net fiscal cost of policies is kept at zero every year in the simulations to allow a clean comparison of the economic efficiency of different policy packages.

[2]The model assumes that Iceland, Norway, Switzerland, and the United Kingdom (that is, countries that are currently in the EU ETS) participate in EU climate packages.

R&D toward low-carbon technologies, improving energy efficiency as well as the energy mix. Compared to directed interventions such as regulations or subsidies to specific technologies (which also entail a cost), it lets the market decide which technologies are best to devote resources to. Currently, carbon prices in the EU vary across sectors and countries, generating an inefficient allocation of abatement efforts. This is partly due to distributional concerns and political resistance to raising carbon prices in high-emitting countries. To improve social acceptance of a uniform carbon price, it can be combined with welfare-preserving transfers (see the following).

A cap-and-trade system with full sectoral coverage and a carbon tax are broadly equivalent. Given the same sectoral coverage, both systems can achieve the same carbon prices and raise the same amount of revenue (Goulder and Schein 2013). Carbon prices can be set at the same point in the production chain under both systems. Nevertheless, there are some important differences. For instance, explicit carbon taxes provide more certainty about future prices, but the resulting emissions reduction is uncertain (given uncertainty about future technologies and abatement costs) and can deviate significantly from the desired path. On the other hand, a cap-and-trade system provides more certainty about the quantity of emissions but implies higher price volatility. Moreover, a cap-and-trade system could be more costly to set up and administer, although once it is in place the administrative burden is broadly the same as that for carbon tax collection. Finally, carbon taxes combine more easily with other instruments such as regulations and standards. Having such policies for sectors already covered by an ETS creates a "waterbed effect," where the price of emission permits falls due to the complementary polices, and no reduction in overall emissions is achieved.

Unified carbon pricing can be implemented by expanding the EU ETS to all major emitting sectors.

- A comprehensive cap-and-trade system covering all emissions implies a lower uniform carbon price and smaller aggregate income loss for the same EU-wide reduction in emissions compared to the average prices and income effects in the current framework with limited trade between sectors and countries. See Table 4 for a comparison of two scenarios to achieve 50 percent emissions reduction—one with a uniform carbon price and trade among countries, and the second with each country reaching the target individually without trade. Some individual countries for which the implied income loss is higher under uniform carbon prices could be compensated through transfers, whereas the overall welfare still improves as emission reduction is concentrated in countries and sectors with the lowest marginal abatement costs.

Table 4. EU: Impact on Income of Emission Reduction Policies, 2030

	Emissions (rel. to 1990, percent)	Income (rel. to BaU, percent)
EU-wide Carbon Price (40%)	−40	−0.3
EU-wide Carbon Price (50%)	−50	−0.9
National Targets (50%)[1]	−50	−1.2

Source: Authors' calculations.
Note: Carbon price revenue used as lump-sum transfer. Income losses reflect transitional effects due to wage rigidities and capital reallocation frictions. BaU = business as usual (baseline); EU = European Union.
[1]No trade is allowed between EU member states.

- Extending the EU ETS is feasible; some countries already have a cap-and-trade system with a broader coverage than the EU, such as the Western Climate Initiative, California, and the New Zealand ETS. Germany will introduce an ETS in the transport and building sectors starting in 2021 (see Box 1). The system can be based on the carbon content of fossil fuels and implemented midstream (that is, at the fuel distributor level) to mitigate the administrative burden.
- If the ETS coverage is not extended to all sectors, the existing limitations on trade of ETS allowances between member states to achieve national targets in non-ETS sectors could be removed to attain a more efficient allocation of abatement efforts across countries. Alternatively, national-level carbon pricing (carbon taxes or national ETSs) could be introduced for the non-ETS sectors.
- Some individual member states have moved ahead with the implementation of more aggressive mitigation policies on top of the ETS (such as carbon price floors and higher national-level taxes). To prevent a waterbed effect, the resulting excess permits should be cancelled. An alternative prevention policy is to introduce a carbon price floor in the ETS system (see the following).
- When emission trading is extended to more sectors, such as transport, any existing carbon pricing on these sectors could be reduced by a commensurate amount.[3]

The price signal in the ETS framework should be strengthened. Under a cap-and-trade system, prices are endogenously determined and hence subject to fluctuations. Such a system provides certainty and control on the quantity of emissions allowed. However, price volatility can undermine political support for climate policy and discourage investment and R&D (Aldy and

[3]Despite high levels of taxation for road transport fuel, fuel prices still appear to be below their economically efficient levels, reflecting multiple negative externalities (Arregui and others forthcoming; Coady and others 2019). Thus, including the transportation sector in the ETS should not be used as an argument for a generalized reduction of existing fuel duties. Fuel duties should only decrease by the amount that was attributed to emission externalities; duties targeted to other purposes such as road congestion or revenue collection should remain in place.

Stavins 2011). A more stable carbon price path, calibrated exogenously and broadly consistent with the overall emission goals, could be introduced through the following two approaches:

- **An ETS auction price floor could be set.**[4] Such a price floor can provide stability in the event of unexpected shocks, thereby eliminating uncertainty for investors and supporting market confidence. Price floors are already embedded in some other large-scale cap-and-trade systems (for example, California, Massachusetts, Quebec, and the Regional Greenhouse Gas Initiative covering 10 US states). Although Fischer and others (2019) conclude that introducing an auction reserve price in the EU ETS is legally feasible, political constraints could remain, including the difficulty in securing unanimity on fiscal or energy source matters among member states (Flachsland and others 2018).[5]
- **Strengthening the MSR.** Quantitative allowances could be made consistent with a predictable carbon price floor. This can be achieved by replacing the current quantity surplus trigger with a price-based threshold for the purpose of activating the reserve. The review of the MSR in 2022 will provide an opportunity to revisit its functioning.

The free allowances to sectors deemed at risk of carbon leakage could be phased out. Free allowances have been justified on international competitiveness grounds as compensation for the environmental compliance costs borne by carbon-intensive companies. However, the foregone auction revenues could be used more efficiently to benefit the whole economy by, for example, avoiding economy-wide distortionary taxes. Other tools could be considered to prevent leakage (see the section on carbon border adjustment). Any compensation for the cost of electricity for energy-intensive industries should also be removed (see Arregui and others, forthcoming).[6]

The remaining subsidies and tax exemptions to fossil fuels in the EU should be discontinued. This is a prerequisite to achieve a uniform pricing of emissions at the efficient level. While the EU has eliminated most direct subsidies to fossil fuels (remaining direct subsidies are estimated at only about $1 billion, see Coady and others 2019), important tax exemptions remain.

[4]An implicit reserve price already exists in the EU ETS. Article 7(6) of the Auctioning Regulation stipulates that an auction shall be canceled if the clearing price is significantly below the secondary market price. Nonetheless, this system has not prevented the carbon price from being low and volatile.

[5]While the absence of a price floor may provide relief during cyclical downturns, the social cost of emissions is roughly unchanged, so it is not optimal for the carbon price to drop to the extent observed after the global financial crisis.

[6]For example, in 2017, some member states transferred part of their ETS revenue to the industry, ranging from less than 5 percent in Lithuania to 30 percent in France and 50 percent in Luxembourg (EC 2019). These compensations have not always been driven by an economic rationale (Roques and Laroche 2020).

Table 5. EU: Impact on Macroeconomic Aggregates of Revenue Recycling Options, 2030

	Emissions (rel. to 1990, percent)	Carbon Price (2019€ per ton of CO_2)	Income (rel. BaU, percent)	Unemployment (rel. BaU, ppts)	Energy Share of Renewables (percent)
Unchanged Policies (BaU)	−40	11	–	–	32.6
Lump-sum Transfers	−50	101	−0.9	0.5	41.0
Labor Tax Cut	−50	102	−0.4	0.0	41.2
Renewable Subsidy	−50	59	−0.7	0.1	47.9

Source: IMF staff calculations.
Note: Income, unemployment, and capital are expressed as percentage deviations from the baseline. BaU = business as usual (baseline).

Estimates of the latter range from around $46 billion for the component corresponding to foregone consumption tax revenue (Coady and others 2019) up to more than $200 billion when using the highest prevailing rate in member states (EC 2014b).

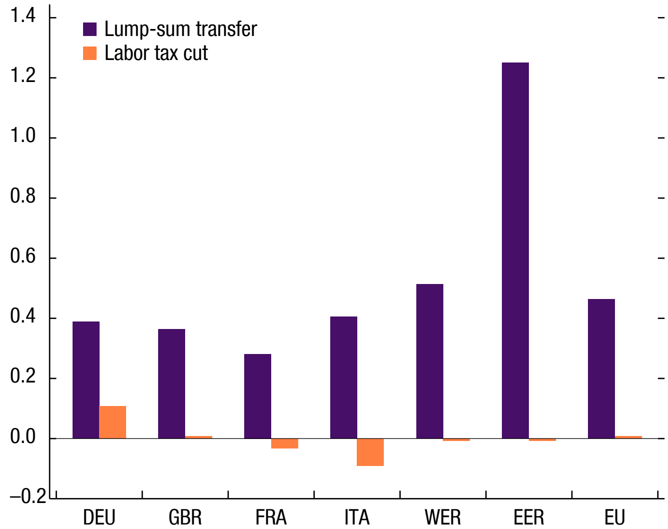
Using Revenues to Enhance Economic Efficiency and Political Acceptability

Using carbon pricing revenue to cut labor taxes would recoup almost all income losses from higher carbon prices. Carbon pricing generates fiscal revenue, either from emission allowance auctions or carbon taxes. To maximize economic efficiency, revenue should be used to decrease (or to avoid the need to raise) distortionary taxes such as the labor income tax, or to address critical public investment gaps. The reduction in labor taxes could be designed to protect low-income households (discussed later). The model simulations indicate that the EU can achieve a more ambitious emission reduction by 2030 with a minimal impact on aggregate income and employment by using the carbon price revenue to cut labor taxes (see Table 5 or Annex 1 for more detail).[7] For comparison, rebating the revenue to households as a lump sum would lead to an income loss of 0.9 percent and 0.5 percentage point higher unemployment (Figure 9).[8] This is because with high initial labor tax rates and unemployment rates, labor taxes are roughly as distortionary as carbon taxes. A simultaneous announcement of an increase in carbon prices combined with a tax cut on labor should enhance the political acceptability of higher carbon prices. Taking into account the potential reduction in labor informality after shifting taxes from labor to carbon would result in more

[7]Beyond 2030, carbon pricing revenue would start to decrease as the EU approaches its 2050 goal of net zero emissions, because the revenue base will shrink. Hence, the use of revenue will provide support during the transition, not permanently.

[8]The income losses from a carbon price increase reflect distortions in economic efficiency and transitory frictions in labor and capital markets. Labor market frictions are modeled as rigid wages, and capital market frictions as the inability to reallocate old capital vintages between sectors. In reality, job reallocation frictions may also play an important role. Note that the model does not take into account income gains from avoided environmental damages.

Figure 9. Change in Unemployment Rate, 2030
(Relative to baseline, in percentage points)



Source: Authors' calculations.
Note: Data labels in the figure use International Organization for Standardization (ISO) country codes. WER = other Western European countries; EER = Eastern Europe; EU = EU average.

positive income effects (Bento, Jacobsen, and Liu 2018; Kuralbayeva 2019). Empirical estimates also suggest that the effect of carbon pricing on output and employment in the EU has been close to zero.[9]

The simulated income effects from carbon pricing do not account for the global and domestic environmental benefits that would result from mitigating global warming. In the long term, the economic benefits of mitigating global warming would more than compensate the transition cost (Kahn and others 2019). Global warming can lead to catastrophic scenarios, including the extinction of humans, and the small estimated mitigation costs are well worth the benefit of reducing the risk of such outcomes. In addition to the long-term climate benefits, Box 2 shows that reducing fossil fuel consumption can have other important domestic environmental benefits, even in the short term. These include fewer deaths from exposure to local air pollution, but also reductions in traffic congestion, accidents, and other vehicle-related externalities.

Well-targeted public support for green investment is a critical element of an effective package, though it could entail a slightly higher income cost.

[9]Metcalf and Stock (2020) estimate that the impact on output and employment of carbon pricing in the EU is not statistically significant.

Robust carbon pricing will already provide a strong incentive for green investment, but public support is critical to address externalities that keep investment below its optimal level (see the last section of the paper). In the model, the income loss from a subsidy to investment in renewable generation is slightly larger compared to using the carbon revenue for a labor tax cut (as a subsidy adds a distortion to the economy whereas cutting taxes lowers distortions), but smaller than the loss from using the revenues for lump sum transfers (because the subsidy increases the aggregate capital stock). However, the model does not capture externalities that would increase the social return of green investment in areas such as R&D or networks, so the true income effect is likely to be more positive than suggested by the simulation. Moreover, public support for green investment should not be tied to carbon pricing revenue, as its optimal level may exceed these revenues, especially in the initial years (if carbon prices are increased gradually).

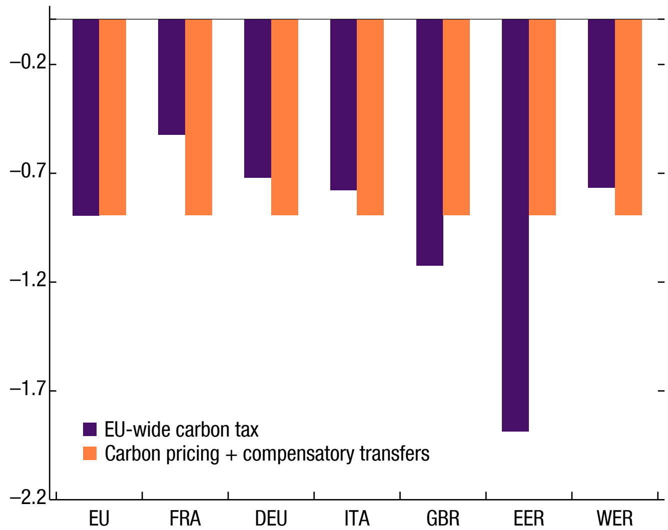
Renewable subsidies could also facilitate political acceptability and limit carbon leakage by keeping the carbon price relatively low. Higher carbon prices would put upward pressure on the energy prices faced by households and firms, and generate carbon leakage in non-EU trading partners.[10] Subsidizing renewables would reduce the required level of carbon prices compared to other revenue recycling options, as it lowers the relative price of renewables without the need to tax carbon. This increases the political attractiveness of a package of carbon pricing combined with investment subsidies.

Two additional policies, which have been proposed to complement pricing and enhance incentives for the green transition, are feebates and regulations. These policies are especially useful for difficult to decarbonize sectors like transport and buildings (see Arregui and others forthcoming).

- **Feebates.** A feebate is a scheme of taxes and rebates on firms or products proportional to the difference between the firm or product specific and the industry average carbon emission rates. Low-emission technologies receive a subsidy, whereas high-emission ones pay a tax (see Box 3). Feebates are usually designed to be approximately revenue neutral within a sector. Hence, they are effective at lowering the emissions from that sector (with an economic cost related to readjusting production or consumer choices), but not at reducing total demand. Thus, they are less cost efficient than carbon pricing (IMF 2019a; Stern and Stiglitz 2017). On the positive side, they can provide powerful mitigation incentives and can be more acceptable politically as they impose little burden on the average household. In fact, the renewable subsidy simulation discussed previously, combined with an economy-wide carbon price, is similar to a feebate for the energy sector.

[10]Carbon leakage is defined as the increase in rest-of-the-world emissions caused by an increase in the cost of EU emissions. This can be due to either import substitution or outsourcing of industries.

Figure 10. Change in Aggregate Income, 2030
(Relative to baseline, in percentage points)



Source: Authors' calculations.
Note: Data labels in the figure use International Organization for Standardization (ISO) country codes. EER = Eastern Europe; EU = EU average; WER = other Western European countries.

- **Regulations.** Regulations or standards to increase the share of low-emission sources in the energy mix or improve energy efficiency can yield similar emission reductions as a feebate if applied comprehensively. However, regulations provide less flexibility at the individual level, and so would generate higher welfare losses for consumers with heterogenous preferences and firms with different production functions (IMF 2019a). Moreover, they require that the government makes strong assumptions on the future evolution of technologies.

Ensuring Equal Burden Sharing Across Member States

A transfer system between EU member states could be set up to ensure that the costs of mitigation polices are shared equally. The introduction of a uniform carbon price would reduce the aggregate EU-level income losses, but it could lead to disproportionate economic costs for some EU countries. The income cost in the scenario with lump-sum transfers ranges from 0.5 percent of GDP in France to 1.9 percent in Eastern Europe. Intra-EU compensatory transfers could be used to share the burden more equally while preserving the efficiency of uniform carbon pricing (Figure 10). This would increase the political acceptability of uniform carbon prices among lower-income countries, which typically have larger emissions per unit of output, and thus would see a higher increase in the tax burden.[11] The transfers can go into the general budgets of member states and could be used to mitigate the impact of higher taxes on vulnerable households and workers as well as to promote the development of green technologies. Transfers could be implemented via the EU's Just Transition Mechanism. A system of transfers neutralizing the income impact of mitigation policy across countries would not significantly alter the average EU macroeconomic variables.

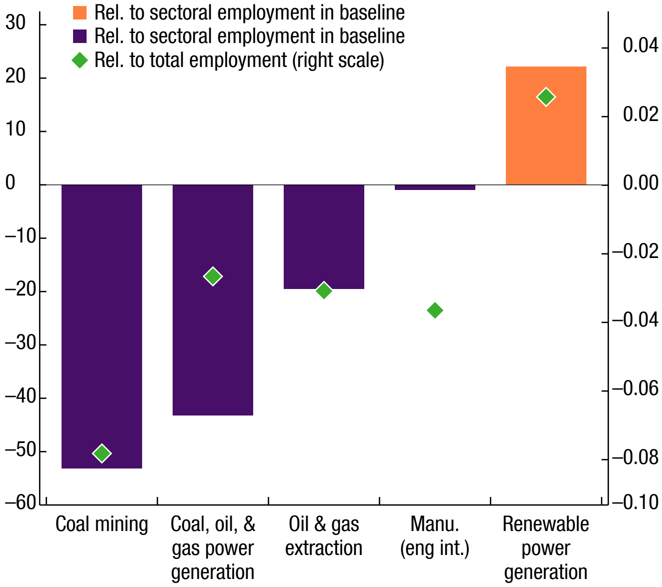
Managing the Sectoral Transition

The transition to a low carbon economy will involve a reallocation of employment across sectors. Sectors that would be most affected include extractive industries as well as those that rely heavily on carbon-intensive inputs, those with high elasticity of demand to carbon price changes, and potentially import-competing sectors with a high elasticity of substitution between foreign and domestic goods. Model simulation of policies to reduce emissions by 50 percent by 2030 suggest that employment in coal mining and fossil fuel power generation would decline sharply. Oil and gas extraction would also see significant losses, whereas the renewable power sectors would gain employment (Figure 11). In a world with wage rigidities, unemployment can rise temporarily as workers relocate slowly across sectors (the estimated overall increase in unemployment is 0.3 to 1 percentage points depending on the scenario, but some regions could see greater job losses).

Policies could help ensure a smooth transition. The goal should be to support workers and not particular jobs or sectors. Policies should be well targeted given the relatively small share of workers affected and their geographical concentration (Figure 12). For instance, active labor market polices including re-training (such as the National Retraining Scheme in the United Kingdom or the Job-rotation program in Denmark) could help workers acquire the necessary skills to move to new sectors. Training programs should be complemented with other interventions (such as employment services, transportation stipends, job search assistance, and localized investment) to maximize their impact.

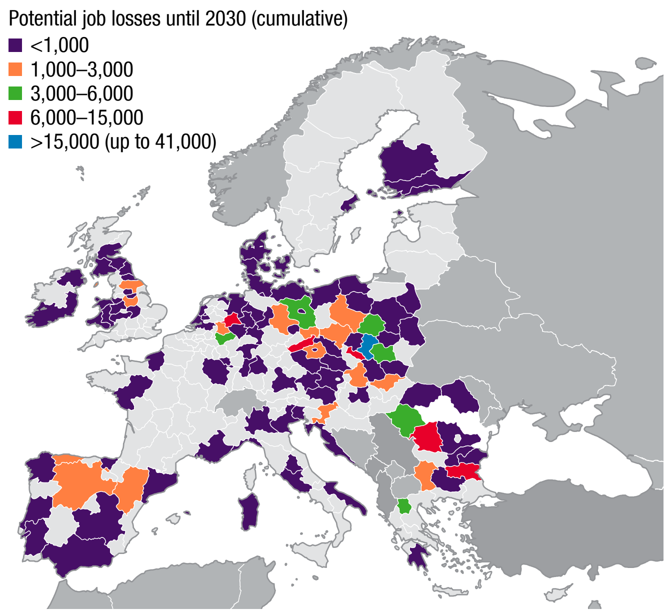
[11]As discussed earlier, uniform carbon prices reduce aggregate income losses (at the individual country level, income losses would decline especially sharply for countries with high marginal abatement costs combined with more ambitious targets). Thus a uniform carbon tax combined with cross-country transfers are in everyone's economic interest.

Figure 11. Change in Employment in Most Affected Sectors, 2030
(Percent)



Source: Authors' calculations.

Figure 12. Projected Job Losses in the Coal Mining Sector by 2030



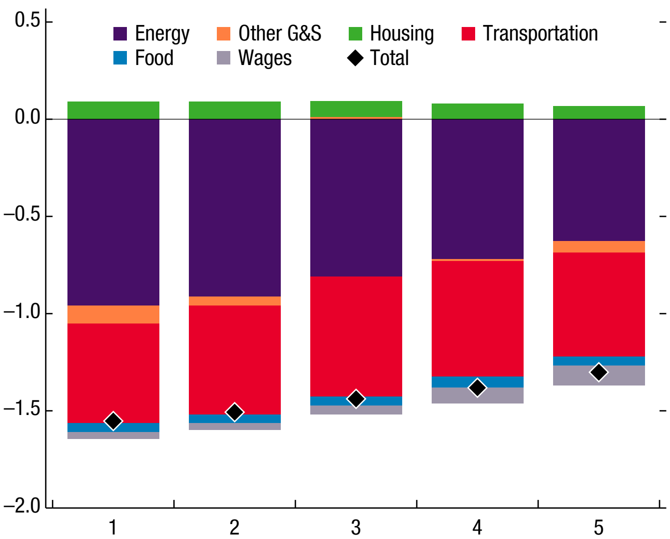
Source: Alves Dias and others 2018.

Mitigating the Distributional Impact Across Households

A carbon price increase could affect households differently. Higher carbon prices affect households directly by raising the price of energy and indirectly through general equilibrium effects on other consumption good prices and wages. An analysis of the incidence of raising the carbon price to €100 per ton of CO_2 by 2030 is conducted using consumption survey data by income quintile, combined with the endogenous changes in consumption prices and wages from the Envisage simulations. Note that the analysis may overestimate the actual impact due to the following factors. First, energy consumption is assumed to remain fixed over time despite the increase of energy prices. In practice, consumers will switch away from more heavily taxed products. Second, the burden calculation does not take into account the use of carbon price revenue, which could correct for any regressive impact.[12]

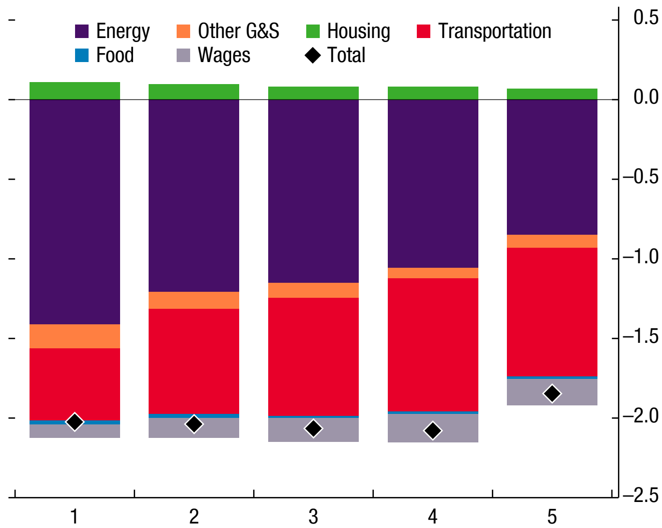
[12]There is a potential third factor as well. Energy consumption is likely to be reflected fairly accurately in the surveys, but total consumption may be underestimated. Aggregate consumption measured through household survey data is typically smaller than the aggregate final consumption of private households in the national accounts. This is due to several measurement and conceptual issues. An important difference is the imputation

Figure 13. €100 Carbon Price Burden by Category, France
(Percent of total consumption, by household income quintile)



Sources: ENVISAGE; Eurostat; LIS database; and authors' calculations.
Note: G&S = goods and services.

Figure 14. €100 Carbon Price Burden by Category, Germany
(Percent of total consumption, by household income quintile)



Sources: ENVISAGE; Eurostat; LIS database; and authors' calculations.
Note: G&S = goods and services.

The data suggests that for most EU countries the burden is greater for poorer households, as energy typically represents a larger share of their consumption. For example, in France the effect is regressive: the purchasing power will decline by about 1½ percent for the lowest income quintile and by about 1¼ percent for the highest income quintile (Figure 13). However, this is not always the case. In Germany, the effect is similar for the bottom four quintiles at about 2 percent of consumption (Figure 14). The average effects would be larger in lower-income countries where energy is a higher share of the consumption basket.

Fiscal policy could be deployed to protect the most vulnerable households from the effects of higher carbon pricing. The specific design of the compensation mechanism and the share of the population that receives support are a matter of political choice and societal preferences over equity and efficiency. A simple-to-implement progressive compensation scheme would be to give lump sum transfers calibrated to fully compensate the bottom quintile of the household income distribution. For example, compensating the lowest quintile fully for the effect of increasing carbon price to a €100 per ton in Germany and France would require a €374 and €232 per capita yearly dividend, respectively. The fiscal cost will be around 0.6 percent of GDP in Germany

of rents for owner-occupied housing and financial services included in the national accounts data. See Eurostat (2020) for details.

Table 6. EU: Carbon Leakage Under Different Policies, 2030

	Emissions (% change rel. to 1990)	Carbon Leakage to the ROW (percent)	Income (% change from BaU)
Unchanged Policies (BaU)	−40	–	–
EU-wide Carbon Price	−50	14.7	−0.9
Border-adj. (BCA)	−50	−1.1	−0.5
Global Carbon Price	−47	NA	−0.7

Source: Authors' calculation.
Note: Carbon leakage is defined as the change in emissions in the rest of the world divided by the decline in emissions in the EU. A positive (negative) sign indicates increasing (decreasing) emissions abroad. BaU = business as usual (baseline); BCA = border carbon adjustment; NA = not applicable; ROW = rest of world.

and 0.4 percent of GDP in France if the dividend is phased out linearly from the second to the top quintiles, substantially less than the carbon revenue raised. A more elaborate compensation mechanism could instead seek to reduce high marginal tax rates, thus ensuring economic efficiency through a positive effect on labor supply, while providing compensation to all households for the loss of purchasing power (see Batini, Parry, and Wingender, forthcoming). The latter mechanism can also be made progressive by reducing more the marginal tax rates for lower-income earners.

Carbon Leakage and Global Coordination

As the EU scales up its climate mitigation policies faster than the rest of the world, the potential for carbon leakage has become a concern. An increase in global emissions that partially offsets the decline of EU emissions could happen through two main channels: (1) the EU increases imports or outsourcing of energy-intensive goods instead of producing them locally as domestic costs increase, and (2) global energy prices fall as EU demand for fossil fuels declines (Burniaux, Chateau, and Duval 2013). The second channel would be relatively small in the case of the EU because it accounts for a small share of global fossil fuel consumption. According to Envisage model simulation, which accounts for both effects, an increase in EU carbon prices would raise emissions in the rest of the world by about 15 percent for each unit of EU emissions avoided (see Table 6). Empirical analysis suggests a similar effect, with a carbon leakage rate around 13 percent for the EU, and higher rates for some individual countries (Wingender and Misch 2020). The leakage would be much higher for emission-intensive and trade-exposed industries such as cement, aluminum, steel, and iron, especially in the presence of large carbon price differentials (Cosbey and others, 2019).

A coordinated global emission reduction effort would be most effective in reducing emissions and eliminating carbon leakage. If all countries agree on a common carbon price, abatement will take place at the lowest possible global economic cost (the relative welfare of countries can be preserved through transfers or other policies). Based on the model results, if the world adopts a global carbon price to reduce global emissions by 50 percent in 2030 relative to 1990, the equilibrium price would be lower compared to the case where the EU acts alone. With global price action, the EU would need to cut emissions by less (47 percent) and would therefore have lower output losses, because it has a higher marginal abatement cost than many other economies. Implementing a uniform carbon price even just in the three largest emitting non-European countries (China, India, and the United States) would go a long way in reducing global emissions and improving economic efficiency (see Box 4 and IMF 2019a).

In the absence of coordinated global action, the Green Deal proposes the introduction of a BCA mechanism as a policy option to reduce carbon leakage. One way to design a BCA is as a levy on the carbon content of imports equal to the EU carbon price minus the carbon price at origin. Such an adjustment would reduce the leakage by discouraging import substitution of energy intensive goods and would also generate fiscal revenue. Furthermore, it could provide an incentive for EU trading partners to reduce the carbon content of their exports.[13]

Nonetheless, implementing a BCA presents several practical challenges. There are many practical economic, political, and implementational aspects that would need to be considered when evaluating the potential introduction of a BCA. On the political front, some trading partners might regard a BCA as a protectionist measure rather than an environmental one, and seek to impose retaliatory trade measures, with negative economic consequences. The compliance of a BCA with the World Trade Organization rules depends on its specific design and has not been legally tested so far. It is not the goal of this paper to have a comprehensive discussion (see Cosbey and others 2019 for a survey). Among the many complex issues that need to be considered are the following:

- Measuring the carbon content of traded goods would be difficult. A possible solution is to use “macro measures” such as country or sector averages. While macro-based measures do not provide incentives to individual producers to implement carbon mitigation, it could incentivize trading partner countries to increase carbon pricing. Further down the road, as experience with measurement accumulates, it could become possible for individual

[13]Any type of BCA would eliminate only the leakage embodied in trade. It would not address the potential increase in global fossil fuel consumption induced by the reduction in fossil fuel prices due to lower demand by the EU.

producers to obtain emissions certifications from an internationally recognized institution.[14]

- Adjusting precisely the border levy for the differences in effective carbon taxes implied by the trading partners' carbon mitigation schemes is also challenging. It is relatively easy to calculate the average effective tax rates when the trading partner relies mostly on explicit price mechanisms, such as an ETS or a carbon tax, but quantifying the implicit monetary cost of regulations and standards could be difficult.
- A decision must be made on which sectors to include in the BCA. It could be applied initially to just emission-intensive and trade-exposed sectors because they account for the largest share of trade-embedded carbon and face the highest carbon leakage rates. As measurement and administrative costs decline over time, consideration could be given to extending coverage to other sectors.
- A decision also needs to be made on other design features, such as whether to refund the tax paid on the carbon content of EU exports. If exports are exempt, the competitiveness impact from higher domestic carbon taxes on domestic producers would be avoided but at the cost of higher domestic emissions and lost fiscal revenues. Fischer and Fox (2012) compare different instrument designs to reduce leakage (including different BCAs and carbon price rebates/exemptions for domestic producers) and discuss their effectiveness in reducing global emissions under different conditions—they conclude that the effectiveness depends on the relative emission rates, elasticities of substitution, and consumption volumes.

Supporting Investment and Promoting a Green Recovery

Higher carbon pricing needs to be complemented with public support to ensure a rapid expansion of investment in green technologies.[15] Higher carbon pricing would already provide strong incentives for green private investment. Based on the model estimates, the increase in carbon prices needed to reduce EU emissions by 50 percent would lead to 11 percent annual growth in renewables capital (helping to achieve the EU 2030 renewables share goal). Moreover, higher prices would stimulate innovation in green technologies.[16] Nevertheless, green investment is constrained by market failures beyond emission externalities that cannot be entirely corrected with carbon pricing.

[14]Examples of such certification institutions include the World Resource Institute/World Business Council on Sustainable Development GHG Protocol or the ISO 14064 standard.

[15]Note that the label "green" in this context refers to activities that have broadly neutral impact on the environment or help reduce GHG emissions.

[16]Popp (2002) estimates that a 10 percent increase in energy prices leads to a 3.5 percent rise in the number of patents in renewable energy and energy efficiency technology. Ley, Stucki, and Woerter (2016) find that a 10 percent increase of energy prices results in a 3.4 percent increase in the number of green innovations.

Therefore, it is critical to complement carbon prices with well-designed public support to ensure an optimal level of investment.

As member states put in place ambitious recovery programs, they should continue to prioritize support for green investment (IMF, 2020). Direct public investment in green R&D and infrastructure as well as government subsidies and guarantees to strengthen the demand for and deployment of low-carbon technologies can lead to job-rich growth (see Wei and others 2010) and boost productivity. Frontloading investment support while stepping in carbon pricing more gradually over time could yield a boost to aggregate demand in the short term and help close the current large output gaps (Hepburn and others 2020). The low interest rate environment provides the opportunity for a low-cost funding of green investment opportunities with high long-term returns. The policy packages announced by the EC and many of the large economies so far feature support for green investment and products (for example, subsidies for electric and low-emission cars). More could be done, including prioritizing investments in projects such as the retrofitting of buildings, building charging stations, and upgrading of the electric grids (see Arregui and others [forthcoming] for further suggestions). Moreover, policymakers should exercise caution in funding sectors that will become unsustainable as carbon prices rise.

Public support should be directed to areas with high social returns. The Green Deal aims to mobilize €1 trillion of green investment over the next 10 years—a significant fraction of the total (public and private) gross investment needed to achieve the EU's 2030 emissions and renewable targets, estimated between €140–€290 billion *per year* (EC 2019; and staff simulations). Support policies that would complement and spur private sector investment in green technologies include:

- **Public investment in networks to achieve the efficient level of provision.** Network infrastructure requires coordination and has public good properties, which implies underprovision by the market. Examples of public network investments that would facilitate emission reductions include electricity grids that would support renewable energy penetration and electrification of downstream sectors, electric vehicle charging stations, public transport infrastructure, and internet broadband connectivity—which would reduce the need for transport and enhance smart energy use (see, for example, Springel 2018 and Avner, Rentschler, and Hallegatte 2014).
- **Public provision and subsidies for R&D in green technologies to encourage knowledge spillovers.** Clean-energy R&D tends to generate large knowledge spillovers, with applications outside the energy sector as

well. This is especially true for early stage technologies, where public R&D could be more effective than subsidies to private R&D.[17]

- **Support for private investment in the early deployment stage to promote learning by doing.** Learning by doing occurs when production costs fall as cumulative output increases. To the extent that some of the benefits of learning accrue to other producers or consumers, subsidies for early deployers are justified.[18] Public support should be discontinued as technologies mature.

Public support is also justified where financial constraints hamper green private investment. Financial constraints are particularly acute in the energy sector, given long time horizons to profitability and large initial fixed costs.[19] Government grants, especially for small producers, can help clean energy technologies overcome financial constraints (Howell 2017). Another area where large initial costs are a frequent impediment to investment (even when the net long-term returns are positive) is building efficiency. Financing assistance for low-income households for energy efficiency improvements could help overcome that. Path dependency, where producers are locked in high-emitting technologies for long periods of time, provide a further motive to subsidize the deployment of green technologies (Aghion and others 2016).

The operationalization of the EU taxonomy of environmentally sustainable activities will be the key element of the EU effort to strengthen green finance. The EU Action Plan on Sustainable Finance is appropriately centered on developing a classification system for sustainable economic activities that would serve as a guide for investors who want to support activities with a positive impact on climate.[20] Strengthening the reporting verification systems should help prevent "greenwashing" or false claims of environmental soundness (IMF 2019b). Comparability between reporting entities could be improved by requiring a limited number of common indicators to be disclosed, ideally building on existing measures (for example, emissions reported to the ETS), thus avoiding data manipulation and excessive administrative costs for firms and regulators. Disclosure requirements should be introduced gradually and flexibly to allow market participants to adapt. More broadly, comprehensive carbon pricing would be a more effective and less administratively costly way to reorient finance to greener activities.

[17]See Popp and Newell (2012); Popp (2016); Dechezleprêtre, Martin, and Mohnen (2017); and Noailly and Shetalova (2017).

[18]See Soderholm and Sundqvist (2007) for renewable energy technologies, Nemet (2012) for wind turbines, and Bollinger and Gillingham (2014) for solar photovoltaic installations.

[19]See Branstatter and Ogura (2005); Finardi (2011); Mowrey, Nelson, and Martin (2010); Popp (2017); and Weyant (2011).

[20]However, there is a risk that investors without environmental goals undo part of the effect by chasing higher yields in high-emitting companies.

Preserving political support for large-scale green investment hinges on the efficient and transparent use of public funds. Public money should be used wisely and with strong safeguards against abuse. The Organization for Economic Co-operation and Development has developed a checklist to curb corruption in public investment at different steps of the cycle (Organization for Economic Co-operation and Development 2015). In general, industrial policy should follow the following basic principles:[21]

- **Embeddedness:** Policymakers need to understand the needs of and bottlenecks faced by the private sector.
- **Discipline:** Governments must have a transparent system of decision-making and use disciplining devices against abuse. This requires monitoring and evaluation of the performance of firms using support programs against existing benchmarks. Unbundling the roles of policy formulation, funding, implementation, and evaluation can be helpful to insulate such performance-based systems from political interference. Using tenders, encouraging competition among service providers, and monitoring performance through independent agencies further enhances effectiveness. Having clear and transparent rules, as well as conditionality and sunset clauses, helps to prevent rent-seeking behavior.
- **Accountability:** Periodic reporting requirements should be established as well as a checks-and-balances system including central auditing authorities, independent courts, and the press.

[21]See Altenburg and others (2008); Evans (1995); and Rodrik (2004).

Box 1. German Emission Trading System

The German government will start pricing greenhouse gas emissions in the transport and building sectors from 2021 as a key instrument to help reach its climate targets. The national emissions trading system for transport and building will exist in parallel to the EU-wide emission trading system (ETS) and will cover the bulk of emissions not included in the ETS. The participants are the distributors or suppliers of the fuels (a midstream approach). To avoid a double burden, fuel deliveries to ETS facilities are exempt from the national price. The scheme is a cap-and-trade system in which the federal government sets an annual total emissions limit for transport and heating fuels in line with its annual total non-ETS targets prescribed by the EU (but excludes nonfuel emissions such as methane from agriculture). Emission allowances are transferable and tradeable. They will generally be auctioned, but until 2025 they will be sold to companies at a fixed price. More specifically, the allowance price will be fixed at 25 euros per unit in 2021 (consistent with the current EU ETS price) and will increase to 55 euros in 2025. It will be auctioned with a price corridor of 55–65 euros in 2026, and at a market price starting in 2027 (possibly with a corridor to be decided later).

Box 2. The Domestic Environmental Co-Benefits from Carbon Mitigation

In addition to climate benefits, reducing fossil fuel consumption can have other important domestic environmental benefits. These include fewer deaths from exposure to local air pollution, but also reductions in traffic congestion, accidents, and other vehicle-related externalities. In principle, domestic environmental problems should be addressed through instruments other than carbon mitigation policies (for example, fees on local emissions to reduce air pollution, peak-period pricing of busy roads to reduce congestion). Until these instruments have been comprehensively implemented, however, it is appropriate to include (unpriced) domestic environmental co-benefits in evaluating the economic effects of carbon pricing.

The domestic environmental cost of fossil fuel use is estimated in the IMF's mitigation spreadsheet tool. The tool projects fuel use and emissions by energy sector for 135 countries, and estimates the impact of carbon mitigation policies on emissions, the fiscal accounts, and economic welfare.[1] The welfare gain is the difference between the domestic environmental co-benefits and the economic efficiency costs of mitigation policies, as measured by changes in consumer and producer surplus in fossil fuel markets (accounting for preexisting fuel taxes).[2] The pollution cost estimates from stationary sources are built up through estimates of plant-level "intake fractions" (that is, the fraction of air emissions inhaled by locally exposed populations), local mortality rates from pollution-related illness (from the World Health Organization), the relation between these mortality rates and pollution exposure, country-level air pollution emission rates, and local estimates of people's willingness to pay to reduce health risk. Estimates of local pollution, congestion, and accident externalities from mobile sources are extrapolated to the national level using a variety of procedures.[3]

For most EU countries, the domestic environmental benefits of a (nationwide) €50 carbon price exceed the efficiency costs (Figure 2.1).[4] This is especially the case for countries with relatively high local air pollution damages. This finding reflects the general lack of existing taxes to price the air pollution costs of coal use and the undertaxing of gasoline and diesel fuel for the full range of environmental costs from vehicle use (despite high road fuel excises). Other carbon mitigation policies would produce

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[1]The price responsiveness of fuel use in the model is parameterized to be broadly consistent with that implied from energy models and empirical evidence. Cross-border effects (for example, due to the mobility of road fuel tax bases) are not considered. The tool has been used in several recent reports, for example, Black and Parry (2020); IMF (2019a, 2019c); and Parry, Mylonas, and Vernon (2020).

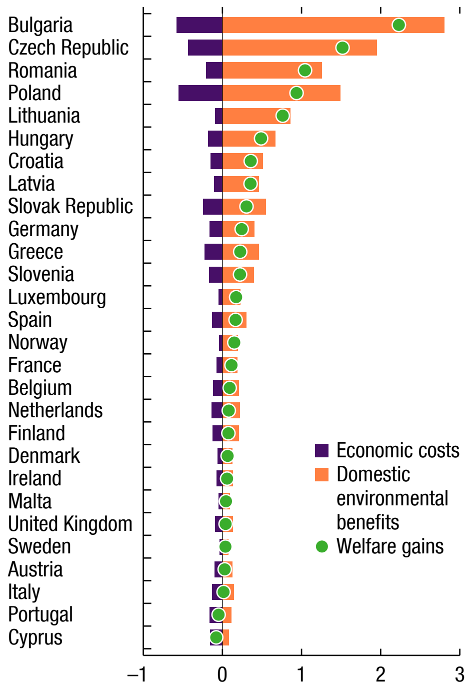
[2]Linkages with tax distortions from the broader fiscal system are not included, due to the lack of a solid cross-country database for comprehensively measuring these distortions. The calculation also abstracts from temporary frictions due to factor reallocation across sectors.

[3]See Parry and others (2014) for a full discussion of methodologies.

[4]The estimates compare the impacts of an economy-wide carbon price to a baseline in 2030 with no new, or tightening of existing, mitigation policies (beyond those implicit in recently observed fuel use).

Box 2. The Domestic Environmental Co-Benefits from Carbon Mitigation *(continued)*

Figure 2.1. Costs and Domestic Net Benefits of a €50/Tonne Carbon Price in 2030, Selected Countries
(Percent of GDP)



Source: Updated from IMF (2019b).

similar domestic environmental co-benefits to carbon pricing, to the extent they lead to a comparable reduction in use of fossil fuels.

In short, carbon pricing can be in countries' own domestic interests, even before counting global climate benefits. This is because pricing helps to achieve a more efficient allocation of a country's scarce resources across green and brown sectors, accounting for the full social costs of production.

Box 3. Reinforcing Carbon Pricing with Feebates

Where the acceptability of carbon pricing is constrained, it can be reinforced with feebates. Feebates apply a revenue-neutral sliding scale of fees to products/activities with above average emission rates and a sliding scale of rebates to products/activities with below average emission rates. For example:

For vehicles, new purchases would be subject to a fee equal the product of (1) a CO_2 price, (2) the difference between the vehicle's CO_2/km and the fleetwide average CO_2/km, and (3) the (discounted) lifetime mileage of the average vehicle.

For industries, firms would pay a fee equal to the product of (1) a CO_2 price, (2) the difference between the firm's and the industry average CO_2/unit of production, and (3) their output.

For power generation, utilities would pay a fee equal to the product of (1) a CO_2 price, (2) the difference between their average CO_2/kWh and the industry-wide average CO_2/kWh, and (3) their output.

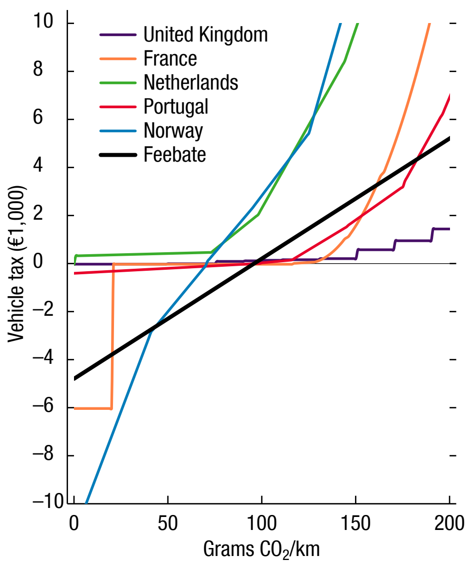
For electricity-using products (for example, refrigerators, heating systems), these goods would incur a fee equal to the product of (1) a per unit energy charge and (2) the difference between their energy consumption rate and the industry-wide energy consumption rate for that good.

Feebates have several key features, including:

- They can potentially be more acceptable politically and socially as they impose little or no burden on the average household and firm.
- They promote a range of relevant behavioral responses, for example, in power generation, switching from coal to gas, co-firing of biomass, shifting to combined cycle generation with carbon capture, improving generation efficiency, and shifting to wind and solar. However, they are less efficient than a carbon price as they do not incentivize a decline in the demand for energy, which is also a key driver of emissions.
- They are more cost-effective than regulations, as they provide the same incremental reward for reducing emissions across responses and feebate prices can be harmonized across sectors (in contrast, regulatory approaches are difficult to coordinate cost effectively across firms and sectors).
- They are revenue neutral, if the "pivot point" (the point above/below which fees/rebates are applied) is set equal to the industry average emission rate and updated over time (in contrast, subsidies for renewables and electric vehicles lose revenue)

Box 3. Reinforcing Carbon Pricing with Feebates *(continued)*

Figure 3.1. CO_2-Based Components of Vehicle Taxes



Source: ACEA (2018); and authors' calculations.
Note: Feebate assumes CO_2 price of €500/tonne, pivot point of 95 grams CO_2/km and lifetime discounted driving of 100,000 km.

and consumer reactions are anticipated correctly.[1]

- They are straightforward administratively (for example, feebates can be integrated into existing vehicle tax systems or build off emissions monitoring capacity for generators and industries).

Feebates can be set to imply high carbon taxes, providing powerful mitigation incentives. For illustration, a feebate of €500 per ton of CO_2 for vehicles would provide a subsidy of €4,800 for zero-emission vehicles (ZEVs) while imposing a tax of €2,750 on a 150 grams CO_2/km vehicle, assuming a new vehicle fleetwide CO_2 emission rate of 95 grams per km (the 2021 EU standard). Subsidies for ZEVs would decline over time as the pivot point declines (for example, by 32 percent when the fleetwide average falls to 65 grams CO_2/km, the 2030 EU standard), which is appropriate as the costs of ZEVs fall with technology development over time (although not necessarily at the same pace).

Elements of feebates have been integrated in vehicle tax systems though design features typically differ from those recommended here (Figure 3.1). For example, often schemes are not revenue neutral (that is, governments lose revenue as people shift to low-emission vehicles) because pivot points do not automatically update or subsidy outlays for below average emission vehicles do not match taxes collected on above average emission vehicles. In some cases, incentives are not very strong (for example, the tax differential between a 150 grams CO_2/km and a ZEV in the United Kingdom is €240). And some systems provide discontinuous incentives which miss some mitigation opportunities (for example, in France and United Kingdom there is little difference in tax rates for vehicles with emission rates below 130 grams CO_2/km).

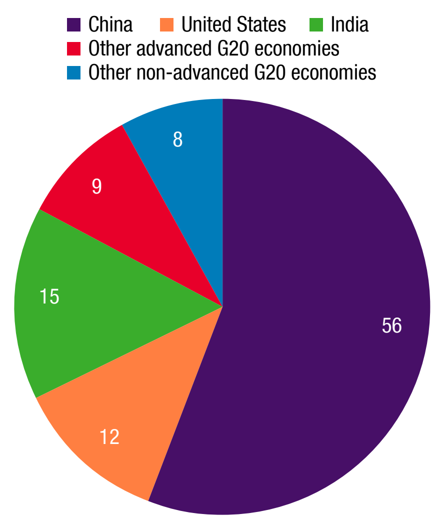
[1]Where governments have fiscal objectives, feebates can be combined with another revenue-raising instrument (for example, a tax on vehicle sales values).

Box 4. The Rationale for an International Carbon Price Floor

A carbon price floor arrangement among the EU and large emitting countries could complement and reinforce the Paris Agreement. The arrangement:

- Would be the best way to address concerns about carbon leakage and the effect of carbon pricing on countries' competitiveness, as pricing would be internationally coordinated;
- Need only cover a limited number of countries, in fact under a uniform carbon price across G20 emitters (who collectively account for 80 percent of global emissions), over 80 percent of the emissions reductions would be in China, India, and the United States alone (Figure 4.1);
- Could be designed equitably, with lower price floor requirements for emerging market economies (to reflect their lower per capita income and small contribution to the accumulated atmospheric stock of greenhouse gases);
- Could be designed flexibly to accommodate different approaches at the national level including carbon taxes, trading systems, and combinations of feebates and regulations as long as approaches yield equivalent emissions reductions to those from implementing the floor price;
- Is strikingly effective in scaling up global mitigation even at modest prices. For example, if advanced and emerging market G20 countries agree to a \$50 and \$25 carbon price floor, respectively, in 2030 (or their Paris pledge, whichever is the more stringent) this would double mitigation effort among G20 countries over and above what is currently pledged (Figure 4.2), though higher prices would still be needed to reach the 2°C target;
- Might be enforced through a common border carbon adjustment applied to nonparticipating (middle- and high-income) countries.

Figure 4.1. Country Shares of G20 CO_2 Reductions Below Baseline Under a Uniform \$50/Ton Carbon Price in 2030, Selected Countries
(Percent)



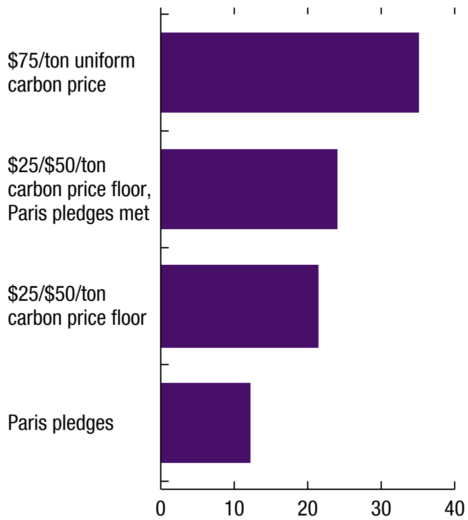
Source: IMF (2019a).

To operationalize the arrangement, the focus should be on raising the "effective carbon price," without offsetting reductions in preexisting energy taxes. Precedents for a carbon price floor arrangement include Canada, where states and provinces are required

Box 4. The Rationale for an International Carbon Price Floor *(continued)*

Figure 4.2. CO_2 Reduction for G20 Countries Under Alternative Ambition Scenarios, 2030

(Emissions-weighted average percent reduction in G20 CO_2 below baseline)



Source: IMF (2019a).
Note: For some emerging market economies the $25 ($50) floor is not enough to meet the Paris pledges. In the second scenario from the top, countries meet the price floor or the Paris pledge, whichever is more stringent; in the third scenario from the top, all countries meet their respective price floor, but some may not meet their Paris pledges.

to meet a federally set carbon price rising to CAN $50 by 2022[1] and (in a nonclimate context) floors for indirect taxes in the EU. Participants in the price floor arrangement would need to form a governance structure that, for example, includes external verification procedures for tracking their effective carbon prices.

[1]Parry and Mylonas (2018).

CHAPTER

4 Conclusions

This paper discusses a comprehensive set of policies that could allow the EU to achieve more ambitious reduction of emissions by 2030. The policy package emphasizes economic efficiency but also fairness and political acceptability. It includes the following key elements:

- **More robust carbon pricing.** This can be achieved by extending the EU ETS to other major emitting sectors or by introducing complementary carbon pricing frameworks at the national level. Introducing a uniform EU carbon price combined with transfers across member states would help reduce emissions at a lower economic cost than a system with national-level targets. Moreover, carbon prices under the EU ETS should be made more predictable, either by further strengthening the MSR or by introducing a carbon price floor.
- **An effective use of the revenue from carbon pricing.** Using revenue in part to reduce distortionary taxes (or to avoid any increase in distortionary taxes) would help offset the aggregate income losses from a higher carbon price. Revenues should also be directed to promote climate-friendly investment and to ensure broad public support for climate policies.
- **Targeted public support to promote green investment.** Carbon prices need to be complemented with public investment support for the package to be effective. For instance, public investment is warranted to improve infrastructure such as public transportation networks and electricity grids, R&D subsidies are needed to boost research in green technologies, and the development of a robust green taxonomy would foster green financing.
- **Complementary mitigation instruments could help reduce the carbon price needed to achieve the emission reduction objectives.** They can be especially useful for sectors like transportation and building that are difficult to decarbonize through pricing alone. For example, feebates can pro-

vide incentives for shifting purchases toward low-emission vehicles without a tax burden on the average household. Building standards and support for the financing of investment in energy efficiency would help decarbonize the building sector.

- **Protecting the vulnerable and facilitating the transition.** Policymakers need to facilitate the transition of workers to greener industries, as well as support the most affected regions. The impact from higher energy prices on low-income households could be mitigated through direct social support and through changes in the tax system.
- **Mechanisms to contain leakage.** Introducing an international carbon price floor, at least for the largest emitting economies, including China, India, and the United States, would be the most efficient way to reduce leakage and bring down global emissions. In the absence of such a floor, implementing a carbon border adjustment mechanism would help prevent carbon leakage (subject to the resolution of various political and design considerations), so that cutting EU production emissions does not lead to higher emissions abroad.

The recovery from the COVID-19 crisis creates a window of opportunity to build a more robust and sustainable economy. Public support for green investment should be prioritized in the initial stages of the recovery to help create jobs. Setting a predictable gradually increasing carbon price floor for the coming years would strengthen the incentives for consumers and investors to adjust their behavior now, while providing much needed fiscal revenue. With a well-designed package, the EU can achieve its more ambitious emission goals while ensuring a robust recovery.

Annex 1. Model Specification and Results

A computable general-equilibrium model is used to simulate the impact of different policy packages. The Envisage model (van der Mensbrugghe 2019) computes the carbon price needed to achieve a certain emission target and its economic impact.[1] In a nutshell, it solves the dynamic general equilibrium for 16 country groups spanning more than 180 countries, incorporating a detailed input-output matrix with 27 economic sectors, including 13 energy sectors.[2] Sectors are aggregated through a nested constant elasticity of substitution (CES) structure with heterogeneous elasticities. The level of sectoral granularity allows to capture substitution between different energy sources as well as the overall intensity of energy usage as carbon prices move. The model also features temporary wage rigidities, frictions in capital reallocation, trade costs, energy efficiency gains over time, progressive electrification of the economy, and a declining cost of renewable generation.

The policy simulations focus on the impacts on emissions, carbon prices and macroeconomic variables. Annex Table 1 describes each simulation, with policy scenarios designed to meet the EU's current target to cut GHG emissions by 40 percent by 2030 relative to 1990 levels or a more ambitious goal of 50 percent.[3] For each scenario, Annex Table 2 reports the emission reduc-

[1]One of the key strengths of the Envisage model is a consistent and complete representation of the global economy, including interactions between different economic agents. Though the level of the technological details is lower than in energy-system models, and productivity growth is exogenous, energy demand is represented endogenously. Combined with a sufficient level of sectoral details, the model provides a comprehensive framework for a multiregion energy and environmental policy assessment.

[2]The country groups are Germany, France, Italy, EU Eastern Europe, other Western Europe, the United Kingdom, the United States, other OECD, China, Russia, OPEC, advanced Asia, other East Asia, South Asia, other Latin America, and rest of the world. The energy sectors are coal, oil, gas, refined oil, nuclear power, coal power, gas power, hydro power, solar power, wind power, oil power, other, and electricity transmission and generation.

[3]The agreement covers three types of gas emissions (carbon dioxide, nitrous oxide, and perfluorocarbons), but the focus here is on carbon dioxide from fossil fuel combustion, which accounts for most GHG emissions.

Annex Table 1. Simulation Scenarios

Scenario Label	Emission Target	Description
Unchanged Policies	NA	Carbon price (economy average) at €9 in 2020, growing with GDP thereafter.
Lump-sum Transfers (40%)	−40%	Carbon price revenue used as lump-sum transfer.
Lump-sum Transfers	−50%	Carbon price revenue used as lump-sum transfer.
National Targets	−50%	No trade in permits between member states. All other scenarios have full trade in permits in all sectors and all member states.
Labor Tax Cut	−50%	Carbon price revenue used to cut labor taxes.
Renewable Subsidy	−50%	Carbon price revenue used to subsidize physical capital investment in renewable energy sectors. Subsidy rate capped at 75%.
Border-adj.	−50%	"Lump-sum transfers" plus a border adjustment carbon price to EU imports.
Global Carbon Price	−50%	Carbon price applied to the whole world, full global trade.
EU Compensatory Transfers	−50%	"Lump-sum transfers" plus intra-EU fiscal transfers to equalize welfare impact.

Annex Table 2. EU: Simulation Results, 2030

Scenario	**Emissions** (rel. to 1990, percent)	**Carbon Price** (€2019/ton of CO_2, economy average)	**Income** (rel. to BaU, percent)	**Unemployment** (rel. to BaU, ppts)	**Carbon Leakage to the ROW** (percent)	**Cross-country std. of income impact**	**Energy share of renewables** (percent)
Unchanged Policies (BaU)	−40	11	19.6	6.8	NA	NA	32.6
Lump-sum Transfers (40%)	−40	40	−0.3	0.1	15.5	0.1	34.7
Lump-sum Transfers	−50	101	−0.9	0.5	14.7	0.5	41.0
National Targets	−50	136	−1.2	0.7	24.3	0.5	41.6
Labor Tax Cut	−50	102	−0.4	0.0	15.1	0.3	41.2
Renewable Subsidy	−50	59	−0.7	0.1	6.8	0.9	47.9
Border-adj.	−50	101	−0.5	0.6	−1.1	0.4	41.3
Global Carbon Price	−47	93	−0.7	0.6	NA	0.4	39.2
EU Compensatory Transfers	−50	101	−0.9	0.5	14.8	0.0	41.0

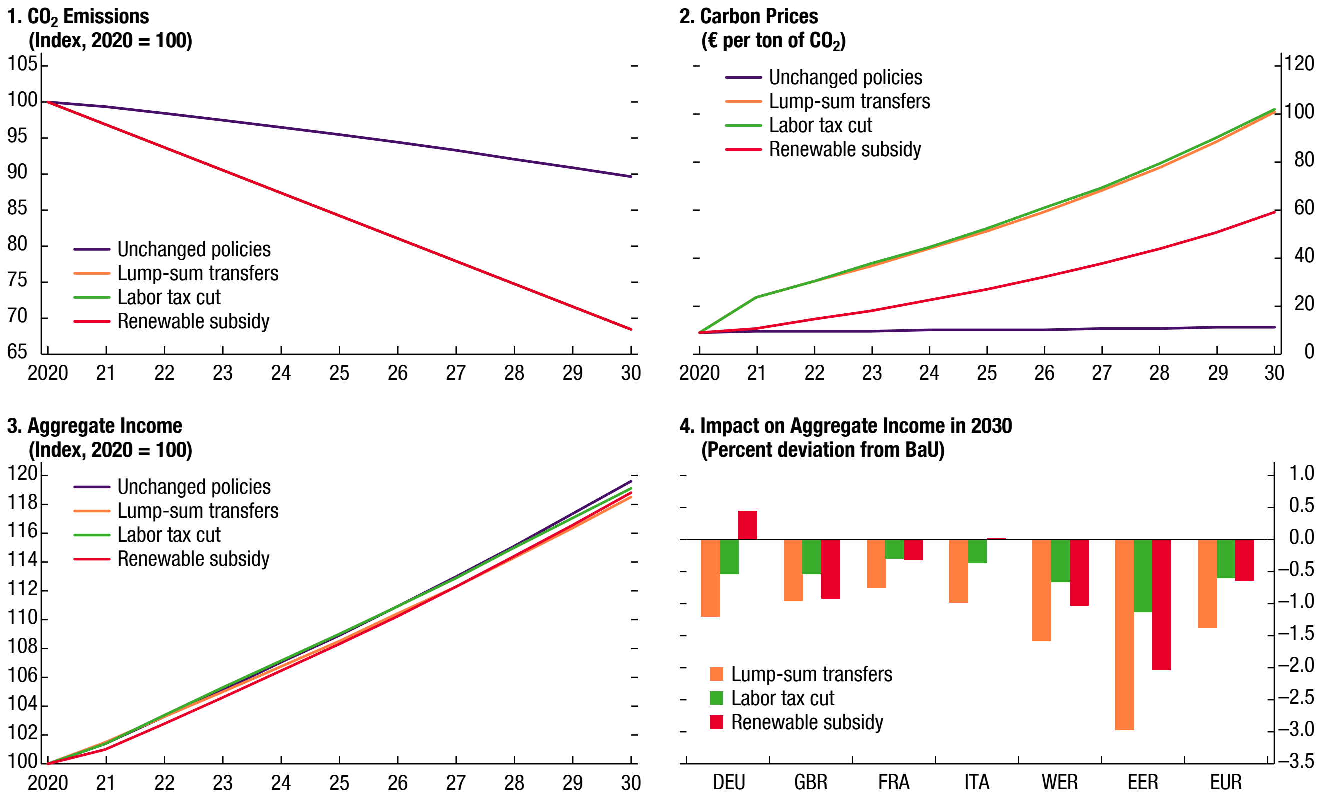
Note: Carbon prices are in 2019 euros and calculated as the economy wide average. For the "Unchanged policies" scenario, the variables income and unemployment are expressed as the cumulative percent growth relative to 2020. For the rest of scenarios, these variables are expressed as percentage point differences with respect to "Unchanged policies" in 2030. Carbon leakage is defined as the emission increase in the rest of the world relative to the decline in EU emissions. Cross-country standard deviations are calculated over the percentage impact in each scenario relative to the baseline. The renewable share is computed over energy production but excludes most of the energy produced by biofuels and biomass, which makes the share smaller than the value reported by Eurostat. BaU = ???; EU = European Union; NA = ???.

tion, carbon price needed, real income, unemployment and capital impact, carbon leakage generated, and share of renewable energy, all by 2030 and for the EU aggregate.[4,5] It also shows the dispersion of the income impact across EU countries or country groups. Policy scenarios are measured against an unchanged policies baseline calibrated with policies currently in place (that is, excluding announced future policy changes). Annex Figure 1, panel 1, shows the time series of emissions, carbon taxes, and aggregate income under selected scenarios for the period 2020–30. The last panel shows the aggregate income impact across EU countries of those same scenarios. The reported

[4]The term EU is used loosely throughout this section as the model data cover all European Economic Area countries. All European Economic Area countries participate in the EU ETS.

[5]Real income is defined as the equivalent variation in income derived from the consumer's expenditure function. It differs from GDP given the geometric aggregation of heterogeneous sectors into a final consumption good via a nested CES function.

Annex Figure 1.



Source: Authors' calculations.
Note: Data labels in the figure use International Organization for Standardization (ISO) country codes.

income loss estimates reflect transitional dynamics due to wage rigidities, which cause temporary unemployment and capital reallocation frictions. Steady state income losses would be substantially smaller.

Model results are inevitably subject to considerable uncertainty. With a highly parametrized model and forecasts extending over a decade, the results are surrounded by large uncertainty bands. Specific assumptions have to be made regarding the values of substitution and transformation elasticities based on available empirical estimates. Among others, this includes the elasticity of substitution between different energy generation technologies, which has a major impact on abatement cost estimates. Reassuringly, the implied marginal abatement cost curve from Envisage falls in the middle of the range across several other computable general-equilibrium models (Böhringer and others, forthcoming). Envisage model results on required carbon prices are also compared to a spreadsheet tool developed by Parry and Mylonas (2018), which is highly streamlined but provides more transparent intuition.[6] In any case, the relative impact of different policy options is broadly invariant to the required level of carbon prices. It is also important to note that the current version of Envisage does not have forward-looking behavior and does not incorporate the economic value of positive environmental effects, such as avoided damages from climate change and air pollution, which would point to a more positive welfare impact from cutting emissions.

The unchanged policies baseline is calibrated broadly based on current policy settings. The starting economy-wide average price is about €9 per ton (a weighted average of the current EU ETS price and non-ETS carbon prices). In the baseline, the associated fiscal revenue is transferred as a lump sum to households. GDP and population growth forecasts are from the IMF April 2020 *World Economic Outlook*, whereas energy efficiency is assumed to improve by 1.5 percent annually, in line with gains in the previous two decades.[7] Electrification increases by 50 percent by 2030 (in proportion to the 2014 electrification rate) in all sectors except transportation, which sees a 75 percent rise. Modest renewable energy share growth is assumed with country-specific targets.[8] The elasticity of substitution between electricity generation technologies is set at 3. The rest of parameters are borrowed from the Organisation for Economic Co-operation and Development Green model (Lee, Martins, and van der Mensbrugghe 1994), and the data is from the GTAP Power 10 database (Chepeliev 2020; Peters 2016). Under these assumptions, EU emissions fall by 35 percent relative to 1990, broadly consistent with the European Environment Agency existing policies scenario.[9] This scenario is labeled "Unchanged policies" in Annex Table 1.

A series of policy scenarios are then compared to the baseline. In the first two policy scenarios, the emission target is set at a 40 percent reduction of EU emissions by 2030 (the current target), and in the next five scenarios, at a more stringent target of 50. These scenarios are described in more detail in the following.

[6]The tool simulates the use of fossil fuels in three sectors (power generation, road transport, and "other energy") until 2030, assuming a fixed energy supply. Energy demand is mainly driven by income growth, which is exogenous, and energy prices, which increase with a carbon tax.

[7]No changes in energy efficiency are assumed for coal power generation, oil power generation, and oil refining.

[8]This is achieved by assuming costs decline by 13 percent for wind power generation, by 35 percent for solar power, and by 18 percent other renewables from 2014 to 2030.

[9]This baseline is not directly comparable to the EU Reference Scenario (EC 2018b), which includes policies to achieve legislated targets, including on renewable shares and energy efficiency, and thus implies a faster emission reduction.

National Targets Scenario

Without comprehensive trade in emissions between EU countries, the current emission goal would require large carbon prices increases in some countries. The current EU cap-and-trade system only covers the power sector and energy-intensive industries. For the rest of sectors, emission reduction goals are defined nationally, and trade is extremely restricted. The "national targets" scenario is a simplified scenario which assumes that *each country* has to meet the 50 percent reduction target by 2030 (relative to 1990) individually. Based on the model results, this would imply an increase in *average* carbon prices across EU countries to €136 per ton by 2030.[10] However, countries with less technological margin left to cut emissions, such as France, would see higher carbon prices of up to €216 per ton of CO_2 if they were not allowed to trade emission permits. In contrast, Eastern European countries would benefit from smaller-than-average required prices, reflecting their cheaper abatement options. This scenario would lead to a fall in EU aggregate income of 1.2 percent compared to the baseline, as higher carbon prices distort the decisions of both consumers and producers.[11]

Emission Trade Scenario

A cap-and-trade system covering all sectors would reap the benefits of intra-EU trade and reduce the required carbon price considerably. If all EU countries and sectors were allowed to trade permits in order to meet a joint 50 percent target, mitigation efforts would be directed to countries/sectors with a lower marginal abatement cost. In Envisage, this would lower the required uniform carbon price to €101 per ton in 2030 and the associated aggregate income loss to (0.9 percent), underlying the income gains from an EU-level approach (see scenario "Lump-sum transfers").[12] For comparison, other computable general-equilibrium models estimate a range of prices between €65 and €140 for a similar emission reduction (Böhringer and others, forthcoming). The associated cumulative increase in gasoline and elec-

[10]All prices are expressed in 2019 euros. By assumption, nuclear energy and hydro power are not allowed to grow in the simulation.

[11]This estimate likely underestimates the income loss from a lack of full emissions trading, because the stylized scenario allows for trade between ETS and non-ETS sectors within a country, and between different countries in a country group (such as Eastern Europe). On the other hand, it does not allow for trade in ETS sectors between country groups.

[12]Note that a comparison of the estimated carbon prices across different models is complicated because the prices depend on the assumed baseline (among other things). For example, the model developed by Parry and Mylonas (2018) calculates a higher carbon tax of €78 per ton of CO2 in 2030 needed to achieve the EU goals, but that model has much smaller reduction in emissions in the baseline (about 25 percent compared to 33 percent in the baseline used in this paper).

tricity prices would be €0.24 per liter and €0.02 per kWh by 2030.[13] Note that a €101 price would be below the current carbon tax in Sweden or the planned tax in the Netherlands. The current more modest emission reduction target of 40 percent would require a much lower increase in carbon prices to €40 (scenario "Lump-sum transfers (40%)") and an income loss of 0.3 percent of GDP. The more ambitious target requires a more-than-proportional increase in carbon prices because the cost of additional emission reductions grows as cheaper abatement margins (such as shifting away from coal power) are exhausted.

Labor Tax Cut and Renewable Investment Subsidies Scenarios

Carbon pricing revenue can be used to lower distortionary taxation or incentivize green investment. Carbon pricing revenue (either from carbon taxes or emission permit auctions) is significant, at about 1.1 percent of EU GDP by 2030 in the "Lump-sum transfers" scenario. The scenarios discussed so far all assumed that domestically collected revenue is rebated as a lump-sum transfer to households. The following two scenarios show the impact of alternative uses of the revenue for the 50 percent emission reduction target. The policies considered are cuts in labor tax rates and subsidies to investment in renewable energy sources. We also discuss the required carbon prices under other investment policies. Investment in green technologies and energy efficiency reduces emissions and therefore the required equilibrium carbon price. The impact of such policies on emissions in turn affects the required carbon price in equilibrium.

- **Labor tax cut.** If all revenue from carbon taxes is used to reduce labor tax rates (scenario "Labor tax cut"), income is only 0.4 percent below the baseline. In other words, recycling carbon pricing revenue to reduce labor taxes can offset a significant share of the negative impact on real income from higher carbon price. This is because with high initial labor tax rates, rigid wages, and unemployment, labor taxes are roughly as distortionary as carbon taxes.[14] Indeed, neutralizing the increase in EU average unemployment in the "Lump-sum transfers" scenario contributes to improve the income impact.[15] Interestingly, Annex Figure 1, panel 3, shows that during the first

[13]The latter implies a €120 increase in the annual electricity bill for an average EU citizen (given 2014 electricity consumption values).

[14]A well-known result in public economics is that the welfare deadweight loss from taxation is more than proportionally increasing in the tax rate (Ramsey 1927). Parry and Bento (2000) provide empirical support for the result that labor taxes can be more distortionary than carbon taxes, as labor taxes distort not only labor markets but also the choice between ordinary and tax-preferred spending (for example, on housing, fringe benefits, informal production).

[15]The income impact is sensitive to the calibration of unemployment. Initial unemployment is assumed to be equal to the natural unemployment rate, sourced from the IMF *World Economic Outlook*. The minimum unem-

years of the policy, income is *above* the baseline, as small carbon taxes are less distortionary and there is more margin to reduce unemployment. As carbon taxes grow, the income path crosses below the baseline.

- **Renewable investment subsidy.** In this scenario, the revenue is used to subsidize investment in solar, wind, and other renewable sources (scenario "Renewable subsidy"). The scope of this policy is limited by the current small size of the renewables sector and the technological limits to the speed at which capacity can be expanded. To avoid unrealistic growth, a 75 percent cap is assumed on the subsidy rate for investment costs, and any remaining revenue is transferred to households.[16] A renewable subsidy implies lower required carbon prices at €59 per ton, as it hastens the shift toward cleaner energy sources, making it less necessary to increase taxes. The renewable share in total energy supply increases to 48 percent in the EU on average, compared to 33 percent in the baseline. Income in 2030 is 0.2 percentage points higher than in the scenario with lump sum transfers, as the subsidy increases the aggregate capital stock, but is not as high as in the labor tax cut scenario (which allows for more revenue to be used in cutting taxes).[17] Of note, the "Renewable subsidy" scenario is akin to a feebate scheme for the energy sector, coupled with an economy-wide carbon tax.
- **Supplementary investment policies.** A different model, developed by Parry and Mylonas (2018), is used to calculate the potential carbon price reduction from three additional investment policies: electrification of cars, housing energy efficiency, and renewable energy R&D.[18] The model allows the estimation of the required carbon prices in each scenario, but not the overall output effects. Policy scenarios are applied homogeneously across the EU. The cumulative impact on carbon prices of each policy is as follows:
    - Raising the share of electric cars to 20 percent (consistent with the target set by Germany) of the on-road car fleet by 2030 could lower by 10 percent the required carbon price to reach the current emissions target of 40 percent reduction.

ployment rate that can be achieved is capped for each country at either 70 percent of the distance between natural unemployment and 2.5 percent, or 2.5 percent, whatever is the larger value, consistent with historical data.

[16]Such a subsidy rate leads to an expansion of the renewable energy share to 73 percent in Germany, which is slightly above its national target of 65 percent.

[17]For a fairer comparison with the labor tax scenario, an alternative scenario where labor taxes are lowered by the same amount as the renewable subsidy is run (not shown). Even in that case, cutting labor taxes generates a more benign income impact, as the current labor tax rates are more distortionary than the effect of higher energy prices.

[18]The Envisage sectoral aggregation does not provide the granularity needed to model these policies explicitly. However, the model by Parry and Mylonas (2018) does not calculate the full general equilibrium effects on macroeconomic variables. In the latter model, the increase in carbon price is relative to a baseline with no new or tightening of existing policies beyond those implicit in recently observed fuel use.

- o In addition, increasing the energy efficiency of residential housing to the second highest efficiency rating would allow a 32 percent reduction in the carbon price relative to the baseline.
- o Supplementing these two measures with R&D subsidies delivering a 1 percent annual productivity growth (on top of the baseline growth) in renewable energy production would lower the needed carbon price by 40 percent relative to the baseline.

EU Compensatory Transfers Scenario

Introducing a uniform carbon price across sectors and countries can lead to disproportionate economic costs in some EU countries. The income cost in the 50-percent emission reduction scenario with lump-sum transfers ranges from 0.5 percent of GDP in France to 1.9 percent in Eastern Europe.[19] Intra-EU compensatory transfers could be considered to lift the burden on lower-income Eastern European countries, which feature larger emissions per unit of output, and thus would see a larger increase in the tax burden. A system of transfers neutralizing the income impact of the policy across countries would not change the aggregate income effect at the EU level (relative to the "lump-sum transfers" scenario).

Border Adjustment and Global Carbon Price Scenarios

Strict emission policies at the EU level without international coordination can lead to carbon leakage to the rest of the world. According to the model simulation, a uniform carbon tax cutting emissions by 50 percent in the EU would increase emissions by 15 percent in the rest of the world for each unit of EU emissions avoided, as the EU would turn to importing or outsourcing energy-intensive goods instead of producing them domestically. A carbon border adjustment would contain carbon leakage by setting a levy on the carbon content of imports (based on the carbon intensity of the country of origin) equal to the carbon price applied to EU production (scenario "Border adjustment").[20]

A global emission reduction effort would be more efficient. If the entire world implemented policies to reduce global emissions by 50 percent relative to 1990 (scenario "Global carbon price"), allowing for international trade in ETS permits, the global price of carbon required would be €93 per ton.[21] For the EU, this would raise income by 0.2 percentage points relative to the scenario without international policy action.

[19]This range would be even wider if all individual countries were disaggregated in the simulation.

[20]In the simulation, carbon exports are not exempt from carbon pricing, although this could be modeled as well (see section in the main text).

[21]This scenario illustrates the efficiency gains from global carbon emissions trading. A practical global solution should take other factors into consideration as well, such as level of economic developments and mitigation possibilities, and may involve different targets for different countries.

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