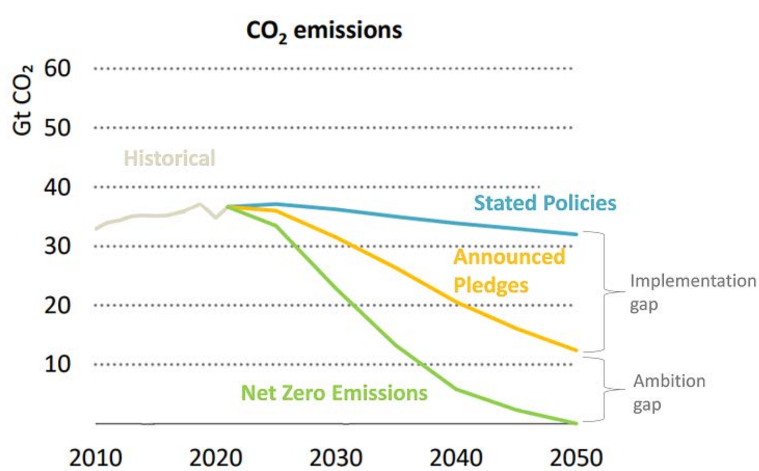
1 Introduction

1.1. Limiting global warming

Attaining the 1.5°C or 2°C goals set out by the Paris Agreement requires immediate and global action, as recently stressed by the 2023 Intergovernmental Panel on Climate Change's Sixth Assessment Report (AR6, IPCC (2023[1])). By absorbing long-wave infrared radiation reflected by the earth's surface, GHG emissions are directly responsible for climate change through global warming. While this is already causing weather and climate extremes worldwide, increased global warming could ultimately result in crossing tipping points beyond which severe and disruptive changes to human society would become irreversible. To face these threats, the objective set out by the Paris Agreement is to keep the increase in the global average temperature to well below 2°C above pre-industrial levels and to preferably limit the increase to 1.5°C above pre-industrial levels. Even if these goals were to be overshot, every incremental degree would escalate risks "and projected adverse impacts and related losses and damages" (IPCC, 2023[1]).

To reach this objective, over 130 countries are seeking to attain carbon neutrality between 2050 and 2060 (Net Zero Tracker, 2023[2]). However, mitigation efforts should be strengthened, as implementation and ambition gaps remain (IEA, 2022[3]). These gaps respectively highlight a lack of coherence between current stated policies and announced pledges emission pathways and between the emission pathway implied by announced pledges and the pathway required to reach net zero emissions by mid-century (see Figure 1.1). With current pledges and policies, global warming is set to exceed 2°C (OECD, 2023[4]; IPCC, 2023[1]).

Figure 1.1. Implementation and ambition gaps



Note: The Stated Policies Scenario (STEPS) shows the trajectory implied by today's policy settings. The Announced Pledges Scenario (APS) assumes that all aspirational targets announced by governments are met on time and in full, including their long-term net zero and energy access goals. The Net Zero Emissions by 2050 (NZE) Scenario maps out a way to achieve a 1.5 °C stabilisation in the rise in global average temperatures, alongside universal access to modern energy by 2030.
Source: Adapted from Figure 1.19 of IEA (2022[3]).

Mitigation policy packages vary with many factors, including country circumstances, policy objectives and targeted sectors. Carbon pricing is a core mitigation policy in some countries, while others rely more on non-carbon price-based instruments, e.g. regulation or technology support. This may be due to many factors, including administrative capacity, historical context, the technical and methodological challenges of pricing emissions from dispersed sources, and political constraints. The approach to carbon pricing instruments itself also varies with the mentioned factors shaping more broadly the design of climate change mitigation approaches. For instance, fuel excise taxes are more common than carbon taxes and emissions trading systems and in general were initially introduced to raise revenue (so that aligning them better with climate goals often requires reform). Carbon taxes may require less administrative capacity to implement than ETSs, as they are generally based on the carbon content of fuels. On the other hand, ETSs, while generally requiring sophisticated monitoring, reporting and verification mechanisms, can face fewer political barriers to implementation.

Climate change is not the only externality to be addressed on the path to net-zero emissions. Other market-failures and externalities such as path-dependency, knowledge spillovers, network externalities or learning-by-doing require additional instruments, e.g. direct research and development (R&D) support or support for infrastructure and technology adoption and deployment. Finally, political barriers to the introduction of carbon mitigation policies and carbon leakage risks underscore the importance of accompanying policies to address distributional, affordability and competitiveness concerns as well as ensure the availability of low-carbon alternatives (Dechezleprêtre et al., 2022[5]) – to help households and firms adapt in the pathway to net-zero emissions. Evidence also shows that climate policy mixes may be more effective than relying on a single type of policy (Dimanchev and Knittel, 2023[6]; van der Ploeg and Venables, 2022[7]). Effective, efficient and broadly supported climate policy therefore requires a policy mix. Accordingly, while this report focusses on carbon pricing instruments across a large set of countries, the OECD's Inclusive Forum on Carbon Mitigation Approaches (IFCMA) will consider the full range of climate mitigation approaches (Box 1.1).

Box 1.1. The OECD Inclusive Forum on Carbon Mitigation Approaches

The OECD launched the Inclusive Forum on Carbon Mitigation Approaches (IFCMA) in June 2022, with a first meeting in February 2023. It brings together a diverse range of countries from around the world, who participate in the initiative on an equal footing.

The IFCMA is designed to facilitate evidence-based mutual learning and inclusive multilateral dialogue on emission reduction efforts around the world. The initiative seeks to facilitate information sharing to take stock of a wide range of carbon mitigation approaches[1] and consider the effectiveness[2] of mitigation policies and policy packages.

The IFCMA will enable policy makers to showcase good practice. Sharing data and information about the comparative effectiveness of different carbon mitigation approaches will help inform future policy decisions in countries around the world so that mitigation policies that best suit countries' objectives be adopted while being adapted to their circumstances. This will also contribute to a globally more coherent and better coordinated approach to carbon mitigation efforts, which should help reduce global emissions and not just shift emissions to other parts of the world.

Notes:
1. In particular, the forum goes beyond carbon pricing, and considers market-based instruments, such as taxes, subsidies, and tradable schemes, as well as non-market-based instruments, such as regulation and standards.
2. Effectiveness is meant as policies' GHG emissions reduction effect.
Source: https://www.oecd.org/climate-change/inclusive-forum-on-carbon-mitigation-approaches/.

The principal appeal of carbon pricing is that in contrast with other mitigation instruments it encourages cost-effective abatement and at the same time it can raise public revenue. Carbon pricing promotes emission cuts up to the point at which marginal abatement costs equal the carbon price. By decentralising abatement decisions, it helps overcomes the asymmetry of information between the government and polluters and encourages emissions cuts at the lowest cost. Moreover, carbon pricing creates ongoing mitigation incentives and it reduces rebound effects (Van Dender and Raj, 2022[8]). Unlike non-pricing instruments, it also raises revenue.

There is growing empirical evidence that carbon pricing is effective in reducing emissions. For example, Leroutier (2022[9]), Green (2021[10]), Dussaux (2020[11]), Andersson (2019[12]) and Dechezleprêtre et al. (2018[13]) present results for various sectors and carbon pricing instruments. Recent studies also present carbon dioxide (CO_2) emissions responsiveness results within a unified framework for a large panel of countries, sectors and fuels (Sen and Vollebergh, 2018[14]; D'Arcangelo et al., 2022[15]) and find a negative impact of carbon pricing on CO_2 emissions from energy use.

Revenue raised from carbon pricing can be non-negligeable. Fetet and Postic (2021[16]) find that for the fiscal year 2020-21, the revenues generated from carbon taxes and emissions trading systems (ETS) amounted to USD 56.8 billion globally, corresponding to around 0.07% of world GDP in 2020. The recently released International Carbon Action Partnership Emissions Trading Worldwide Status Report (ICAP, 2023[17]) highlights a record USD 63 billion raised from carbon allowance sales in 2022. Simulations have also been conducted on the revenue impact of carbon pricing reform. For instance, D'Arcangelo et al. (2022[15]) present the simulated revenue impact of introducing a carbon pricing floor of EUR 60 per tonne of CO_2 and find that this could generate revenues of 2% of countries' GDP on average. This share would vary depending on countries' starting points – e.g. their initial carbon price level or the carbon-intensity of the economy. Marten and Van Dender (n.d.[18]) calculate that in 2015 the revenues generated from effective carbon rates exceeded 1% of GDP in many OECD and G20 countries. They suggest that a carbon price floor of EUR 30 per tonne of CO_2 could more than double such revenues.

Finally, while direct support measures for innovation are essential, evidence also shows that carbon pricing spurs innovation and investment in low-carbon technologies, such as carbon capture and utilisation or electrolytic hydrogen. Hicks (1963[19]) and recent empirical evidence (Aghion et al., 2016[20]; Calel and Dechezleprêtre, 2016[21]) suggest a positive relationship between carbon pricing and clean innovation. Similarly, evidence shows that when carbon prices are high, the cost of capital for firms is lower (D'Arcangelo et al., 2023[22]).

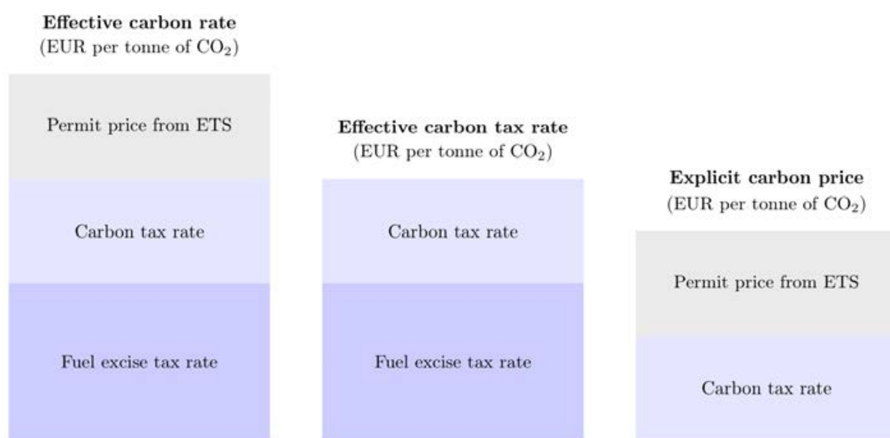
1.2. The OECD Effective Carbon Rates

The OECD ECR database presents carbon prices arising from carbon taxes, ETSs and fuel excise taxes and their mapping to the GHG emissions they cover for each country by sector and fuel.[1] Here, the term "carbon tax" covers the broad range of all taxes that apply to greenhouse gases (including taxes on fluorinated gases (F-gases), for instance). The pricing instruments covered by effective carbon rates either set an explicit price per unit of GHG (e.g., tonnes) or set a price per unit of fuel, which is then proportional to resulting CO_2 emissions.[2] These instruments encourage a switch away from carbon-intensive fuels.

While this report mainly relies on the effective carbon rates indicator, it also refers to explicit carbon pricing and effective carbon tax rates (see Figure 1.2). Explicit carbon pricing refers to carbon taxation and emissions trading systems. Emissions trading systems are discussed in more detail in Chapter 3. Effective carbon taxes refer to fuel excise taxes and carbon taxes and are discussed in more detail in Chapter 4.

Figure 1.2. Effective carbon rates and sub-indicators

Effective carbon rates and sub-indicators: Effective carbon tax rates and explicit carbon prices.



Note: The term carbon taxes here is used in a broad sense, i.e. they include taxes on any GHG. Permit prices can result from the primary or secondary market. Where possible, the permit price data used in this report is based on the ICAP allowance price explorer, which may rely on either spot or auction prices (see ICAP (2023[23])).

The database covers CO_2 emissions from energy use from six sectors that together span all energy uses, and covers other GHG emissions (i.e., emissions from methane (CH_4), nitrous oxide (N_2O), F-gases[3] and process CO_2 emissions) excluding Land use change and forestry (LUCF)[4] (Table 1.1). Due to data limitations and to facilitate comparisons with previous ECR vintages, other GHG emissions are not allocated to the six economic sectors but are considered as a seventh sector. Fuels are grouped into 9 categories (Table 1.2). CO_2 emissions in the ECR database are based on energy use data from the International Energy Agency's World Energy Statistics and Balances (IEA, 2020[24]). Other GHG emissions are sourced from the CAIT database (Climate Watch, 2022[25]).

Table 1.1. ECR sectors and users

Sector	Definition	Energy users
Road transport	Fossil fuel CO_2 emissions from all primary energy used in road transport.	Road
Electricity	Fossil fuel CO_2 emissions from primary energy used to generate electricity (excl. auto-producer electricity plants which are assigned to industry), including for electricity exports. Electricity imports are excluded.	Main activity producer electricity plants
Industry	Fossil fuel CO_2 emissions from primary energy used in industrial facilities (incl. district heating and auto-producer electricity plants).	Adjusted losses in energy distribution, transmission and transport; Adjusted energy industry own use; Adjusted transformation processes; Auto-generation of electricity; Chemical and petrochemical; Construction; Food and tobacco; Industry not elsewhere specified; Iron and steel; Machinery; Mining and quarrying; Non-ferrous metals; Non-metallic minerals; Paper, pulp and print; Sold heat; Textile and leather; Transport equipment; Wood and wood products
Buildings(*)	Fossil fuel CO_2 emissions from primary energy used by households, commercial and public services for activities other than electricity generation and transport.	Commercial and public services; Final consumption not elsewhere specified; Residential

Off-road transport	Fossil fuel CO_2 emissions from all primary energy used in off-road transport (incl. pipelines, rail transport, aviation and maritime transport). Fuels used in international aviation and maritime transport are not included.	Domestic aviation; Domestic navigation; Pipeline transport; Rail; Transport not elsewhere specified
Agriculture & fisheries	Fossil fuel CO_2 emissions from primary energy used in agriculture, fisheries and forestry for activities other than electricity generation and transport.	Agriculture; Fishing
Other GHG (excl. LUCF)	All other GHG emissions include methane, nitrous oxide from agriculture; fugitive emissions from oil, gas and coal mining activities; waste; non-fuel combustion CO_2 emissions from industrial processes (mainly cement production), N_2O and CH_4 emissions from industrial processes and F-gas emissions. Excludes LUCF emissions. Excludes CO_2 emissions from fuel combustion which are already reported in the agriculture & fisheries sector.	n.a.

Note: Estimates of primary energy use are based on the territoriality principle, and include energy sold in the territory of a country but potentially used elsewhere (e.g. because of fuel tourism in road transport). Own classification based on information on energy flows contained in the IEA's extended world energy balances (IEA, 2020[26]) and "other GHG" reported in the Climate Watch dataset (2022[25]).
(*) In previous Effective Carbon Rates editions, this sector was referred to as "Residential and Commercial".
Source: OECD (2016[27]) and (OECD, 2022[28]).

Table 1.2. Fuel category breakdown

Energy type	Fuel category	Energy Products
Fossil fuels	Coal and other solid fossil fuels	Anthracite; Bitumen; Bituminous coal; Brown coal briquettes; Oven coke; Coking coal; Gas coke; Lignite; Oil shale; Patent fuel; Peat; Peat products; Petroleum coke; Sub-bituminous coal
	Fuel oil	Fuel oil
	Diesel	Gas/diesel oil excluding biofuels
	Kerosene	Jet kerosene; Other kerosene
	Gasoline	Aviation gasoline; Jet gasoline; Motor gasoline
	LPG	Liquefied Petroleum Gas
	Natural gas	Natural gas
	Other fossil fuels and non-renewable waste	Additives; Blast furnace gas; Coal tar; Coke oven gas; Converter gas; Crude oil; Ethane; Gas works gas; Lubricants; Naphtha; Natural gas liquids; Other hydrocarbons; Other oil products; Paraffin waxes; Refinery feedstocks; Refinery gas; White and industrial spirit; Industrial waste; Non-renewable municipal waste
Biofuels	Biofuels	Bio jet kerosene; Biodiesels; Biogases; Biogasoline; Charcoal; Municipal waste (renewable); non-specified primary biofuels and waste; Other liquid biofuels; Primary solid biofuels

Note: Energy products are defined as in IEA (2020[26]). Emissions from the combustion of biofuels are not included in the main analysis of this edition (Appendix A presents results including them).
Source: OECD (2019[33]).

The ECR database covers pricing instruments that apply to a base that is directly proportional to energy use or GHG emissions. It therefore excludes taxes and fees that are only partially correlated with energy use or GHG emissions. These include vehicle purchase taxes, registration or circulation taxes, and taxes that are directly levied on air pollution emissions (e.g. the Danish tax on SO_x or the Swedish NO_x fee). Production taxes on the extraction or exploitation of energy resources (e.g. severance taxes on oil extraction) are not within the scope of instruments covered either, as supply-side measures are not directly linked to domestic energy use or emissions.

The database covers specific taxes (i.e. taxes that apply per unit of good as opposed to ad-valorem taxes, which depend on the good's price) taxes that affect the relative price of carbon-intensive goods. In line with these two criteria, value added taxes (VAT) or sales taxes are not accounted for. Indeed, in principle VAT applies equally to a wide range of goods, so does not change the relative prices of products and services (i.e. it does not make carbon-intensive goods and services more expensive relative to cleaner alternatives). In practice, differential VAT treatment and concessionary rates may target certain forms of energy use, thereby changing their relative price (OECD, 2015[29]). However, quantifying the effects of differential VAT treatment is beyond the scope of the database. Such an exercise would entail extensive price information, which is generally not available for all energy products. Also, electricity excise taxes do not treat fossil fuels in a differential manner as compared to clean sources and are therefore not part of the ECR indicator.

The ECR database includes support measures for fossil fuel consumption that are delivered through the tax code, such as excise or carbon tax exemptions, rate reductions and refunds, which are pervasive in energy tax and carbon pricing systems. This is different from the Net ECR (nECR) database, which includes also fossil fuel subsidies that lower pre-tax prices. Indeed, the availability of preferential treatment varies substantially across countries, and even within a country such preferential treatment frequently changes over time. As a result, simply comparing statutory rates (also sometimes referred to as standard or advertised rates) across countries and time would be misleading. More precisely, certain energy users or GHG emitters frequently enjoy preferential treatment that effectively reduces prices on energy or emissions. Therefore, effective tax rates measured by the database are adjusted accordingly irrespective of whether countries report such policy measures as tax expenditures (OECD, 2022[28]).[5]

Data on ETS permit prices and coverage is originally gathered for the Effective Carbon Rates database. The Effective Carbon Rates database then builds on the Taxing Energy Use database for fuel excise tax and carbon tax data. The first publication of Effective Carbon Rates describes the methodology for matching ETS permit prices and coverage with taxes (OECD, 2016[27]).

The recently established OECD Series on Carbon Pricing and Energy Taxation brings together the Effective Carbon Rates and Taxing Energy Use (TEU) databases with the report Pricing Greenhouse Gas Emissions (PGHG). The interlinkages, similarities, and differences between these three reports are further explained in Box 1.2.

Box 1.2. Understanding the relationship between the Effective Carbon Rates and Taxing Energy Use models and processes: An alternating relay for two

The recently established OECD Series on Carbon Pricing and Energy Taxation brings together the ECR and TEU databases with the report PGHG.

Previously, TEU focused on gathering and calculating the effective tax rates exclusively applied to energy[1] and its corresponding carbon dioxide emissions base. The analysis did not include emissions trading systems. Nonetheless, its merit lay in the dual perspective on energy and carbon emissions and the provision of up-to-date tax rates and instruments. The successor to TEU, PGHG, addressed this gap, by incorporating estimates from the already established Effective Carbon Rates database including reconciling emissions bases subject to ETSs, energy and carbon taxes.

More specifically, ECR builds on the effective carbon tax rate indicator and calculates ETS coverage estimates, typically starting from granular verified emissions data at facility level. To accurately attribute verified emissions data to (sub)sectors, an important requirement is to match data on the energy base (representing the main sources of GHG emissions especially ETS covered emissions) to the verified ETS emissions in the same year. This approach allows for a consolidated emissions base and computing reliable ETS coverage estimates. There is also a feedback loop between the estimation of ETS emissions coverage and tax emissions coverage estimates for cases where ETS and taxes are complementary. Currently, official energy and CO_2 emissions from energy datasets have a lag of two years.[2]

This edition of Effective Carbon Rates marks the first time that consolidated ETS coverage estimates are made available the same year that verified emissions and CO_2 emissions from energy use are released. It also discusses pricing and emissions coverage of other GHGs in detail, improves estimates on free allocation and (sub)sectors and even provides a within current year direction of travel for ECRs incorporating recent tax changes in transport, the latest permit prices and new systems.

Behind the scenes, there is still value in running two separate cycles of the resource intensive data collection and update processes for TEU and ECR, with all the new features (extension to fossil fuel subsidies, covering all greenhouse gases, increasing number of countries and carbon pricing instruments). The recent PGHG and the current report set the bar for the coming years.

Notes:
1. Specifically, energy tax rates included those applied to clean energy sources and electricity output.
2. For example, the IEA releases data on 2021 in the course of 2023, in April for OECD and most G20 countries, and during August for global coverage.
Source: Authors

1.3. Scope of the present edition

This edition first presents ECRs in 2021 and details on the “other GHG” sector, which was included for the first time in the Pricing Greenhouse Gas Emissions publication in 2022. It then focuses on emissions trading systems in 2021 and developments therein over the course of 2022 and 2023, with discussions and evidence on free allocation and price stability mechanisms. Finally, it analyses recent developments in road transport fuel excise and carbon taxes amid the energy crisis.

The ECR indicator for 2021 covers 72 countries[6], which together account for about 80% of global GHG emissions (excluding emissions from LUCF). This edition includes the 71 countries covered in the 2022 Pricing Greenhouse Gas Emissions report (OECD, 2022[28]) and an additional country: Kazakhstan.[7] The 71 countries are made up of all 45 OECD and G20 countries other than Saudi Arabia and 26 other countries. Eleven of these 26 countries are in Africa (Burkina Faso, Côte d’Ivoire, Egypt, Ethiopia, Ghana, Kenya, Madagascar, Morocco, Nigeria, Rwanda, Uganda), eight in Latin America and the Caribbean (Dominican Republic, Ecuador, Guatemala, Jamaica, Panama, Paraguay, Peru, Uruguay), five are in Asia (Bangladesh, Kyrgyzstan, Malaysia, Philippines, Sri Lanka) and two in Europe (Cyprus, Ukraine).

The term “total emissions” is used to refer to GHG emissions from the 72 countries considered in this report. Effective carbon rates in 2021 consist of tax rates as of 1 April 2021 and permit prices from ETSs averaged over 2021. The coverage of emissions trading systems is estimated based on data by the authorities governing the respective systems (see Chapter 3 for details on emissions trading systems). CO_2 emissions from energy use data is for 2021 when available, namely OECD and G20 countries plus Cyprus and Kazakhstan and for 2018 elsewhere. It is based on energy use data from the International Energy Agency’s World Energy Statistics and Balances (IEA, 2023[30]). Other GHG emissions data is for 2018 and is from the CAIT database (Climate Watch, 2022[25]). Official exchange rate and inflation data are used to express prices in constant terms when required and noted.[8]

This edition presents results excluding biofuel emissions, to stay consistent with the approach taken in earlier vintages. Previous editions of *Effective Carbon Rates* and *Taxing Energy Use*, for which the emissions base consisted in CO_2 emissions from energy use only, relied on the “combustion approach” as opposed to a “life-cycle approach” (see Annex 3.A of OECD (2018[31]) for a discussion on the implications of the combustion approach), and they hence included emissions from the combustion of biofuels. In line with the latest *Pricing Greenhouse Gas Emissions* report, this edition presents results that exclude emissions from the combustion of biofuels, consistent with the fact that the other GHG emissions (emissions from CH_4, N_2O, F-gases and process CO_2 emissions) that were added to the emissions base exclude LUCF. This should not be interpreted as a view in favour of one approach over the other but rather as a consistency measure, and results including emissions from the combustion of biofuels are presented in Annex A as a memo item. Biofuel taxation is further discussed in Box 1.3.

Box 1.3. Pricing CO_2 emissions from biofuel use

While not all biofuels are carbon neutral, they can be. When combusted, biofuels release CO_2. However, as discussed in OECD (2019[32]), sustainably sourced biofuels may be carbon-neutral over the lifecycle because before being burnt, feedstocks have previously absorbed an equivalent amount of CO_2 from the atmosphere. To what extent biofuel use is carbon-neutral over the lifecycle is an empirical question.

CO_2 emissions from biofuel combustion are not explicitly reported in the greenhouse gas inventories submitted under the UN Framework Convention on Climate Change (UNFCCC). The guidelines of the UN Intergovernmental Panel on Climate Change (IPCC) require accounting for emissions and sinks from biofuels as net changes in carbon stocks under the annual reporting of Land Use, Land Use Change and Forestry.

Most governments do not tax biofuels outside the road transport sector. Instead of taxation, they generally use sustainability standards for biofuels. This requires gathering reliable data on their sustainability. This is a challenging task, and such data is often lacking (Jeswani, Chilvers and Azapagic, 2020[33]; Baudry et al., 2017[34]). The European Union (EU) revised Renewable Energy Directive, RED II[1] provides detailed sustainability and greenhouse gas emissions saving criteria (Article 29) and guidelines for the calculation of the greenhouse gas impact of biofuels (Article 31). It also defines the term “advanced biofuels” to mean biofuels that are produced from a specific list of feedstocks.

Some governments have attempted to design comprehensive biofuel taxation. For example, the Finnish carbon tax for transport fuels is based on lifecycle CO_2 emissions – a unique feature in the world today (OECD, 2021[35]). Under the Finnish tax, biofuels are classified under three categories: i) biofuels that do not meet sustainability criteria are subject to the same carbon tax as fossil fuels; ii) sustainable first-generation biofuels are subject to 50% of the rate which applies to equivalent fossil fuels; and iii) sustainable second-generation biofuels are exempt. In 2019, the methodology based on lifecycle carbon emissions was extended to fuels for heating and machinery. While also requiring a comprehensive assessment of biofuel sustainability, this kind of category-dependent tax rate constitutes a novel approach to taxing biofuels, which encompasses lifecycle emissions. Germany has also included some biofuels in its newly introduced national emissions trading system (nEHS) which applies to transport and heating fuels. The biofuels included are those that do not meet sustainability criteria set out in national regulations.[2] In 2021, the proposed revision to the EU Energy Taxation Directive (ETD) considered different minimum taxation rates for non-sustainable, sustainable but not advanced and advanced biofuels.

Alternatively, taxing the CO_2 emissions from the combustion of woody biomass could be combined with simultaneously rewarding forest owners for the carbon they store. This, along with the trade-offs between forest harvesting levels and the forests’ potential as a carbon sink,[3] is discussed in Kooten, Binkley and Delcourt (1995[36]) and OECD (2021[35]). The design of such a subsidy and tax system, however, would require careful consideration of incidence. Indeed, the subsidy on the upstream actor of the supply chain (e.g. the forest owner) or the tax on the downstream actor (the biofuel user) could pass-through to the other, which might mute or over-emphasise price signals.

Moreover, the prevalence of forestry offset provisions in ETSs (including California, multiple Chinese pilots, New Zealand, Quebec, Regional Greenhouse Gas Initiative (RGGI))[4] requires careful consideration by governments. If the forests cannot be logged, such provisions may stand alone. However, if over time forests that were once used as offsets can be used as woody biomass, the question of the non-taxation of combustion emissions from such biofuels arises, given that the initial part of the lifecycle of these biofuels has already been positively rewarded. New Zealand has an approach that imposes ongoing, indefinite liability for any reversal of credited removals. Maintaining liability for reversals over an indefinite period provides an incentive to protect carbon sinks over the long term. New Zealand employs this approach within its Nationally Determined Contribution (NDC) and domestic ETS. For example, in the New Zealand system carbon stocks (including reversals) are monitored and accounted for over time both within New Zealand's NDC and domestic ETS. Liability to surrender ETS units in the event of reversal generally remains with the landowner.

Finally, the increased use of biofuels raises additional concerns, which go beyond climate change. Harvesting raises issues for biodiversity, soil health and water quality, and biofuel combustion may worsen local air pollution (different from greenhouse gas emissions), especially from particulate matter (PM) and nitrogen oxides (NOx) emissions, which is not compensated for from a lifecycle point of view. Local air pollution, in turn, can have substantial environmental, health and economic costs (OECD, 2020[37]; OECD, 2023[38]).

Notes:
1. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG, as accessed on 06 June 2023.
2. These are sustainability criteria set out in national Regulations, transposing the "European Renewable Energy Directives 2029/28/EC" and "2018/2001" (ICAP, 2023[39]). While biofuels present an important share of energy use in the German buildings sector (about 26%) and a non-negligeable share in the road transport sector (about 5.5%), most of it meets the sustainability criteria.
3. The EU revised Renewable Energy Directive also seeks to address such trade-offs: sustainability criteria were revised to account for the negative direct impact that the production of biofuels may have because of indirect land use change (https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/biofuels_en, as accessed on 30 May 2022). This occurs when biofuel production leads to the extension of agricultural land into non-crop land such as forests, wetlands and peatlands, which constitute high carbon stock.
4. See (La Hoz Theuer et al., 2023[40]) for an in-depth analysis of carbon offset use in ETSs.
Source: Based on Box 4.2 of OECD (2023[41]).

This report uses the same benchmark rates as those in previous *Effective Carbon Rates* editions and in the latest *Pricing Greenhouse Gas Emissions* report to assess carbon pricing progress and alignment with net zero goals. The carbon benchmark of EUR 30 is a minimum price level to start triggering meaningful abatement efforts today. The carbon benchmark of EUR 60 is a low-end estimate of the carbon prices that would be needed by 2030 for consistency with net-zero emissions targets, while EUR 120 per tonne is a mid-range estimate of carbon prices required by 2030 (OECD, 2021[42]; Kaufman et al., 2020[43]; European Commission, 2018[44]). These are benchmark rates that adopt a target-oriented approach as opposed to an external cost pricing approach (e.g. the social cost of carbon or SCC), and they depend on the support of policy measures implemented beyond carbon pricing (Stern et al., 2022[45]). Carbon pricing pathways which take a whole-of economy approach as opposed to a pure external cost pricing perspective are increasingly prevalent. These pathways account for assumptions regarding the evolution of countries' economic conditions (e.g. growth), the introduction of new technologies and additional non-carbon pricing measures (see e.g. IPCC (2018[46]), IEA (2021[47]), Quinet (2019[48]), Climate Change Committee (2020[49]; 2020[50])). Estimates of carbon prices required to reach net zero objectives can be even higher, reaching for example EUR 250 per tonne of CO_2 by 2030 (European Investment Bank Group, 2020[51]), but such estimates consider carbon pricing as the only climate mitigation instrument.

References

Aghion, P. et al. (2016), “Carbon Taxes, Path Dependency, and Directed Technical Change: Evidence from the Auto Industry”, *Journal of Political Economy*, Vol. 124/1, pp. 1-51, https://doi.org/10.1086/684581. [20]

Andersson, J. (2019), “Carbon Taxes and CO2 Emissions: Sweden as a Case Study”, *American Economic Journal: Economic Policy*, Vol. 11/4, pp. 1-30, https://doi.org/10.1257/pol.20170144. [12]

Baudry, G. et al. (2017), “The challenge of measuring biofuel sustainability: A stakeholder-driven approach applied to the French case”, *Renewable and Sustainable Energy Reviews*, Vol. 69, pp. 933-947, https://doi.org/10.1016/j.rser.2016.11.022. [34]

Calel, R. and A. Dechezleprêtre (2016), “Environmental Policy and Directed Technological Change: Evidence from the European Carbon Market”, *Review of Economics and Statistics*, Vol. 98/1, pp. 173-191, https://doi.org/10.1162/rest_a_00470. [21]

CCC (2020), *The Sixth Carbon Budget - Methodology Report*. [50]

CCC (2020), *The Sixth Carbon Budget - The UK’s path to Net Zero*. [49]

Climate Watch (2022), *https://www.climatewatchdata.org*. [25]

D’Arcangelo, F. et al. (2023), “Corporate cost of debt in the low-carbon transition: The effect of climate policies on firm financing and investment through the banking channel”*, OECD Economics Department Working Papers*, No. 1761, OECD Publishing, Paris, https://doi.org/10.1787/35a3fbb7-en. [22]

D’Arcangelo, F. et al. (2022), “Estimating the CO2 emission and revenue effects of carbon pricing: New evidence from a large cross-country dataset”*, OECD Economics Department Working Papers*, No. 1732, OECD Publishing, Paris, https://doi.org/10.1787/39aa16d4-en. [15]

Dechezleprêtre, A. et al. (2022), “Fighting climate change: International attitudes toward climate policies”*, OECD Economics Department Working Papers*, No. 1714, OECD Publishing, Paris, https://doi.org/10.1787/3406f29a-en. [5]

Dechezleprêtre, A., D. Nachtigall and F. Venmans (2018), “The joint impact of the European Union emissions trading system on carbon emissions and economic performance”*, OECD Economics Department Working Papers*, No. 1515, OECD Publishing, Paris, https://doi.org/10.1787/4819b016-en. [13]

Dimanchev, E. and C. Knittel (2023), “Designing climate policy mixes: Analytical and energy system modeling approaches”, *Energy Economics*, Vol. 122, p. 106697, https://doi.org/10.1016/j.eneco.2023.106697. [6]

Dussaux, D. (2020), “The joint effects of energy prices and carbon taxes on environmental and economic performance: Evidence from the French manufacturing sector”*, OECD Environment Working Papers*, No. 154, OECD Publishing, Paris, https://doi.org/10.1787/b84b1b7d-en. [11]

European Commission (2018), “A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy”, *COM(2018) 773 final*, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773. [44]

European Investment Bank Group (2020), "Climate Bank Roadmap. 2021-2025", https://www.eib.org/attachments/thematic/eib_group_climate_bank_roadmap_en.pdf. [51]

Fetet, S. and M. Postic (2021), *Global carbon accounts in 2021*, https://www.i4ce.org/download/global-carbon-account-in-2021/. [16]

Green, J. (2021), "Does carbon pricing reduce emissions? A review of ex-post analyses", *Environmental Research Letters*, Vol. 16/4, https://doi.org/10.1088/1748-9326/abdae9. [10]

Hicks, J. (1963), *The Theory of Wages*, Palgrave Macmillan UK, London, https://doi.org/10.1007/978-1-349-00189-7. [19]

ICAP (2023), *Documentation Allowance Price Explorer*, https://icapcarbonaction.com/en/documentation-allowance-price-explorer (accessed on 30 May 2023). [23]

ICAP (2023), "Emissions Trading Worldwide: Status Report 2023", *Berlin: International Carbon Action Partnership*, https://icapcarbonaction.com/system/files/document/ICAP%20Emissions%20Trading%20Worldwide%202023%20Status%20Report_0.pdf. [39]

ICAP (2023), "Emissions Trading Worldwide: Status Report 2023.", *Berlin: International Carbon Action Partnership.*. [17]

IEA (2023), "Extended world energy balances", *IEA World Energy Statistics and Balances* (database), https://doi.org/10.1787/data-00513-en (accessed on 28 March 2023). [30]

IEA (2022), "World Energy Outlook 2022", *IEA, Paris*, License: CC BY 4.0 (report); CC BY NC SA 4.0 (Annex A), https://www.iea.org/reports/world-energy-outlook-2022. [3]

IEA (2021), *Net Zero by 2050 - A Roadmap for the Global Energy Sector*. [47]

IEA (2020), *Extended world energy balances (database)*, http://www.iea.org/statistics/topics/energybalances. [24]

IEA (2020), "World Energy Balances - 2020 Edition - Database documentation", https://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics. [26]

IPCC (2023), "Synthesis Report of the IPCC Sixth Assessment Report (AR6)", https://report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_LongerReport.pdf. [1]

IPCC (2018), *Global Warming of 1.5°C*. [46]

Jeswani, H., A. Chilvers and A. Azapagic (2020), "Environmental sustainability of biofuels: a review", *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, Vol. 476/2243, https://doi.org/10.1098/rspa.2020.0351. [33]

Kaufman, N. et al. (2020), "A near-term to net zero alternative to the social cost of carbon for setting carbon prices", *Nature Climate Change*, Vol. 10/11, pp. 1010-1014, https://doi.org/10.1038/s41558-020-0880-3. [43]

Kooten, G., C. Binkley and G. Delcourt (1995), "Effect of Carbon Taxes and Subsidies on Optimal Forest Rotation Age and Supply of Carbon Services", *American Journal of Agricultural Economics*, Vol. 77/2, pp. 365-374, https://doi.org/10.2307/1243546. [36]

La Hoz Theuer, S. et al. (2023), “Offset Use Across Emissions Trading Systems”, *Berlin: ICAP*. [40]

Leroutier, M. (2022), “Carbon Pricing and Power Sector Decarbonisation: Evidence from the UK”, *Journal of Environmental Economics and Management*, Vol. 111, https://doi.org/10.1016/j.jeem.2021.102580. [9]

Net Zero Tracker (2023), *Data Explorer*, https://zerotracker.net/. [2]

OECD (2023), *Air pollution effects* (indicator), https://doi.org/10.1787/573e3faf-en (accessed on 4 May 2023). [38]

OECD (2023), *Net Zero+: Climate and Economic Resilience in a Changing World*, OECD Publishing, Paris, https://doi.org/10.1787/da477dda-en. [4]

OECD (2023), *Reform Options for Lithuanian Climate Neutrality by 2050*, OECD Publishing, Paris, https://doi.org/10.1787/0d570e99-en. [41]

OECD (2022), *Pricing Greenhouse Gas Emissions: Turning Climate Targets into Climate Action*, OECD Series on Carbon Pricing and Energy Taxation, OECD Publishing, Paris, https://doi.org/10.1787/e9778969-en. [28]

OECD (2021), *Effective Carbon Rates 2021: Pricing Carbon Emissions through Taxes and Emissions Trading*, OECD Series on Carbon Pricing and Energy Taxation, OECD Publishing, Paris, https://doi.org/10.1787/0e8e24f5-en. [42]

OECD (2021), *OECD Environmental Performance Reviews: Finland 2021*, OECD Environmental Performance Reviews, OECD Publishing, Paris, https://doi.org/10.1787/d73547b7-en. [35]

OECD (2020), *Environment at a Glance 2020*, OECD Publishing, Paris, https://doi.org/10.1787/4ea7d35f-en. [37]

OECD (2019), *Taxing Energy Use 2019: Using Taxes for Climate Action*, OECD Publishing, Paris, https://doi.org/10.1787/058ca239-en. [32]

OECD (2018), *Effective Carbon Rates 2018: Pricing Carbon Emissions Through Taxes and Emissions Trading*, OECD Series on Carbon Pricing and Energy Taxation, OECD Publishing, Paris, https://doi.org/10.1787/9789264305304-en. [31]

OECD (2016), *Effective Carbon Rates: Pricing CO2 through Taxes and Emissions Trading Systems*, OECD Series on Carbon Pricing and Energy Taxation, OECD Publishing, Paris, https://doi.org/10.1787/9789264260115-en. [27]

OECD (2015), *Taxing Energy Use 2015: OECD and Selected Partner Economies*, OECD Publishing, Paris, https://doi.org/10.1787/9789264232334-en. [29]

OECD (n.d.), *OECD Taxation Working Papers*, OECD Publishing, Paris, https://doi.org/10.1787/22235558. [18]

Quinet, A. (2019), *La valeur de l’action pour le climat - Une valeur tutélaire du carbone pour évaluer les investissements et les politiques publiques*. [48]

Sen, S. and H. Vollebergh (2018), “The effectiveness of taxing the carbon content of energy consumption”, *Journal of Environmental Economics and Management*, Vol. 92, pp. 74-99. [14]

Stern, N. et al. (2022), “A Social Cost of Carbon consistent with a net-zero climate goal”, *Roosevelt Institute*, https://rooseveltinstitute.org/wp-content/uploads/2022/01/RI_Social-Cost-of-Carbon_202201-1.pdf. [45]

Van Dender, K. and A. Raj (2022), “Progressing carbon pricing - a Sisyphean task?”, *Gestion & Finances Publiques* 7, pp. 43-57, https://doi.org/10.3166/gfp.2022.ns.010. [8]

van der Ploeg, F. and A. Venables (2022), *Radical climate policies*, University of Oxford, https://ora.ox.ac.uk/objects/uuid:75d49b40-396d-454d-a07f-59b452de6e51. [7]

Notes

[1] Effective Carbon Rates account for fossil fuel support when delivered through preferential excise or carbon tax rates, so they are always greater than or equal to zero. However, they do not account for government measures that decrease pre-tax prices of fossil fuels. *Net* Effective Carbon Rates (Garsous et al., 2023[55]) account for a broader range of fossil fuel subsidies but are not included in this edition.

[2] In the latter case, rates are typically expressed in common commercial units (e.g., as a price per kilogram for solid fuels, per litre for liquid fuels, per cubic metre for gaseous fuels). These can be converted into a price per energy unit (e.g. GJ) using calorific factors from the IEA World Energy Statistics and Balances (IEA, 2023[30]) and then into a price per tonne of CO_2 using IPCC emissions conversion factors (Intergovernmental Panel on Climate Change’s Guidelines for National Greenhouse Gas Inventories (IPCC, 2006[53]), volume 2). More precisely, such calculations make use of the fact that CO_2 emissions are constant per unit of fuel (e.g., one litre of diesel produces on average around 2.76 kilograms of CO_2). This applies to fuel excise taxes but also to many carbon taxes. See OECD (2019[33]), Chapters 1 and 3, for further details.

[3] HFCs, PFCs, and SF_6.

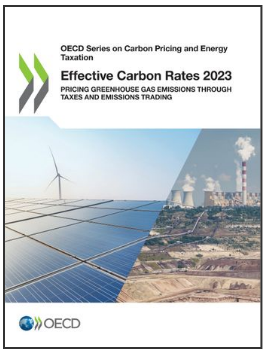
[4] As (OECD, 2022[28]), this report uses the abbreviation LUCF (as opposed to the term LULUCF, i.e. land use, land-use change, and forestry), to emphasise that the underlying GHG emissions data is sourced from the CAIT dataset (Climate Watch, 2022[25]), which does not rely on countries’ official inventories reported to the UNFCCC.

[5] This represents a different approach from the OECD’s Inventory of Fossil Fuel Support (2023[54]). See Box 1.2 of (OECD, 2022[28]) for additional details on the difference in approaches.

[6] All aggregate values involving G20 countries include the Russia Federation.

[7] Kazakhstan was the only country with an ETS in 2021 which was not covered in OECD (2022[28]).

[8] Where OECD exchange rate period averages were not available, they were supplemented using IMF International Financial Statistics. Inflation data gaps were supplemented using the World Bank’s World Development Indicators Consumer Prices. In the case of Argentina and Kazakhstan, the GDP deflator was used as an approximation for inflation. Remaining missing values were filled with the most recent available values.



From:

Effective Carbon Rates 2023

Pricing Greenhouse Gas Emissions through Taxes and Emissions Trading

Access the complete publication at:
https://doi.org/10.1787/b84d5b36-en

Please cite this chapter as:

OECD (2023), “Introduction”, in *Effective Carbon Rates 2023: Pricing Greenhouse Gas Emissions through Taxes and Emissions Trading*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/a5ceae89-en