

INCLUSIVE FORUM **ON CARBON MITIGATION APPROACHES**
PAPERS

Towards more accurate, timely, and granular product-level carbon intensity metrics: challenges and potential solutions

An IFCMA Report

OECD

Inclusive Forum on Carbon Mitigation Approaches Papers

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Inclusive Forum on Carbon Mitigation Approaches Papers

The IFCMA Papers series brings together outputs from the initiative's work to take stock of different carbon mitigation approaches, map policies to the emissions they cover, and estimate their impact on greenhouse gas emissions, as well as its work on analysing methodologies for computing the carbon intensity of goods and sectors. Comments on IFCMA Papers are welcome at IFCMA@oecd.org.

Background

The Inclusive Forum on Carbon Mitigation Approaches is the OECD's flagship initiative to help optimise the global impact of emissions reduction efforts around the world through better data and information sharing, evidence-based mutual learning, and inclusive multilateral dialogue.

By taking stock of different carbon mitigation approaches, mapping policies to the emissions they cover, and estimating their comparative impact in terms of emissions reductions, the IFCMA is enhancing understanding of the effect of the full spectrum of carbon mitigation approaches deployed around the world and their combined global impact. The IFCMA is also identifying and addressing challenges related to the calculation of sector- and product-level carbon intensity metrics, relevant to the design and evaluation of mitigation policies, and to steer firms' and consumers' decisions towards lower-emission products. This work supports better international coordination to avoid the proliferation of different standards, help minimise compliance costs for business, and avoid disruptions to trade.

To advance its technical work, the IFCMA brings together delegates from the climate, tax, and structural economic policy communities from more than 55 IFCMA members and numerous countries participating as Invitees around the world.

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Executive Summary

Prepared under the auspices of the Inclusive Forum on Carbon Mitigation Approaches (IFCMA), this report presents an overview of the main approaches to, and challenges faced when, calculating product-level carbon intensity metrics, including those applicable to collecting and verifying information along the supply chain. The analysis focuses on the approaches used in and the common challenges across emissions-intensive trade-exposed sectors (EITE). Still, the findings have broader relevance to other sectors. Additionally, the report considers the challenges of computing sector-level carbon intensity metrics, underscoring their complementarity with product-level metrics and importance in gauging countries' progress towards decarbonisation and climate change mitigation targets.

The work provides insights on how to minimise duplication among various initiatives, minimise compliance and reporting costs for firms, and avoid possible disruptions to trade. Whilst the work does not delve into sector-specific or product-specific issues, it builds on relevant literature and initiatives.

The main messages of this report are the following:

- **Carbon intensity metrics have several use cases for governments, firms, and households**. Governments can use them to develop, monitor, and evaluate the domestic and global absolute emission-reduction impact of relevant policies. Such policies can take the form of economic instruments (e.g. taxes), regulatory instruments (e.g. standards), and other instruments (e.g. public procurement initiatives). Trade-related climate measures (e.g. border carbon adjustments) are one example of polices that rely on accurate and timely product-level carbon intensity metrics. While this report considers many of these policies, it is not its intention to provide an assessment or endorsement of any particular policy or policy approach. Carbon intensity metrics can also help firms to manage and communicate the carbon intensity of their production to investors and consumers. Households can use them as a guide to choose lower-carbon goods.
- **Many of the use cases of carbon intensity metrics call for more granular, accurate, and timely data than are currently available**. Existing approaches to compute product-level carbon intensity metrics often use default values and make limited use of primary data due to lack of availability or high costs. This hinders emerging use cases such as steering consumption and investment decisions towards low-carbon goods and pricing firms' transition risks.
- **Governments and international co-operation could play an important role to align product-level carbon intensity methodologies across sectors and countries**. Cross-sectoral carbon accounting methodologies supplemented with sector-specific guidance can improve the quality and compatibility of different approaches to carbon accounting. In many cases, such as in steel, pre-existing private-sector methodologies provide a good starting point.
- **Using site and supplier-specific primary data will generally yield the highest accuracy, but there is a trade-off between accuracy and resource requirements**. Product-level metrics that draw on secondary data, such as sector-level averages, financial data and other proxy data, are not sufficiently accurate and granular for emerging use cases. Rules to allocate emissions from multi-product installations to individual products are key to computing product-level carbon intensity metrics relying on primary data. Furthermore, even when emissions are perfectly measured,

comparing the carbon intensity metrics of individual products is challenging because the products themselves may not be directly comparable.

- **The verification and sharing of data along the supply chain to enable the calculation of product-level metrics faces various economic, technical, legal, and regulatory barriers**. Building on ongoing government and private sector initiatives is crucial for overcoming these barriers. Initiatives such as developing interoperable greenhouse gas accounting and reporting standards, and establishing secure data-sharing platforms, are essential for enabling more accurate, transparent, and comprehensive carbon intensity metrics.
- **The proliferation of product-level carbon intensity standards, initiatives, and methods that vary across sectors and regions can increase firms' reporting costs and fragment global supply chains**. This variation may encourage firms producing and selling low-carbon goods to forsake the benefits of international trade by sourcing local inputs, which are potentially more emission intensive. Ensuring technical and operational interoperability among different standards and methods is challenging but necessary to preserve open markets and avoid raising firms' reporting costs due to different and inconsistent reporting regimes.
- **Common approaches and best practices can reduce the complexity and risk of fragmentation arising from the use of carbon intensity metrics within policies**. Governments could take steps to ensure that actions to promote the development of carbon intensity metrics and the introduction of policies using them are proportional, pro-competition, pro-innovation and based on interoperable standards. Making strides in this direction would contribute to decarbonising economies while minimising economic distortions and avoiding stifling economic growth.
- **Sector-level carbon intensity metrics remain indispensable for analysing sectoral and national progress toward decarbonisation**. Enhancing these metrics' granularity, timeliness, and frequency is contingent upon a better integration of existing databases and standards. Moreover, there is significant potential in linking sector- and product-level metrics more effectively to ensure consistency and accuracy. Installation-level data and novel technologies, such as satellite imagery, offer promising avenues to bridge existing data gaps.
- **Firms in developing countries and SMEs face greater challenges than firms in developed countries and large firms in computing carbon intensity metrics, which merit targeted support**. Developing countries may have limited administrative capacity and face high resource burdens in establishing effective emission measurement, reporting and verification systems to enable the computation of carbon intensity metrics. Developing tools and guidance addressing developing countries' specific needs as well as providing training and technical assistance would contribute to ease their resource and capacity constraints, promoting inclusivity. Policies based on carbon intensity metrics with strict and exacting regulatory requirements can present high compliance costs for SMEs and firms within developing countries. Easing these burdens may call for proportionate and timebound derogations alongside the provision of capacity building activities.

The IFCMA can play a key role in bringing countries together to agree on a common way forward towards the computation and use of carbon intensity metrics. Developing and adhering to shared economic principles for the computation and use of granular and timely carbon intensity metrics could help to minimise economic distortions due to duplication in data collection efforts, differences and inconsistencies in computation methods and high administration and compliance costs for firms. This report puts forward the following principles:

- **Ensuring proportionality**: assessing fitness for purpose when evaluating the resource requirements to develop metrics so as to strike a balance between accuracy and resource requirements, which may differ across sectors, products and use cases;

- **Promoting innovation and competition**: enhancing innovation incentives to decarbonise production processes and preserving open and competitive markets at national and international levels;
- **Fostering interoperability**: developing processes, methods and infrastructure in different regions, countries, sectors or products that share common foundations and can “speak” with each other to avoid multiple reporting requirements and increasing firms reporting costs.

To this end, this report has highlighted areas of further work. Currently, no further work is foreseen for the IFCMA’s Carbon Intensity Workstream (ICIW) as part of the terms of reference, however, a number of work areas identified in this report could form the basis of the second phase of the ICIW depending on how IFCMA members wish to take the work forward. These can be categorised into:

- Exploring data sources, measurement and calculation methods
- Convergence of public and private sector initiatives and capacity building
- Supporting policy design development that is proportional, pro-competition and undergirding trade and cross-border investment.

1 Introduction

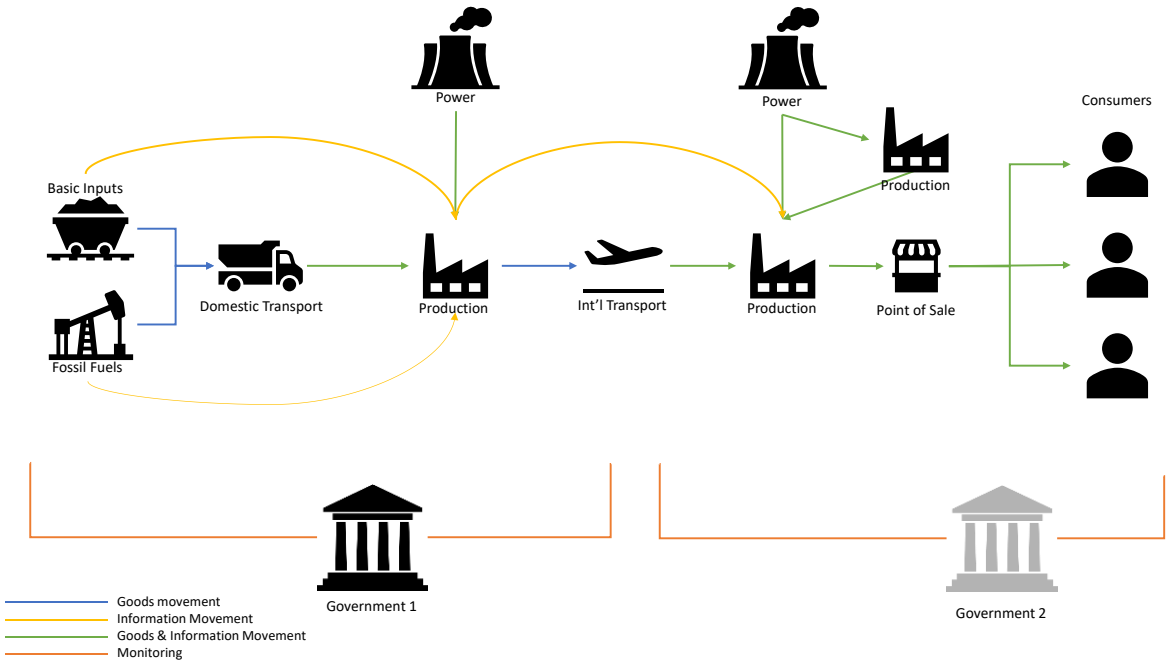
Reducing the carbon intensity of production is key to achieving ambitious emissions reduction goals while promoting growth and raising living standards. Focusing on reducing carbon intensity can drive innovation in clean technologies and foster the development of new markets, industries and job opportunities. When used as part of a toolkit of mitigation policies, carbon intensity metrics can contribute to efforts to reduce absolute emissions – the ultimate mitigation goal in line with the Paris Agreement.

Reliable carbon intensity metrics that track the carbon emissions associated with producing outputs (either at country, sector, or product-level) can support efforts to lower the carbon intensity of production. Carbon intensity metrics are defined in this analysis as the ratio between the greenhouse gasses (GHG) emitted (measured in tonnes of CO_2-equivalent) in the production of an output and the total output produced (measured in physical volume or economic value). They can be calculated at different levels of aggregation, and this report focuses on sector and product-level metrics. Other reporting levels of carbon intensity metrics include firms, asset classes, and financial portfolios (Noels and Jachnik, 2022[1]). Carbon intensity metrics have also been calculated and used at country-level. In the UNFCCC context, some countries have set emissions mitigation targets in terms of carbon emissions intensity per GDP unit (UNFCCC, 2022[2]). The different levels of aggregation at which carbon intensity metrics can be computed and used (e.g. products, plants, firms, sectors, countries) are a source of complication in the design and implementation of data collection systems.

This report suggests approaches to developing more accurate, timely, and granular product-level carbon intensity metrics and how the Inclusive Forum on Carbon Mitigation Approaches (IFCMA) can contribute to this process. As part of the analysis, this report also considers challenges relating to computing sector-level carbon intensity metrics, including how novel data sources and approaches can lead to better and timelier sector-level metrics. To maintain a reasonable scope, the analysis focuses on approaches taken in emissions-intensive trade-exposed sectors (EITE), though the findings have broader relevance as well.

The analysis identifies common challenges across products and sectors in computing reliable and timely product-level carbon intensity metrics and suggests approaches to overcoming them. It builds on sector and product-specific analyses already available (IEA, 2023[3]; WBCSD, 2023[4]; Greenhouse Gas Protocol, 2011[5]; OECD, 2023[6]) to identify good practices and synergies among different initiatives. Within sectors and countries, choices concerning carbon intensity methodologies and data collection efforts pose accuracy/resource-requirement trade-offs and have implication for SMEs, which may have less capacity to compute such metrics than large companies. Complex supply chains and international trade linkages add further complications (see Figure 1.1). Choices made in one sector or country have reverberations along the supply chain and across borders. These affect the capacity to, and the costs involved in, computing reliable carbon intensity metrics in downstream sectors and in other countries. The report underlines the role governments can play, along with numerous private sector initiatives that are already underway, to facilitate the computation of carbon intensity metrics. Governments can also advance international co-operation to promote the adoption of methodological choices and data collection methods that minimise distortions to global supply chains and limit firms' reporting costs, including through the IFCMA.

Figure 1.1. Example of the interactions between various actors required to enable the computation of carbon intensity metrics across a supply chain



Source: Authors (OECD).

Carbon intensity metrics have several uses cases, many of them demanding more timely and granular data than what is available to date. Section 2 outlines some of them. They can help steer firms' and consumers' decisions towards lower-emission products, support the development of markets for low-carbon goods and help diminish the risk of "greenwashing" (Noels and Jachnik, 2022[1]; Deconinck, Jansen and Barisone, 2023[7]). They can also be used to measure progress in a more objective way than current metrics, such as Environmental, Social and Governance (ESG) scores as they are often based on subjective judgments (D'Arcangelo et al., 2023[8]; Boffo, Marshall and R., 2020[9]). As such, carbon intensity metrics can help firms and investors to better manage transition risks (i.e. the risks stemming from changes in policies, technologies, market sentiment, and consumer choices that moving towards countries' emission reduction goals might entail). At the sector-level, carbon intensity metrics can be used to track progress towards net-zero emissions targets, as has been done in the IEA's Tracking Clean Energy Progress report (IEA, 2023[10]). Moreover, sector-level carbon intensity metrics can provide default values to ease the computation of product-level carbon intensity metrics if the collection of primary data is too costly. Used in conjunction with input-output tables, sector-level carbon intensity metrics are crucial inputs to production and consumption-based emissions, which are used to evaluate the contribution of international trade to global emissions (Yamano and Guilhoto, 2020[11]).

Carbon intensity metrics are also crucial to informing discussions on carbon leakage risks and the design of policies to mitigate them (IEA, 2022[12]). Internationally uncoordinated decarbonisation policies can create spillovers inhibiting the attainment of global climate goals. Carbon leakage is one such spillover, which may arise from asymmetric mitigation policies across countries. This may result in production and emissions shifting to jurisdictions with less stringent mitigation policies and higher carbon intensity of production. Carbon intensity metrics can help to pinpoint where and how carbon leakage risks may manifest (Yamano and Guilhoto, 2020[11]; OECD, 2023[13]). Policy tools, such as mandatory product emission standards and border carbon adjustment mechanisms, rely on the use of product-level carbon

intensity metrics to mitigate carbon leakage risks (OECD, 2020[14]). Carbon intensity metrics could also help to identify sectors and places relying on polluting technologies to produce certain products and assess the effect of clean technology diffusion on emissions. While this report considers a number of different policies, its intention is not to provide an assessment or endorsement of any particular policy or policy approach. Irrespective of the policy being considered, establishing mechanisms and certification schemes to ensure the integrity of the data used for the computation of carbon intensity metrics is essential to safeguard fair competition and effective policy.

The analysis of carbon intensity metrics at the sector-level (see Section 3) and the product-level (see Section 4) shows that there is not a single approach to calculating carbon intensity metrics that fits all applications and contexts. There is a clear trade-off between accuracy and resource requirements. The right balance between these two criteria will depend on intended use. Sector-level metrics, and product-level metrics that draw on aggregate data, can both be useful (e.g. to provide high-level overviews and comparisons). However, they are not sufficiently granular for emerging use cases, such as steering consumption and investment decisions towards low-carbon goods and pricing firms' transition risks.

The data and information requirements for granular carbon intensity metrics are high. As underlined in Section 3, methods to compute sector-level carbon intensity metrics using default values and limited primary data can be useful in a transitional phase towards product-level metrics, particularly for resource-constrained countries or firms. There is scope for installation-level data, collected through frameworks by governments or industry bodies, to provide timely and granular complementary data to existing sector-level data sources. Drawing on the range of existing international standards and initiatives, growing the use of installation-level data will require striking the balance between harmonising methods for data collection and computation across sectors, while also allowing for flexibility to capture sector- and product-specific considerations. The use of installation-level data can allow time for capacity to be developed, primary data to be collected and definitions to be agreed (see Section 4). Novel emissions data collection methods at the installation-level, for example using satellite and machine learning technologies, aim to improve the timeliness and completeness of data at lower costs. These can complement conventional data sources and further ensure better consistency between sector and product-level metrics.

There are different methodological approaches to compute product-level carbon intensity metrics, each with its own trade-offs. The trade-offs include the coverage of firms and emission types along the supply chain (i.e. Scope 1-3 emissions), as well as the timeliness, and accuracy of estimates.[1] These trade-offs vary across use cases and level of aggregation, which may justify different choices. For example, government policies such as carbon pricing and emissions reporting requirements, may require reliable and precise installation or product-level metrics as they determine payments or other obligations. For other uses, such as assessing and comparing progress across sectors and firms, less accurate data and metrics can be sufficient.

Developing sector-specific, product-level guidance that is consistent with general-purpose accounting methodologies would improve the quality and comparability of carbon accounting. Under general purpose methodologies, such as the GHG Protocol's Product Life Cycle Accounting and Reporting Standard, firms and industry bodies retain some flexibility to make methodological choices to meet sector-specific needs. To ensure that sector-specific methodological choices are aligned, additional guidance is needed. In many cases, such as in steel, pre-existing private-sector methodologies provide a good starting point. Governments could decide to make following certain guidelines mandatory for specific use cases. Governments could also play an important coordinating role to make sure that methodologies

[1] Scope 1 emissions are direct emissions from owned or controlled sources. Scope 2 covers indirect emissions from the generation of purchased energy. Scope 3 includes all other indirect emissions in a company's supply chain, both upstream and downstream.

are aligned across sectors and countries (so as to make them compatible along supply chains), including through active participation in relevant international fora.

Fragmentation of public and private initiatives, standards, and infrastructure for the computation of product-level carbon intensity metrics could harm global supply chains. Sharing emissions data along the supply chains is necessary to include Scope 3 emissions in product-level carbon intensity metrics. Section 4 assesses the main hurdles that have hindered progress in this direction and points to new and promising public and private-sector initiatives in this field. These initiatives are developing guidelines, emissions accounting standards, and the necessary infrastructure with the aim of mitigating the economic, technical, legal, and regulatory obstacles hindering the collection and verification of data across supply chains. The initiatives are welcome, but the proliferation of standards and methods across sectors, regions, and country blocs also present risks in terms of fragmentation (World Trade Organization, 2023[15]). Government and international action can build on such initiatives. Ensuring the technical and operational interoperability of different initiatives is key to preventing disproportionate transaction costs arising and avoiding the fragmentation of global supply chains.

Common approaches and best practices can play a key role in managing the complexity and risk of fragmentation that arises from the use of carbon intensity metrics within policies. Obligations on firms to service various slightly different reporting regimes, competing methodological approaches, and overlapping private sector initiatives can lead to trade frictions and disproportionate costs. Governments should take steps to ensure that policies that use carbon intensity metrics remain outcome focussed, proportional, pro-competitive and pro-innovation as well as based on interoperable approaches. The internationalisation of carbon intensity measurement systems and active efforts to minimise unintended distortions and make policies more friendly for SMEs and developing countries can help reduce the risk of fragmentation.

The IFCMA can play a key role in bringing countries together to agree a common way forward on the computation and use of carbon intensity metrics. Discussions that contribute to developing shared principles amongst countries could be a promising step. As a “safe space” for peer exchange and mutual learning, the IFCMA brings together different country perspectives to support a common understanding on key issues. This puts the IFCMA in good stead as a forum for such exchange, leading to principles that could help ensure that any standards that may be developed are interoperable and the related costs are proportional.

This report highlights areas of further work to promote the widespread computation and use of product-level intensity. Whilst no further work is foreseen for the IFCMA’s Carbon Intensity Workstream (ICIW) as part of the terms of reference, a number of areas merit further work that could form the second phase of the ICIW. These areas of further work can be categorised into:

- Exploring data sources, measurement and calculation methods;
- Convergence of public and private sector initiatives and capacity building;
- Supporting policy design development that is proportional, pro-competition and undergirding trade and cross-border investment.

2 The use cases for carbon intensity metrics

Key Messages

- There are several use cases for carbon intensity metrics for governments, households, and firms.
- Many of these use cases call for more granular and timely carbon intensity metrics than currently available.
- Future work through the IFCMA could further explore use cases to inform policy design and implementation.

Governments, households, and firms can use carbon intensity metrics in several ways to support the transition to net-zero emissions. Governments can use carbon intensity metrics to guide the design of policies, as a metric upon which policies are based, and to evaluate the impact of policies. While this report considers many of these policies, it is not its intention to provide an assessment or endorsement of any particular policy or policy approach. Labels based on carbon intensity metrics bridge information gaps and steer consumer demand towards low carbon products. Firms can use carbon intensity metrics as part of their decision making to improve their environmental performance and better communicate actions and progress to investors. This section will explore key use cases and policy instruments based on them (see Table 2.1).

Further work is needed to explore the design and implementation of policy instruments that use carbon intensity metrics. Many of these policies are novel and little studied in the literature. Furthermore, they involve particular challenges to ensure SMEs and developing countries are not hurt disproportionately by their implementation hurdles and compliance costs. Moreover, policies aiming at reducing carbon intensity, even if successful, do not guarantee that absolute emissions will fall. So, such policy instruments need to be designed or complemented with other policies to ensure they contribute to a reduction in absolute emissions. Overall, a better understanding of these issues could facilitate the design and implementation of policies based on carbon intensity metrics that complement and enhance the effectiveness of other mitigation policies (as discussed in this section).

Table 2.1. Main existing and potential use cases of carbon intensity metrics

Governments Designing carbon emissions reduction policies, evaluating impacts and setting targets	Basis for emissions reduction policies
	Identifying, quantifying and mitigating carbon leakage risks
	Setting mitigation targets, comparing progress across sectors and supporting policy design

Households Supporting the growth of the market for low carbon goods	Product labels to steer choice towards lower carbon products
Firms Strengthening incentives to lower the carbon intensity of production and communicating to investors and consumers	Informing decisions aiming at lowering carbon intensity of production, including through the purchase of low-carbon intermediate goods
	Using carbon intensity metrics to help investors price climate risks and prevent greenwashing

Source: OECD.

Overall, product-level carbon intensity metrics are important for policy making and information provision. Carbon intensity metrics can be used to determine the level of a tax or subsidy for a given product, altering relative prices based on carbon content. Product-level carbon intensity metrics can enable governments to select, for instance, products eligible for public support, decide if additional regulation or support is needed, and evaluate the effectiveness of past policies (Rajagopal, Vanderghem and MacLean, 2017[16]). Information on a products' carbon intensity can help consumers, businesses and governments to make less carbon-intensive choices:

- First, within each product category, such metrics can support the shift to lower-emissions products or producers (e.g. from higher- to lower-emissions producers of a certain type of steel);
- Second, they can help people to shift consumption towards lower-emissions product categories (e.g. through identifying modes of transport with lower emissions per kilometre travelled than alternatives (Hine et al., 2020[17])). Builders, for instance, could use them to consider the trade-off between using timber rather than concrete and steel (Churkina et al., 2020[18]);
- Third, they can provide incentives to producers to invest in lower-emissions techniques and attract additional finance towards this end.

Governments: Designing carbon emissions reduction policies, evaluating impacts and setting targets

Carbon intensity metrics can be a key part of government emissions mitigation strategies. As discussed below, these include using these metrics as a basis for policies or to guide the implementation of market based and regulatory instruments, in addition to other instruments such as public procurement (see Table 2.2). Furthermore, carbon intensity metrics can also be useful in monitoring and evaluating impacts of policies, and as a basis for broad mitigation targets and strategies (see Section 3).

Table 2.2. Select policy instruments that may use carbon intensity metrics

	Economic instruments	Regulatory instruments	Other
Product-level	Taxes, Tax incentives, and Subsidies Border carbon adjustment mechanisms	Mandatory/voluntary labels Mandatory/voluntary standards	Green public procurement
Firm- and installation-level	Emissions Trading Schemes	Information disclosure/reporting requirements	Benchmarking and performance targets

Note: Typology of policies is based on the typology for the stocktake of policies under Module 1 of the IFCMA.
Source: OECD.

Carbon intensity metrics as the basis for emissions reduction policies

Tax incentives for promoting low-carbon activities could use product-level carbon intensity metrics as part of their eligibility criteria. For example, in France, licensing revenue or revenue from the sale of

patents by a French company is taxed at a reduced rate of 15% provided that certain preconditions are fulfilled. Patents for lower-carbon production techniques could be taxed at a further reduced rate or with a sliding scale based on the carbon intensity of the production technique. This could promote technology transfers and lead to an increase in low-carbon production, though foregone revenues and windfall gains to businesses from such schemes would also need to be taken into account. In the United States, domestic manufacturers of components related to low carbon activities are eligible to receive an advanced manufacturing production tax credit (Internal Revenue Service (United States), 2023[19]). Also, the United States' Inflation Reduction Act links tax credits for hydrogen production to the carbon intensity of hydrogen produced (by awarding larger tax credits for the production of hydrogen emitting GHGs, per kilogram of hydrogen, below specific thresholds). The trade-offs related to using carbon intensity metrics to define eligibility of clean investment for corporate tax incentives are further discussed in Dressler and Warwick (Forthcoming[20]). Carbon intensity metrics can also be used as one of many elements to guide the implementation of R&D tax reliefs as governments can use the metrics to make available the largest reliefs for R&D focused on decarbonisation within sectors that are the most carbon intensive.

Taxes based on product-level carbon intensity metrics could strengthen incentives to decarbonise consumption and investment decisions. A product-level consumption tax could make carbon-intensive choices more expensive, thus lowering the demand for highly carbon intensive goods. Such a tax could be levied using product-level metrics at the point of sale to final consumers, or at each point in the supply chain of a good like a value added tax (VAT) (Tovar Reaños, C De Bruin and Mert Yakut, 2022[21]). Additionally, taxes could also be levelled at the installation-level using carbon intensity metrics. Like all taxes, the administrative complexity of a carbon intensity-based tax will be dependent on the number of entities and products it is levied on. In general, a broad-based consumption charge would be more complex than a consumption charge levied on selected carbon-intensive basic materials only (Pollitt, Neuhoff and Lin, 2019[22]). A number of governments have studied such taxes noting that whilst such taxes have emissions reduction potential particularly where there are suitable direct substitutes, there are a number of challenges to resolve before such a tax could be implemented (HM Revenue & Customs and HM Treasury (United Kingdom), 2020[23]; Remes et al., 2023[24]).

Subsidies based on product-level carbon intensity metrics can be used to reduce the price of low-carbon goods and technologies. For example, France recently reformed incentives for the purchase of low-carbon vehicles and now partly bases them on vehicles' carbon intensity of production (see Box 2.1). More broadly carbon intensity metrics could also be used to help direct the implementation of public support for green activities**.** For example, assessments of the embodied carbon of a housebuilding project could inform policy design for decarbonising the housing stock (e.g. grants, subsidised mortgages, mortgage guarantees and property tax discounts).

Box 2.1. Policies in practice – the French low-emission vehicle subsidy scheme

For several years, the French government has offered subsidies towards the purchase of low-emission vehicles to support the decarbonisation of surface transport. These incentives operated on a bonus-malus system and were based on tailpipe emissions, rewarding buyers of low-emission vehicles with a financial bonus and imposing penalties on buyers of high-emission vehicles. However, recently the French government has reformed this system by also tying these subsidies to the vehicle's product-level carbon intensity.

As outlined through supplementary legislative text in October 2023, a vehicle's carbon intensity is calculated by adding the quantities of CO_2 emitted during all the stages of its production (but not its use). This includes considering the steel, aluminium and other materials that make up the vehicle, including its battery and other components, the assembly of the vehicle (this includes assessing the

environmental impact of the assembly plant and its energy consumption) and intermediate transformations and logistics.

The updated legislation defines reference emission factor values for each aspect of the vehicle's production under consideration, differentiated by the place of assembly of the vehicle or battery. The carbon intensity of the vehicle must be calculated and scored using these reference values. Where the manufacturer is unhappy with the score (including where it fails to meet the minimum standard), they can submit additional information, including actual emissions data. Additionally, if the vehicle is assembled at several sites, the legislation outlines methods to weigh the carbon intensity metrics associated with these different sites.

Source: (METS; MCT (France), 2023[25]) (Legifrance (France), 2023[26])

Emissions Trading Schemes (ETSs) have often relied on installation-level carbon intensity metrics for many years (IEA, 2007[27])**.** Many countries allocate pollution permits and set emissions caps for future years by comparing the gap between installations with low carbon intensity and a benchmark. Additionally, regulators allocate free permits to installations with a high carbon intensity where there is a risk of carbon leakage. However, such free allocation has been shown to reduce the effectiveness of carbon pricing at reducing emissions (Dechezleprêtre, Nachtigall and Venmans, 2023[28]). These practices have elements of the approach proposed by Shleifer's (1985[29]) yardstick competition. Following this approach, the benchmark could improve over time, thus encouraging efforts by regulated firms to reduce their emissions intensity. One of the main advantages of yardstick competition is that the regulator does not need to discriminate among different emission reduction technologies. However, yardstick competition is not immune to firms' strategic behaviour and regulatory gaming (Agrell and Teusch, 2020[30]).

Installation and product-level carbon intensity metrics could be further integrated into ETSs. Installation-level carbon intensity metrics are an integral part of baseline and credit ETSs whereby firms exceeding a pre-determined carbon intensity threshold need to acquire credits in order to emit. Australia implements one such system, known as the Safeguard Mechanism (see Box 2.2), and sets carbon intensity ceilings for industrial facilities. These ceilings are intended to be lowered in line with the 2030 emission reduction targets and a 2050 net-zero target. Such installation-level ceilings could also be implemented into other types of ETSs, providing governments an additional lever to promote decarbonisation at the installation-level. This would require taking into account possible waterbed effects, whereby different policies end up reshuffling emissions with no overall reduction. Governments could go further by setting product-level carbon intensity ceilings. However, complementing ETSs with carbon intensity metrics in this way comes with risks and challenges. Governments will need to understand and correctly project decarbonisation and technology pathways to set effective caps. If the caps are set artificially high or in a way that unnecessarily disadvantages a particular business or technology, they can have implications for competition and reduce consumer choice (Competition Bureau Canada, 2020[31]). Additionally, replacing overall carbon emission caps with carbon intensity-based caps risks resulting in larger absolute emissions. Thus, carbon intensity caps are better suited to supplement total emissions caps in ETSs, rather than replacing them.

Box 2.2. Policies in practice – the Australian Safeguard Mechanism

The Safeguard Mechanism is a set of regulations that apply to all industrial facilities in Australia that emit more than 100 000 tonnes of CO_2-e per year. The mechanism sets individual limits, known as baselines, on the net emissions of industrial facilities (more than 200 and accounting for nearly 28% of Australia's total GHG emissions). The Safeguard Mechanism covers a broad range of industrial sectors, including electricity generation, mining, oil and gas extraction, manufacturing, transport, and waste.

How the Safeguard Mechanism works

The Safeguard Mechanism limits industrial emissions by establishing emissions baselines (or ceilings) for every individual facility it covers. Baselines are set in terms of facilities' emissions intensities (emissions per unit of output). Therefore, in any given year the effective ceiling on an individual facility's absolute emissions is calculated as the emissions intensity baseline (or ceiling) multiplied by the facility's output. This means that covered facilities can raise emissions by producing a larger volume of output, as long as the emissions intensity of the product is below the baseline. Facilities that exceed their baselines must purchase and surrender domestic carbon offsets – Australian Carbon Credit Units (ACCUs) generated by Australia's carbon crediting scheme (ACCU Scheme) – for the exceeding amount.

To date, baselines set by the Clean Energy Regulator have generally been set higher than facilities' emissions and have therefore had little effect on emissions. The electricity sector is treated differently than other sectors covered by the Safeguard Mechanism, because electricity production is centrally coordinated, the Safeguard Mechanism applies a common baseline for the whole electricity sector.

Note: Text based on Box 3.2 of the 2023 OECD Economic Survey of Australia (OECD, 2023[32])
Source: (Australian Department of Energy, 2024[33])

Standards that set product-level carbon intensity ceilings can be used to help lower emissions and mitigate carbon leakage risks. Establishing such standards on a voluntary basis (i.e. voluntary regulatory product standards, VPSs) could foster the development of the market for low-carbon goods. Making these standards mandatory (i.e. mandatory regulatory product standards, MPSs) on domestic production would go a step further by guaranteeing emissions reductions. Applying them to imports as well would reduce the risk of carbon leakage arising from the implementation of domestic MPS or other climate policies, to an extent (Department for Business, Energy & Industrial Strategy (United Kingdom), 2021[34]). International action to coordinate standards could help mitigate carbon leakage risks while promoting decarbonisation. To be perceived as fair and safeguard market competition, such standards would need to recognise the compliance challenges of SMEs and developing countries (Section 5 deals in more detail with issues relating to competition and SMEs). Additionally, such standards would also have to comply with a country's bilateral, plurilateral and multilateral agreements (including those under the WTO). More generally, as in the case of the Australian safeguard mechanism, there are challenges in setting effective ceilings. Ceilings set too low risk being unattainable and negatively impacting competition whereas ceilings set too high risk being ineffective.

Green building standards based on carbon intensity metrics can help lower emissions from the construction sector. Such standards are also known as low embodied carbon building standards. Through them governments could set ceilings for the carbon intensity of construction based on the carbon intensity of different construction materials, machinery and activities, complementing price-based instruments such as cap-and-trade systems. However, care must be taken that overlapping policies do not overdetermine the emissions penalty on certain products or technologies as this could lead to overall higher costs of mitigation policies. The city of Oslo provides an example of combing strong policy with public

support as progress is being made towards using only emission-free machinery in construction sites by 2025 (KlimaOslo, 2022[35]).

Integrating product-level carbon intensity metrics into public procurement systems can be used to support demand for low carbon products. For some time, many governments have been introducing green considerations into public procurement (OECD, 2023[36]; OECD, 2015[37]).[2] Examples include energy efficient information technology equipment, recycled paper, low emissions transport vehicles (e.g. buses, ferries), renewable energy supply and others. However, these efforts are based on firms' certifications and have not been able to differentiate products based on their carbon intensity. Product-level carbon intensity metrics would provide the granular information necessary to design and implement advance market commitment schemes for low carbon products, similarly to what has been already done for vaccine developments (Kremer, Levin and Snyder, 2020[38]).

Domestic and international efforts to mainstream the use of carbon intensity metrics in public procurement exist but face challenges inhibiting them becoming mainstream. The Industrial Deep Decarbonisation Initiative (IDDI) has already developed guidelines to progress towards this goal (see Box 2.3). Additionally, in May 2023, the United Sates' Federal Government launched the Federal-State Buy Clean Partnership with 12 states, which committed to support the procurement of lower-carbon infrastructure materials in state-funded projects, and to collaborate to send clear demand signals to markets (Office of the Federal Chief Sustainability Officer (United States), 2023[39]). Furthermore, the US Federal Government is also developing a carbon label to support this initiative (EPA (United States), 2024[40]). More generally, steps to integrate carbon intensity metrics in public procurements need to take into consideration the specific circumstances of SMEs and firms in developing countries. Such firms often have limited technical capability and profit margins making it particularly challenging for them to calculate product-level carbon intensity metrics. That said, many governments have already taken steps to facilitate the participation of SMEs in public procurement tenders, in line with the principles of equal treatment, open access and effective competition (OECD, 2018[41]; EPA (United States), 2024[40]).

Box 2.3. The Industrial Deep Decarbonisation Initiative's Green Procurement Pledge

The Green Procurement Pledge (GPP) under the Clean Energy Ministerial's Industrial Deep Decarbonization Initiative (IDDI) is a live example of carbon intensity metrics being used to help grow the market for low carbon goods.

The IDDI aims to increase the uptake of green public procurement policies in member countries by offering different levels of commitment with decreasing carbon intensity benchmarks. Launched in November 2021 by the governments of the United Kingdom (UK), India, Germany, the United Arab Emirates and Canada, the GPP aims to increase governments' purchasing of low carbon steel and concrete. It offers four commitment levels to countries, beginning initially with just data reporting.

The GPP follows the IEA's methodology (IEA, 2022[12]) for calculating the emissions intensity of steel and cement and aims to ensure that the lowest emissions intensity products received the highest green premium. The pledge has four levels:

- Level 1: Starting no later than 2025, require disclosure of the embodied carbon in cement/concrete and steel procured for public construction projects;

[2] Public procurement accounts for about 12% of GDP and 30% of total government expenditures in OECD countries and even higher shares in some sectors emerging economies (Hoekman and Sanfilippo, 2021[253]; Alvarez and Rubicon, 2015[254]; OECD, 2018[41])

- Level 2: Starting no later than 2030, conduct whole project life cycle assessments for all public construction projects, and, by 2050, achieve net-zero emissions in all public construction projects;
- Level 3: Starting no later than 2030, require procurement of low emission cement/concrete and steel in public construction projects, applying the highest ambition possible under national circumstances;
- Level 4: Starting in 2030, require procurement of a share of cement and/or crude steel from near zero emission material production for signature projects.

Source: Industrial Deep Decarbonisation Initiative (2022[42])

Carbon intensity metrics could accelerate progress towards the trade liberalisation of environmental goods and services. The 2001 WTO Doha Ministerial Declaration instructed members to negotiate on the reduction of tariff and non-tariff barriers on environmental goods and services. However, discussions on this agenda have stalled as developing consensus on how to identify and classify environmental goods and services has proved challenging. That said, WTO members have identified environmentally preferable products (EPPs) (goods whose production, end use or disposal are not harmful to the environment or have positive environmental characteristics relative to similar substitute goods) (Zhuawu and Powell, 2022[43]) as potential candidates for liberalisation. Goods produced in a lower-carbon way than their substitutes could fit under the EPP category. Product-level carbon intensity metrics could thus act as a yardstick to enable future liberalisation. Discussions at the WTO's Trade and Environmental Sustainability Structured Discussions (TESSD) have referenced the work of initiatives, like the Glasgow Breakthrough, to develop definitions of low and zero emission products. As part of these discussions, countries have shown interest in the role these definitions could play in setting thresholds to help define what environmental goods are (World Trade Organization (WTO), 2023[44]).

Identifying, quantifying and mitigating carbon leakage risks

Sector-level carbon intensity metrics can help to assess carbon leakage risks and mitigation policy impacts. Carbon leakage risks have been a growing concern for some time. They stem from climate policy asymmetries and particularly affects emissions-intensive trade-exposed sectors (see Box 2.4) (D'Arcangelo, Kruse and Pisu, 2023[45]). If a sector has a high level of carbon intensity, then carbon pricing or climate regulation may lead to carbon leakage as production costs will rise. Sector-level metrics can be used to assess carbon leakage risks (HM Treasury (United Kingdom), 2021[46]). Sector-level metrics can also be used to estimate the impacts of measures to mitigate carbon leakage risks (e.g. estimating the additional costs faced by products subject to border carbon adjustment measures (World Bank Group, 2023[47])). Examples of databases that are used to calculate sector-level carbon intensity metrics include the OECD's Trade in Embodied CO_2 ($TECO_2$) and Trade in Value Added (TiVA) databases (Yamano and Guilhoto, 2020[11]; OECD, 2023[13]).[3]

[3] The $TECO_2$ dataset provides estimates of embodied emissions across countries and by sector can offer interesting insights, but it also has limitations. For example, there is a relatively high degree of sectoral aggregation which can inadvertently mask large heterogeneity across industries.

Box 2.4. Carbon leakage risks are multifaceted and rising

Carbon leakage can occur through three main channels – trade and investment, international energy prices, and technological spillovers, (see OECD (2020[14])) for further details on the latter two channels). Generally, policymakers are concerned that countries taking ambitious climate action may lose competitiveness relative to those that do not, leading to economic harm and little to no reduction in global emissions as production and emissions shift to countries with less stringent climate policies (Stojanovic, 2018[48]). Through the trade and investment channel, the extent of carbon leakage depends on differences in carbon intensity, costs of production, and climate policy costs across countries.

Carbon leakage risks also pose a challenge for the successful delivery of global climate goals as they could reduce public support for ambitious climate action. Low public support could inhibit governments from taking the necessary action to meet emission reduction pledges.

To date there is limited empirical evidence of carbon leakage (OECD, 2020[14]). Ex-post studies have shown little to no carbon leakage resulting from climate policy differentials (OECD, 2020[14]), while ex-ante modelling approaches tend to indicate that growing differentials in climate policy stringency between trading partners will lead to carbon leakage (Branger and Quirion, 2014[49]; OECD, 2020[14]). One reason for this difference is that mitigation policies have not yet reached the level of stringency needed to affect countries' comparative advantage and affect international trade flows through firms' production and investment decisions (Ellis, Nachtigall and Venmans, 2019[50]).

New empirical evidence suggests that, as some countries have increased their mitigation policy stringency more than others, leakage risks have increased. Teusch et al. (2024[51]) test the effect of the developments on domestic emissions and carbon leakage for cement and steel over the 2015-22 period. The paper finds that higher carbon prices have reduced plant-level emissions; at the same time rising carbon price asymmetries across countries have led to carbon leakage through international trade. Results suggest that, on average, a USD 1/tCO_2e increase in carbon prices reduces cement and steel plants' emissions by 1.3% and that international trade offset around 13% of these domestic emission reductions.

Source: Authors (OECD, 2020[14])

Product-level carbon intensity metrics can add greater granularity to efforts to assess and mitigate carbon leakage risks. Carbon intensity can vary widely across products within a given sector, depending on production techniques and energy usage, so product-level metrics can add greater granularity to carbon leakage risk assessments. Discussions in the G7, G20, Coalition of Finance Ministers for Climate Action, and the Climate Club have indicated interest in using product-level carbon intensity metrics to develop a granular understanding of carbon leakage risks. Product-level carbon intensity metrics also form the basis of Border Carbon Adjustment (BCA) mechanisms and mandatory product standards to mitigate such risks (OECD, 2020[14]; Cosbey et al., 2012[52]). Progress is being made to trace carbon emissions at the product-level through the supply chains, but challenges persist (see Section 4). Governments designing these measures would have to balance considerations around accuracy and granularity, administrative complexity, the costs imposed on firms and consumers, and maintaining open and competitive markets (OECD, 2020[14]).

Ex-post evaluations of carbon leakage can use product- and sector-level carbon intensities as key metrics. Trade-flow data can identify where there has been a reduction in domestic production that corresponds with an increase in imports. Combining this with carbon intensity metrics can help identify whether the replacement of domestic production by imports had led to an increase in domestic, foreign, and global emissions. Carbon intensity metrics can help point out cases of resource shuffling whereby

firms redirect their “cleanest” outputs to countries with the most stringent import requirements without a reduction in their overall carbon intensity.

Countries could use product and sector-level carbon intensity metrics as the basis of an international effort to manage risks to the delivery of global climate goals. Countries could agree on shared carbon intensity-based targets for relevant products and sectors. This will require finding a consensus on methodologies for calculating carbon intensity metrics and setting benchmarks. Countries will then have to take steps to implement policies to meet these targets. Such efforts would mean that regardless of where production is moved to, through carbon leakage or otherwise, it would not lead to an increase in global emissions, provided global output remained constant and standards uniform, binding and applied. Whilst politically challenging, the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) and outcomes from the Industrial Deep Decarbonization Initiative (IDDI) demonstrate that it would be possible for countries to agree and work towards shared emissions intensity targets (see Box 2.3). Discussions in the Climate Club on supporting industrial decarbonisation can also contribute to these efforts.

Setting high-level targets, comparing progress across sectors, and informing policy design

Some governments use carbon intensity metrics to monitor the pace and scale of decarbonisation. Examples include reporting progress towards the Paris Agreement’s Nationally Determined Contributions (NDCs) through emissions as a percentage of GDP in addition to total emissions and or emissions per capita. International organisations, such as the IEA, collect and aggregate data from governments and industry bodies to report progress on global decarbonisation and inform international cooperation on high-level targets (see Box 2.5). Analysing the distribution of carbon intensity metrics for a given sector or product can also help better understand the industry’s overall carbon performance and the impact of specific policies. Furthermore, considering broader indicators, such as changes in carbon intensity over time, can also provide useful perspectives to support the tracking of progress.

Box 2.5. IEA’s Tracking Clean Energy Progress Report

The IEA’s annual Tracking Clean Energy Progress Report measures progress made in key sectors and technologies towards achieving climate mitigation targets, based on its own modelling of national and international policy pathways. The report distinguishes between total emissions and emissions intensity across sectors, pointing to, for example in the aluminium subsector, increases in total emissions but modest decrease in emissions intensity over the past decade. It compares these metrics to the improvements in the aluminium subsector required to meet global net-zero emissions by 2050, as modelled in the IEA’s Net Zero Emissions Scenario. The report also provides detailed analysis useful to policymakers, highlighting that the decrease in emissions intensity achieved to date is mostly attributable to improvements in the efficiency of the aluminium production process and that promoting fuel switching will play a larger role in further reducing the carbon intensity of the sector.

Source: IEA (2023[10])

Carbon intensity metrics can be used to guide the design and help evaluate the impacts of carbon pricing systems. For example, the British Columbia Carbon Tax used carbon intensity metrics to design the tax and monitor the resulting changes in emissions, helping to measure its effectiveness in encouraging a shift toward lower-carbon energy sources and greater energy efficiency (see Box 2.6). Additionally, tracking the reduction in firm-level carbon intensity metrics can also help regulators evaluate the performance of ETSs in driving decarbonisation.

Box 2.6. Policies in practice - the British Columbia Carbon Tax

The British Columbia (BC) Carbon Tax was implemented in 2008 and phased in over several years. The tax aimed to incentivise individuals and businesses to reduce their carbon footprint by taxing the consumption of fossil fuels. In particular, the BC government introduced a carbon tax on fossil fuels, including gasoline, diesel, natural gas, and heating fuels. The tax was applied at the point of sale or consumption, thus effectively increasing the cost of carbon-intensive energy sources.

As part of the policy, BC established a system for monitoring and reporting carbon emissions from various sectors. This included tracking emissions from the combustion of fossil fuels subject to the carbon tax. Carbon intensity metrics were used to quantify emissions reductions associated with the tax. This involved calculating the reduction in carbon emissions per unit of energy consumed, which could be expressed in terms of kilograms or metric tons of CO_2 per MJ or GJ of energy. Carbon intensity metrics also allowed policymakers and analysts to assess the tax's impact on emissions reduction. By comparing emissions data before and after the tax implementation, they could determine how much carbon intensity had decreased in the sectors subject to the tax. This provided a clear measure of the tax's effectiveness in encouraging a shift toward lower-carbon energy sources and greater energy efficiency.

The availability of carbon intensity data helped policymakers make informed decisions about potential adjustments to the tax rate or scope. If emissions reductions were not meeting the desired targets, they could consider modifying the tax to provide stronger incentives for carbon reduction. Moreover, reporting carbon intensity reductions made the tax policy transparent and accountable to the public.

Source: Government of B.C (2023[53]) and Murray and Rivers (2015[54])

Carbon intensity metrics are already used by some export credit agencies to support decarbonisation. Members of the Net-Zero Export Credit Agencies Alliance have committed to, among other things, disclose carbon intensity metrics to demonstrate their commitment net-zero emission goals and align their operations with such goals. This includes issuing relevant international or national GHG emissions reporting protocols and climate portfolio alignment methodologies. (Net-Zero Export Credit Agencies Alliance, 2023[55]). More broadly, a growing number of export credit agencies are now beginning to establish targets to reduce the carbon intensity of their portfolios (OECD, 2023[56]).

Challenges

Carbon intensity metrics are not a panacea to implementing effective mitigation policies. Policies based on carbon intensity metrics face design and implementation challenges such as the choice of carbon intensity benchmarks for detailed product categories and how frequently to update them. Furthermore, implementing these benchmarks will require establishing reliable and affordable systems to verify, monitor and report emission and output data to compute the carbon intensity, based on agreed methodologies, for the selected products covered in the benchmarks. In addition, it is not straightforward to compare the carbon intensity of products that are not functionally equivalent, such as different types of steel (see Section 3). This is even more challenging for different product categories, such as different types of building materials (e.g. wood, steel, concrete – see Section 4).

Like all policies relying on measurement, computation, and information sharing, policies based on fragmented methodologies for the computation and reporting of carbon intensity metrics could negatively affect SMEs and firms in developing countries. Failing to account for these challenges might add to

administrative costs and complexity, with especially adverse consequences on firms with less administrative and financial capacity (i.e. SMEs and firms in developing countries – see Sections 4 and 5).

Households: Product labels to steer consumer choice towards lower carbon products

Clear quantitative metrics can help consumers to understand the environmental consequences of their choices. Various firm-level certification initiatives, relying on a host of different metrics and qualitative statements, have started to fill this information gap. This has not solved asymmetric information problems (Akerlof, 1970[57]) and has often contributed to confusing consumers (Seifert, Ralf W.; Comas Martí, Joana M., 2012[58]), thus hindering the development of markets for low-carbon products. For instance, firms have been able to establish certification initiatives based on definitions and rules that best suit them with limited oversight or regulation (European Commission (European Union), 2023[59]).

Product labels based on product-level carbon intensity metrics can complement carbon pricing schemes and help align consumers purchasing choices with emission reduction goals. Carbon pricing schemes are levied on producers or suppliers, with market structures determining the extent to which the price is passed onto final consumers. Consumers may not always be able to discern the relative carbon intensity of goods they purchase as a firm could either spread the carbon cost equally across its product portfolio or in a way that accounts for the price elasticity of demand for each good (Garsous et al., 2023[60]; OECD, 2020[14]). Accordingly, the price of similar goods conveys little or no information on their different carbon content. Multi-product firms often engage in product cross subsidisation, whereby firms price some products below cost and compensate the resulting loss with profits from other products (Chen and Rey, 2019[61]; Laffont and Tirole, 1990[62]). Depending on market structures and consumer demand, low carbon products could subsidise high carbon products.

Box 2.7. Parallels between food labelling and carbon intensity labelling

Nutrition labelling policies provide supplementary nutritional information in an easy-to-understand label displayed on food products' packages. Forty-four countries have introduced these types of labelling schemes with a view to promoting public health. Preliminary insights on the impact of these schemes show that they can influence reformulation efforts by the food industry as well as consumers' purchasing decisions (Giner, Rodriguez and Elasri, 2023[63]). However, the development of these labels has been a gradual process, with the involvement of many different actors.

As different food laws and standards started developing in various countries, trade in food faced issues of fragmentation and countries realised the need to establish a common framework for food laws. After the FAO (1945) and World Health Organization (1948) were formed, a number of joint experts' meetings were held aimed at solving various challenges facing the international food trade.

This led to the creation of the Codex Alimentarius (Food Code), which is applied by over 180 member countries and includes standards on food labelling. Its main role is to facilitate fair trade practices by giving internationally recognised standards and guidelines that can form the basis for domestic standards.

Firms in the food industry have adapted to regulations like the United States Nutrition Labelling and Education Act of 1990 by collecting data on the nutritional content of their products, using laboratory analyses or databases of nutritional information. These data are then used to create the nutritional information labels required by law. The increased focus on data collection also led to the development of new tools and technologies to help firms manage their data. For example, some firms developed

software applications that could automatically calculate the nutritional information for their products based on the data that had been collected. Others invested in new data management systems to help them track the various inputs required for the calculations. However, the collection and sharing of these data can be a complex and costly process, particularly for small and medium-sized enterprises. In some cases, firms may rely on proxy data, such as using nutrient values from similar products, in order to reduce costs.

The process of collecting and sharing carbon intensity data for products is analogous to the development of nutritional information labels. Just as nutritional information labels provide consumers with information on the nutritional content of food, carbon intensity labels would provide information on the environmental impact of products. However, the challenges of collecting and sharing data on carbon intensities are more complex, given the wide range of factors that can influence a product's carbon footprint, as well as the need to collect data across longer and more complex supply chain (often straddling national borders).

Source: Food Label Solutions (2022[64])

Carbon intensity metrics could support governments wishing to promote carbon intensity labelling. To minimise burdens on firms, governments could undertake coordinated efforts with their main trading partners to develop a common labelling system. This could mirror the approach for nutritional information in food products (see Box 2.7). Labels would need to be simple and streamlined whilst eye-catching to be effective. Environmental Product Declarations (EPDs) are a good example of this approach (see Box 2.8). Existing schemes, such as energy efficiency labelling programmes, do not seek to label all goods; hence there are questions around what products a carbon intensity labelling scheme might cover. Homogeneous products produced in upstream sectors (e.g. steel, cement, aluminium, some chemical feedstock, glass…) might be a good and feasible starting point. Future work through the IFCMA could explore this and other aspects to labelling.

Box 2.8. Policies in practice – Environmental Product Declarations (EPDs)

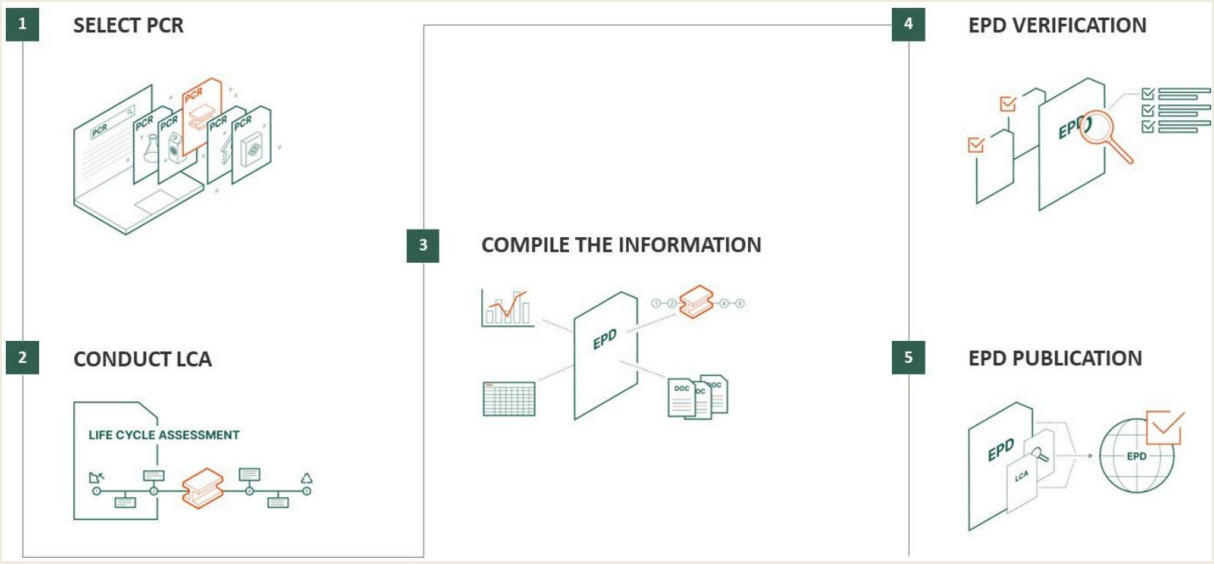
Environmental Product Declarations (EPDs) are certified reports of the environmental data of a product over its lifecycle. They are constructed in accordance with the ISO 14025 standard (Environmental labels and declarations — Type III environmental declarations — Principles and procedures) and contain the following elements:

- **Programme-related information**: Information on registration of a product, product category rules, and the validity of the EPD.
- **Product-specific information**: Specific information such as functional properties and a content declaration of a certain product.
- **Environmental and performance-related information**: A life cycle assessment (LCA), providing information on use of resources and energy as well as various types of emissions.
- **Additional environmental information**: Environmental information additional to the LCA, such as specific information about the user- and the end-of-life phases.
- **Mandatory statements**: Information about the undertaken verification procedure.

Figure 2.1 outlines the key steps to develop an EPD. This begins with categorising the product and matching it with the applicable ruleset, known as the product category rules (PCRs), to conduct a lifecycle assessment (LCA) (see Section 4 for further details on PCRs and LCAs). The results from the

LCA and other information required by the PCRs are then compiled into the EPD reporting format. The EPD is then verified by an approved independent party and published.

Figure 2.1. The main steps involved in environmental product declarations

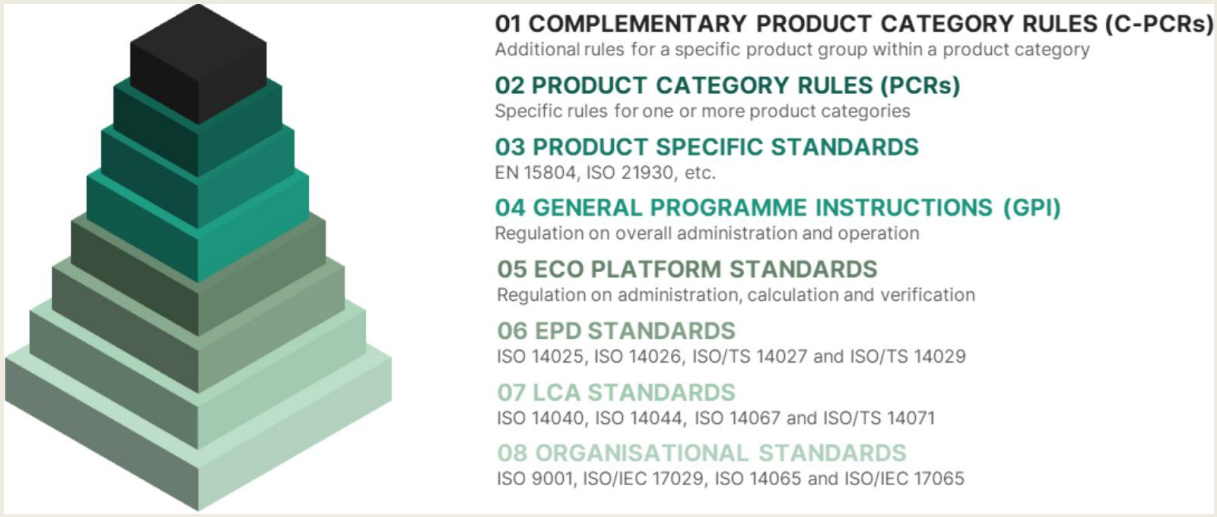


Note: PCR stands for Product Category Rule; LCA for Life Cycle Assessment, EPD for Environmental Product Declaration.
Source: General Programme Instructions for the International EPD System Version 5.0.0 (The International EPD System, 2024[65])

The International EPD System

The International EPD System is a private-sector led international programme to develop and register EPDs. Its main objective is to support organisations in communicating rigorous and transparent product-level environmental information. The scope of the programme includes any type of product from any organisation in any country wishing to communicate the life cycle-based environmental information of one of its product. Figure 2.2 outlines the key documents governing the operations of the International EPD System.

Figure 2.2. Essential documents for the governance and operation of the International EPD System



Source: General Programme Instructions for the International EPD System Version 5.0.0 (The International EPD System, 2024[65])

Source: (The International EPD System, 2024[65]; The International EPD Sustem, 2017[66]; Watkins et al., 2019[67])

Over time governments and firms could consider the use-case of a centralised repository or database that would allow consumers and producers to easily look up the carbon intensity of a given product (see Section 4 for further discussion on information sharing and peer-to-peer exchanges). Such a repository or database could operate in a similar way to the French Agribalyse database which documents the attributes of over 2 500 food products (ADEME - Agency for Ecological Transition (France), 2023[68]). This central repository or database could also contain benchmark values produced by a regulator and be used to conduct benchmarking exercises in a streamlined way.

Firms: Supporting decarbonisation efforts and better communication with investors and consumers

Environment, Sustainability and Governance (ESG) scores, transition plans and other climate related disclosures have grown in importance over recent years. Since its inception, the ESG movement has sought to promote greater transparency from firms (World Bank Group, 2004[69]). The aim is to reward firms for taking more environmentally conscious business decisions by allowing investors to price firms' transition risks (i.e. raising the relative cost of capital of highly polluting firms relative to that of less polluting ones) and customers to orient purchases towards products produced by "green" firms. Firms have also started to disclose climate-related financial information in their financial filings, including financial statements, but progress has been uneven. Yet, firms' disclosure of Scope 1, 2 and 3 emissions remains limited and mostly concentrated in the energy, and material and building sectors (Task Force on Climate-related Financial Disclosure, 2023[70]). The review of about 1 300 public companies' financial filings, annual reports, integrated reports and sustainability reports conducted by the Task Force on Climate-related Financial Disclosure (2023[70]) indicates that only asset managers report carbon intensity metrics (which relate to their asset portfolios). Section 4 discusses recent progress and challenges in the disclosure of carbon intensity metrics in more detail.

Much of the disclosure to date has been incomplete or inadequate. Evidence suggests that the environmental pillar of ESG scores are not informative on firms' actual environmental performance and different ESG scores correlate poorly (D'Arcangelo et al., 2023[8]; Boffo, Marshall and R., 2020[9]). One reason might be that the environmental pillar of ESG metrics include a significant share of subjective components and aim at gauging with a single indicator different aspects of firms' environmental performance (e.g. carbon footprints, resource management, waste, impacts on biodiversity, and others). Furthermore, a plethora of providers of climate performance assessment methodologies produce different and sometimes uncorrelated ESG metrics. The absence of standardisation or an objective metric creates significant risk of greenwashing in the ESG investment market (Noels and Jachnik, 2022[1]).

Carbon intensity metrics can support firms' efforts to track and improve their environmental performance. Carbon intensity metrics based on objective data and shared methodologies could contribute to reducing the scope of subjective assessments within ESG scores and transition plans, thus enhancing their credibility and comparability. Government frameworks, like those proposed under Australia's Guarantee of Origin Scheme, could support and increase trust in firm-level efforts to improve environmental performance (Department of Climate Change, Energy, the Environment and Water (Australia), 2024[71]). More generally, carbon intensity metrics can also play a role in informing the development and use of taxonomies.

Several finance institutions have adopted sustainability targets and are increasingly scrutinising any investments they make or loans they provide to avoid falling foul of their sustainability targets. Carbon intensity metrics can help borrowers and investees to provide lenders and investors with credible information on their mission performance and plans to improve it. For instance, steel companies operating blast furnaces could use product or installation-level carbon intensity metrics to support their case for further finance by highlighting how it will support their transition to a net-zero pathway consistent with national policies and targets. Carbon intensity metrics and emission disclosures could also reduce the risk of green washing in the green bond market (Schmittmann and Gao, 2022[72]; International Capital Market Association (ICMA), 2015[73]).

3 Sector-level carbon data sources and intensity metrics

Key Messages

- Sector-level carbon intensity metrics are important for analysing countries' progress towards decarbonisation and climate change mitigation targets.
- Large variations in approaches to measuring and reporting sector-level carbon intensity metrics remain, even within narrowly defined sectors. Further coordination across government, industry body and other efforts, combining the array of existing international databases and standards for measuring emissions, would benefit the development of harmonised, tailored approaches and minimise the proliferation of additional methodologies.
- Sector-level metrics remain essential, but installation- and/or product-level metrics can provide more disaggregated data and valuable information on the distribution of carbon intensities within a sector to inform policy design.
- There is scope to better link sector- and product-level carbon intensity metrics to achieve greater consistency and accuracy while minimising data collection efforts. Installation-level data, as well as data collected using novel technologies (such as satellites) hold the promise to bridge the gap between sector- and product-level metrics, which are ultimately needed to further improve data on carbon intensities.

Sector-level carbon intensity metrics are better established than product-level metrics due to the availability of national emissions and output data at the sector-level. For this reason, they are easier to compute than product-level metrics and can provide useful fall-back values where product-level metrics are not yet developed, are too burdensome (in particular, for small economies and firms), or primary data for computing them are missing. In addition, they remain a key tool for higher level analysis to track and identify drivers of countries' progress in decarbonising. Sectors, in this context, are the categories of emissions sources, for which existing international standard practices are already established (e.g. from IPCC Guidelines for UNFCCC Inventories reporting and from international classifications used in the National Accounts for economic statistics). Sector-level metrics, however, are provided at high levels of aggregation[4] and are often based on indirect measurement of the emissions per sector (i.e., not directly measured at the installation, but calculated from the inputs used). Where data are available, there is scope for product-level metrics to improve sector-level estimates by providing information on the distribution of

[4] For example, the OECD's harmonised input-output database contains 45 sectors that are assigned emissions, from which carbon intensities can be calculated. GTAP's similar input-output database contains 65 sectors.

carbon intensities within a sector that go beyond a simple average value. As such, this approach can support better policy making.

Current approaches to calculating sector-level carbon intensity face challenges with achieving timeliness, sufficient granularity, and harmonisation within and across countries. This section first presents the methodological approaches for computing sector-level metrics currently available. It then provides an overview of the main data sources and guidelines for computing carbon emissions using nationally reported emissions and economic activity data. Next, the section explores carbon intensity metrics used by governments for public policy analysis and by industry bodies for tracking decarbonisation progress. The section concludes by noting some limitations of traditional data sources and approaches and emphasises the need for developing product-level metrics as a tool to improve and complement sector-level metrics.

Defining sector-level carbon intensity metrics: the choice of a denominator

Computing sector-level carbon intensities requires information on both GHG emissions (the numerator) and output (the denominator). An objective aim is to maximise the reliability and granularity of data for the numerator, which are the GHG emissions. The emissions are expressed in CO_2e (carbon dioxide equivalent) to adjust for the different global warming potential (GWP) of non-CO_2 gases, i.e. methane, nitrous oxide, hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) (Deconinck and Toyama, 2022[74]). For some products, CO_2 dominates the interest of monitoring systems. But, for some sectors, such as agriculture and waste management, non-CO_2 effects dominate, and tracking these are a priority (Harmsen et al., 2023[75]; Teusch and Ribansky, 2021[76]). The scope for these emissions is then matched for the dominator, using measurement of the associated economic output. Additional considerations regarding definitions of the numerator are discussed in Section 4.

Output data for the denominator are derived from well-established common frameworks for countries' national accounts. However, there are still some differences among carbon intensity approaches. This section outlines a few basic considerations with respect to the denominator, in terms of scope, units and evaluation of changes over time. It also explores how choices between different options for normalising and evaluating carbon intensity metrics will depend on their use in analyses.

The first consideration is the units or scope of metric used in the denominator. For cases where the metrics involve a non-homogenous set of products (e.g. for sector-level analysis), the economic value of production (instead of the physical quantities) may be the only feasible option for creating a common denominator as a proxy for output. Sector-level carbon intensity metrics are usually measured in relation to GDP, or the value added in production per economic category. Value added is a measure of economic output net of intermediate consumption, and thus technically could increase or decrease overtime without changes in production volume. Another possibility is to use gross output per sector (i.e. to the total output of produced goods and services available to consumers). Gross output can also be useful to conduct a neutral assessment of technical changes in production (i.e. increased technical efficiency) (OECD, 2001[77]).

Output is reported by companies to national accounts authorities (e.g. national statistics offices and/or central banks) using standard international classifications. Output data are compiled, for example in standard System of National Accounts Supply Tables, by product, using the International Standard Industrial Classification for All Economic Activities (ISIC), the Central Product Classification (CPC), and measurement standards outlined in the System of National Accounts (SNA). Output is compiled for national accounts in value terms, e.g. using basic prices (rather than in physical quantities). Standardised reporting used in SNA Supply Tables can be used for the denominator of sector-level carbon intensity metrics.

A second consideration, relevant for interpretation of carbon intensity metrics in time series, are price changes and the valuation of the denominator (i.e. GDP and gross output in real terms). In principle, value added and gross output can be converted from nominal values (which incorporate price changes) to volume metrics (also known as real terms) using price deflators. However, this implies additional information requirements, such as price indices and the need to account for potential underlying changes to the qualities of products. The conversion to real values is slightly simpler when using gross output as opposed to value added or GDP (because for value added there is a need to develop deflators both for output and for intermediate consumption). If the output is measured in nominal terms, the trends for the intensity metrics over time could be misleading as they will conflate changes to prices (e.g. inflation) with changes to physical quantities. Reporting entities could also report emissions associated with output expressed in terms of physical quantities (e.g. tonnes of steel). However, such reporting depends on a high level of homogeneity of outputs and thus is feasible only for analyses using granular data on homogeneous products.

The availability of data with the right coverage and level of aggregation can be a factor when selecting the scope, units and valuation for the denominator used in carbon intensity metrics. Thus, guidance and documentations for carbon intensity metrics should clarify the aspects of denominator (i.e. output) suggested or used, in addition to providing information on the numerator (i.e. emissions). The basic requirement is that the denominator (output measurement) matches the scope and coverage of the numerator (emissions).

Decisions regarding the scope of carbon intensity metrics are relevant to be able to distinguish the drivers of change to efficiency improvements over time. The gap between emissions and economic growth can be driven by different factors. These include the shift toward lower emissions processes, the switch to zero or low-carbon fuel sources, the relocation of production abroad, or changes to the structure of the economy (e.g. transition towards a greater share of services). Tracking these drivers is key to explaining differences between the evolution of carbon intensity and of absolute emissions, and to designing policies to reach absolute emission reduction targets.

Carbon intensity metrics can also be expressed in relation to final consumption (instead of production) where the national emissions are measured relative to consumption (i.e., taking consideration of emissions embodied in trade). Again, a careful consideration of valuation is needed in such cases, such as using basic prices that exclude transport costs and taxes. In principle, consumption-based intensity metrics can be developed by making use of multi-country input-output matrices (discussed further below).

For cases where more granular carbon emissions data are available for product-level intensity metrics, product-specific units will usually apply in the denominators. For example, carbon intensities for steel (as discussed in Section 4) have multiple potential and complementary measurement approaches, in relation to qualities as well as quantities of output in kilogrammes. Different measurement approaches are suited to different uses of carbon intensity metrics, and ideally, carbon intensities (in multiple units, as relevant) are made accessible so that users can select the unit or scope of intensity measurement that is most relevant for their use case. In principle, producing multiple metrics (or units) for assessing carbon intensity by product- or sector-level is feasible, especially where the numerator (i.e., product or industry-specific emissions data) is already available.

Calculating sector-level intensities with emissions and economic data

Sector-level metrics require the estimation of GHG emissions. These fall into two categories:

- those measured directly, more commonly at the installation-level, usually for specific purposes such as applying emission trading scheme or reporting by industry bodies; and
- those estimated indirectly, usually by governments at the supranational and national level, to track progress in achieving emissions reductions targets.

This section first explores the main data sources and methods for estimating emissions (the numerator), followed by the linking to economic data (the denominator).

Approaches to measuring sector-level emissions

The direct approach is based on verified emissions data collected from emitting installations. This involves monitoring technologies that measure and record the flow rate of gas at the stack or in flues, or the concentration of particulate matter being released from industrial processes at the source. For example, the direct measurement approach is undertaken for a set of activities by the United States Environmental Protection Agency under its Greenhouse Gas Reporting Program (GHGRP), whereby emissions are measured by installations. However, challenges remain in ensuring the consistency of data collection across sectors and countries due to potential differences in methodologies, resource capacity of reporting agencies and technical expertise in measuring, verifying, and reporting emissions.

The indirect approach to measure emissions relies on input data on fuel use and associated emissions factors, along with non-energy use related emissions factors (i.e. inputs to industrial processes). Emissions factors are defined here as the emissions released per unit of input, such as fuel type (which could be measured as CO_2/kg coal). Energy use is multiplied by its associated emissions factor and total emissions from installations are then aggregated to the sector-level. The IEA, for example, adopts the indirect approach whereby it calculates emissions intensity for a variety of sectors, combining the IEA's World Energy Balances (IEA, 2023[78]) with the IPCC's default emissions factors corresponding to the different energy carriers (IPCC, 2006[79]), such as for electricity generation (see Box 3.1).

Box 3.1. IEA methodology for calculating emissions intensity of electricity and heat generation

The methodology for computing IEA emissions intensities for electricity and heat generation (CO_2 per kWh) uses the IEA World Energy Balances for total emissions by energy source in each sector and country (IEA, 2023[78]) and 2006 IPCC Guidelines default values for emission factors (IPCC, 2006[79]). There are some adjustment factors such as for traded and lost energy (i.e., emissions that are transferred to another process or lost due to inefficiencies). In addition, for fuels that are combusted directly in production processes (rather than used for electricity generation), the IEA uses direct combustion factors, which contain specific product, sector, and country coefficients for emissions by input into a process. The IEA use Net Calorific Values for determining these factors (i.e., the physical amount of emissions contained in a fuel source).

Carbon intensity (in CO_2/kWh) for electricity and heat generation =

$$\frac{\sum_{fuels} \langle (Input_{\ Electricity\ plants} + Input_{CHP\ plants} + Input_{Heat\ plants} + Own\ use_{Plants}) \times EF_{fuel} \rangle}{Ele_{Inland} + Heat_{Inland}}$$

Where:

- $\sum fuels$: Sum over the fuels.
- $Input_{plants}$: Fuel input into the plants expressed in energy unit.
- EF_{fuel}: Default emission factors as provided in the 2006 IPCC Guidelines.
- Ele_{Inland} + $Heat_{Inland}$: For the total emissions factor: includes the generation from all sources (i.e. as well the non-emitting sources). For the emissions factors by fuel (oil, coal, gas, non-renewable waste, and Memo: biofuels): includes only the electricity and heat generated by the corresponding fuel.

Source: IEA (2022[80]).

Overall, indirect approaches based on energy and non-energy use related emissions by sector impose fewer data requirements and lower costs than directly measuring and verifying emissions at the installation-level. The indirect approach allows flexibility and lower costs for emissions estimates, particularly for smaller economies where the requirements for direct reporting may be too difficult. However, these estimates remain based on a level of aggregation that does not reflect the specific challenges within the different sectors and subsectors in improving production efficiency or switching to less carbon-intensive fuels. As a result, identifying tailored policies within and across sectors is difficult with current sector-level metrics as they can lump together subsectors that have different production process and barriers to decarbonisation. In addition, such sector-level metrics can differ based on methodological decisions made in the estimation process (e.g. what data sources and default values to use) and the frequency in which they are updated.

For both approaches, the accuracy of the carbon intensity metrics ultimately depends on the quality of data provided by the submitting entity and robust measuring, reporting and verification systems. Inconsistencies in data quality and its treatment may undermine comparability of carbon intensity metrics across sectors and countries. Collecting emissions data at the installation-level is a way to overcome some of these problems, which is discussed further in the next section.

Main data sources for reporting of emissions

Sector-level metrics are most commonly calculated using emissions data from either government inventories or global estimates for fuel and industry process input use, with default emissions factors. The primary sources of data for emissions intensity calculations include the IEA World Energy Balances (IEA, 2023[81]) and the UNFCCC National Inventory Submissions 2022 (UNFCCC, 2022[82]). As mentioned, the first provides estimates for energy use globally and is used together with emissions factors for an indirect calculation of emissions. The second provide estimates of emissions by sector and country and are compiled using the 2006 IPCC Guidelines, which allow countries to choose from both direct and indirect measurement approaches (IPCC, 2006[79]). In addition, IPCC default values can be used to calculate process emissions where emissions are not from fuel use. Although there are a range of emissions databases available serving different purposes (see Table 3.1), the base data used are often derived or calculated from these two primary data sources at the sector-level.

Table 3.1. Selected multi-country data sources for computing sector-level carbon intensity metrics

Metric	Publisher	Units/Type	Updated	Coverage
World Energy Balances	IEA	ktoe	Annually (for global coverage)	98 flows, 69 products
The Greenhouse Gas Emissions from Energy database (upgrade of the former CO2 Emissions from Fuel Combustion)	IEA	g CO_2e/kwh	Annually (for global coverage)	32 flows
Emissions by fuel source	IEA	g CO_2e/kwh	Annually	5 fuels
Emissions factors (EFDB)	IPCC	Varied but generally emissions/input unit	Monthly	27, 263 categories
IPCC National Inventory Submissions	IPCC	CO_2e and CO_2/GDP	Annually	Varied sectors
GHG energy intensity	EEA	g CO_2e/kwh	Annually	1 sector
Air and GHG emissions	OECD	CO_2e	Annually	11 sectors
Air Emission Accounts [5]	OECD	CO_2e	Annually	By ISIC (economic activity category); level of detail varies by country
Carbon dioxide emissions embodied in international trade	OECD	CO_2 and CO_2/EUR	Every three years	36 sectors
Country Greenhouse Gas Emissions Data	CAIT	CO_2e	N/A, three-year lag	11 sectors
Global Carbon Project	GCP	CO_2	Annually, monthly, hourly	6 sectors
PIK PRIMAP	PIK	CO_2	Varied, yearly time series	17 sectors
EDGAR	JRC	CO_2e	Annually, monthly, hourly	8 sectors

The national inventories reported to the UNFCCC commonly use sector-level estimates for energy use and default emissions factors. The IPCC Guidelines (IPCC, 2006[79]) allow countries to use a tiered approach for estimating emissions, following harmonised standards (see Box 3.2). The minimum standard, or the so-called Tier 1 approach, primarily requires the use of internationally available data such as the IEA's World Energy Balances (IEA, 2023[81]). It applies emissions factors that are provided by the IPCC; no direct measurement of emissions is required. Higher tier methods, such as Tier 3, require the use of more sophisticated and direct measurement approaches to calculating emissions, such as those collected at the installation-level. Countries are expected to make every effort to use the recommended tier level for key categories in accordance with the IPCC Guidelines.[6] Depending on countries' reporting capacities, they can use different tiers of emissions' estimation methods, which in turn, influences the accuracy and granularity of emissions data available to computing carbon intensity metrics. Many countries face substantial human, financial and institutional capacity constraints and some face challenges in providing national inventories within specified time frames or at detailed levels of accuracy and consistency. In addition, countries that have not ratified the Paris Agreement may employ different methods from the IPCC Guidelines.

[5] The OECD's Air Emission Accounts are categorised by economic activities (ISIC), in contrast to the Air and GHG Emissions dataset which is categorised by emissions sources of the UNFCCC and IEA.

[6] Key categories are those that are prioritised in the national inventory system because they have significant influence on a country's greenhouse gas inventory in terms of the absolute level, trend or uncertainty in emissions and removals (IPCC, 2006[79]).

Box 3.2. An overview of the 2006 IPCC Guidelines

Guidelines

The 2006 IPCC Guidelines (IPCC, 2006[79]) are intended to be used by all parties to the UNFCCC. They provide guiding principles for measuring GHG emissions, provide default data and methods, and allow a tiered approach for more sophisticated emissions estimation depending on countries' capacities. The 2019 Refinement of the 2006 Guidelines provides additional information to be used in conjunction with the 2006 Guidelines (Calvo Buendia et al., 2019[83]). This covers supplementary information on sources and sinks of emissions, new technologies and production processes that have emerged recently or were previously not well-covered (such as the production of hydrogen, rare earth metals, and alumina), and updated emissions factors and other parameters based on more recently available scientific information. Within the tiered approach, the most basic method takes activity data and multiplies it by an emissions factor.

Principles

The IPCC's pragmatic approach allows for cross-country and cross-sector differences in data availability and quality. The guidelines aid in the identification of key sectors; defining minimum standards for data; providing flexibility for inclusion of better data; establishing guidelines for industries that require a greater detail where more complex data and calculations are needed to yield accurate results.

A tiered approach

These guidelines allow for a 'tiered' approach based on an increasing level of accuracy and granularity. There are three tiers:

1. Simple first order approach: default values corresponding to large spatial regions of the world and based on globally available data are used, allowing the calculations to be done by any country;
2. A more accurate approach: similar calculation method to Tier 1 but using country and region-specific data;
3. Higher order methods: involving the use of countries' own detailed modelling, inventory measurements systems and data at a greater level of granularity.

Source: (IPCC, 2006[79]; Calvo Buendia et al., 2019[83])

The effectiveness of capacity-building efforts for developing countries has been uneven thus far. In particular, many small island states in the Pacific and the Caribbean and several African countries are still dependent on international support for producing data for reporting (Umemiya and White, 2023[84]). There is scope to continue developing tools and guidance targeting developing countries' needs to ease their resource burdens and institutional challenges in establishing effective emission measurement, reporting and verification systems for emissions data. Under the Paris Agreement's Enhanced Transparency Framework, countries will be expected to submit their first Biennial Transparency Report and National Inventory Report, containing emissions inventories, by December 2024 (and bi-annually thereafter) (UNFCCC, 2024[85]). With appropriate capacity-building, this can make progress towards more complete and regular reporting of national emissions inventories by developing countries than under previous national and international efforts (see Box 3.3).

For sector-level carbon intensity metrics, complementing sector-level data with other types of data sources can address resource constraints on compiling data from SMEs. For example, using top-down or bottom-up data compilation methods can achieve a more comprehensive sector-level coverage of emissions. In addition, the analyses of sector-level data can take into account potential differences of

SMEs (e.g. in use of technologies) compared to the rest of the sector (i.e. larger firms), improving its overall accuracy.

Box 3.3. Challenges for developing countries and small firms

Calculating carbon intensity metrics can face a trade-off between accuracy, timeliness, or granularity and resource requirements in collecting, verifying and publishing emissions and economic data. Smaller institutions - whether installations or firms that provide data, or government institutions that compile the data - will have fewer resources for gathering and interpreting data. Establishing formal emissions measurement, reporting and verification mechanisms and technical solutions to compile data from multiple national and international bodies remains a key barrier for many countries (Umemiya and White, 2023[84]). Other challenges include a lack of broader scientific and statistical capacity to operationalise complex data collection and verification systems (Umemiya, 2023[86]). Promoting the widespread understanding and adoption of such systems can be more difficult in particular for countries with many small, resource-constrained firms. The IPCC Guidelines and other complementary standards for emissions inventories are designed with flexible and tiered accounting methods that can be implemented at varying levels of granularity across countries, without sacrificing comparability when aggregated to the same level.

Existing tools for developing countries

There are existing tools and support systems for developing countries to help build their statistical systems and improve the accuracy, granularity, frequency and timeliness of the data underlying carbon intensity metrics. This includes, for example, support from UNFCCC (UNFCCC, 2024[87]), as well as a toolkit from the International Institute for the Environment and Development (Hanle and Alcobe, 2023[88]), especially designed to support countries with meeting the commitments under the Paris Agreement. The United Nations Statistics Division and the OECD have also jointly developed standardised tools and training for compiling emissions according to the International Standard Industrial Classification of All Economic Activities (ISIC) via the Air Emission Accounts from all countries (UNSD, 2024[89]). The Partnership in Statistics for Development in the 21st Century (PARIS21, 2024[90]), - a collaboration between the United Nations, European Commission, OECD, International Monetary Fund and World Bank - provides training and other forms of capacity building for government institutions to make data accessible for policy-making (PARIS21, 2022[91]). There are also initiatives aimed at particular groups of countries, such as the Caribbean Cooperative MRV Hub by the International Climate Initiative, targeting support for small island developing states (MRV HUB, 2022[92]). Such tools to improve national data collection systems, by developing the institutions' capacities to produce detailed and timely figures, can help address some of the disadvantages countries with limited resources face.

Source: Authors.

Linking carbon emissions to economic data

National emissions inventories can be combined with economic data (e.g. GDP) imports and exports, and gross value added (GVA) data, to compute carbon intensity metrics. Linking emissions data with economic data allows for policy analysis of emissions embodied in trade and deriving carbon intensity metrics from a demand perspective. This can be done using input-output (IO) modelling (see Box 3.4) or computable general equilibrium modelling (Bellora and Fontagné, 2023[93]; Timmer et al.,

2015[94])[7]. Linking emissions data with economic data requires creating a concordance between the different sector classifications used in emissions and economic data. For national accounts indicators, such as GDP, this means linking emissions data with the standard classification for economic activities, internationally known as ISIC (International Standard Industrial Classification of All Economic Activities). Air emission accounts (AEAs), under the UN System of Environmental-Economic Accounts (SEEA), an international standard, are used to align emissions data with sector-level economic data used in IO analysis. As such, these links can be seen as an intermediate product between the national inventories and carbon intensity analyses.

IO analysis' strength is the simplicity by which it can account for emissions in international trade without requiring firms to share information along international supply chains. The analytical method, based on approaches such as that of the IEA, which combines fuel and input use data with emissions factors, uses countries' existing national inventories and accounts. The method takes a consistent calculation approach across sectors, suitable for high-level comparisons within and across economies. Relative to more disaggregated methods, it is a faster and lower-cost approach to computing broad carbon intensity metrics, accounting for emissions embodied in trade.

Challenges around data aggregation and timeliness limit the contribution of sector-level metrics derived from IO analysis. IO analysis may, therefore, be insufficient to identify the key drivers of change in sector-level carbon intensities. For example, the OECD Inter-Country Input-Output (ICIO) database and national input-output tables use 45 sector classification groups (OECD, 2022[95]). Ceramic, glass, stone, and clay products are subsumed under a single sector (non-metallic mineral product manufacturing) despite cement's emissions intensity being more than 20 times that of glass (Hasegawa, Kagawa and Tsukui, 2015[96]). Due to the high data requirements for IO tables, there is also a significant time lag between data collection and publication. The OECD's IO tables are published every two years with the underlying national IO tables sometimes published in five year - or more - time lags. Additionally, work is then needed to map emissions data. This risks that the economic linkages between sectors, particularly those with rapid technological developments, may become outdated. Differences in sectoral definitions and the concordance between national emissions and economic activity data, which cannot be matched one-to-one, can also create methodological discrepancies between countries. Depending on the classification system and level of aggregation of data used, establishing a concordance between emissions and economic activity data can be difficult and result in inaccuracies. In addition, simply using the value of trade flows can be a poor proxy for the underlying emissions as intensities can vary widely. Improvements are on the way, however, as a partnership of three international organisations (Eurostat, IMF, and the OECD) has started publishing aggregated emission accounts on a quarterly basis (with less than one year time lag) (Astolfi, 2022[97]) . Additionally, the granularity for emissions data by source and by economic activity is progressively improving over time, although with varying rates of progress across countries (Florian Flachenecker, 2018[98]).

[7] Global databases for IO tables with GHG emissions extensions include the OECD's $TECO_2$ (Yamano and Guilhoto, 2020[11]), Figaro (Eurostat (European Union), 2023[258]), WIOD 16 (Timmer et al., 2015[94]), Exiobase3 (Merciai and Schmidt, 2018[244]), Eora26 (Lenzen et al., 2013[245]), GTAP Extended (Aguiar et al., 2022[246]), Oxford Economics Global Sustainability Model (Oxford Economics, 2024[247]) and others. Some national governments and consultancy firms also have in-house models for policy evaluation, such as Finland with the ENVIMAT model developed by the Finnish Environmental Institute.

Box 3.4. Input-output analysis using carbon intensity metrics

Input-output (IO) tables depict how much of a sector's output is used as an input into production processes in another sector, consumed domestically or exported. These tables can be extended or linked to other data, such as emissions and other environmental indicators. IO analysis can then be used to estimate the impact of an intervention in a sector by modelling the flow of inputs and outputs across all sectors of the economy that have economic linkages to the initial sector. This technique has been used for policy analysis to model the effects of mitigation policies, for example. Changes in sectoral output and emissions due to the policy intervention are reflected in the sector-level carbon intensities. Examples include both international and national analysis, such as the OECD's CO_2 Emissions Embodied in International Trade and Domestic Final Demand using the Trade in Embodied CO_2 ($TECO_2$) database (Kang, 2021[99]), which is also used by the IMF (IMF, 2022[100]). There are many other examples of such policy analysis in the literature, covering various countries and policy interventions (Su and Ang, 2014[101]; Guo et al., 2012[102]; Skelton et al., 2011[103]; Wiedmann et al., 2007[104]; Tiwaree and Imura, 1994[105]; Romanos, Kerr and Will, 2014[106]; Chandrakumar et al., 2020[107]).

The OECD's $TECO_2$ database presents a set of indicators to reveal patterns of CO_2 consumption compared to CO_2 production (via resident industry or household emissions). The aim is to provide policy makers with new insights into the environmental impacts of global production systems. The comparison of consumption- and production-based carbon intensity metrics, done by measuring countries' emissions embodied in their imports and exports, also sheds insight on patterns of carbon leakage through international trade. Typical indicators presented in $TECO_2$ database include:

- CO_2 emissions based on production (i.e., emitted by countries)
- CO_2 emissions embodied in domestic final demand (i.e., consumed by countries)
- Net exports of CO_2 emissions
- Per capita emissions (production- and demand-based)

Source: Authors.

How installation-level data can enhance sector-level carbon metrics

Installation-level data and metrics sit at the intersection of sector- and product-level metrics. Installation-level data can be aggregated to deliver more detailed and timelier sector-level carbon intensity metrics or disaggregated to the product level (see Section 4). This bottom-up approach can produce alternative and complementary estimates to sector-level GHG emissions estimated by national governments (using data sources such as the IEA World Energy Balances), while remaining consistent with the IPCC Guidelines. This section explores how installation-level emissions data requirements from governments and voluntary reporting from industry bodies can provide additional granularity and detail to sector-level metrics.

There are two main approaches to gathering installation-level emissions data. Either public authorities can collect data from firms (i.e., installations' owners) for regulatory purposes or industry bodies can collect data from their members, e.g. for benchmarking. In addition, there are some private-sector entities that also collect data through various means. Collecting and reporting installation-level data can be highly resource- and cost-intensive, which justifies the adoption of different tiers of data collection for entities (countries, firms) of differing capacities. In an initial phase, resource-constrained installations may choose to adopt a lower-tier methods based on default values (referring to the IPCC Guidelines) until they

gradually build the resources and capacities to monitor, report and verify installation-level data at a higher level of accuracy and granularity.

How installation-level emissions are measured

Recording emissions at the installation-level must take into account several inputs and intermediate inputs used simultaneously to produce different outputs at the same plant. A single installation can include a range of processes and outputs. For instance, an installation is defined by the European Union (EU) Emissions Trading Scheme (ETS) Directive as a "stationary technical unit where one or more activities under the scope of the EU ETS and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution" (The European Parliament; The Council of the European Union, 2013[108]). The various activities associated with a single installation can differ in terms of the complexity and resources required for different emissions measurement methodologies. Allocating emissions and carbon intensity data to different products or activities can therefore be challenging when using installation-level data.

There are three main measurement methodologies for reporting on emissions at the installation level. From the most direct to the more indirect methods, they are:

- **Direct measurement**: Continuous Emissions Monitoring Systems (CEMS) are tools to measure and record the flow rate of effluent gas at the stack or in flues, or the concentration of particulate matter being released from industrial processes at the source. This is the most accurate method as it directly and continuously monitors the concentration of GHGs emitted by installations, including both fuel combustion and process emissions. However, this method requires specific monitoring technologies and systems that can be more costly than other methods.
- **Net calorific value (NCV):** This method involves assessing the carbon content per atom or product of fuel input used in a production process. To measure total emissions, emission factors are applied to the respective NCV of inputs, according to the actual amount of input used by the installation. Hence, it is used to measure emissions from fuel combustion, while other methods are needed to account for electricity and process emissions. This method requires detailed data on inputs and efficiencies of the system (i.e. heat loss).
- **Other methods**: Predictive Emissions Monitoring Systems (PEMS) are a tool to estimate or predict emissions from industrial processes where direct measurement of emissions are infeasible. This method relies on real-time process parameters (such as temperature, pressure, flow rates and chemical concentrations) and mathematical models to measure emissions indirectly. In some cases, PEMS is the default method, whereas in other cases, it is used as a fallback method when the first two methods cannot be applied due to, for example, technical challenges or cost constraints. For example, Chile's carbon tax and the US EPA allow for the use of PEMS in cases they are equivalent to CEMS.

It is usually more straightforward to monitor the total emissions of an installation than of individual products. This is because many installations produce more than one product and usually have one metering device for each fuel or process which is used in the whole installation (see Section 4, also for considerations regarding data sharing). It is uncommon to have various sub-meters that allow for the measurement of fuel quantity per individual production processes. There are also some sectors and products where specific methodologies must be used for accurate measuring (as discussed below). These can create additional measurement challenges to installations, in terms of cost and other resource burdens.

Government systems for collecting installation-level data

A range of environmental reporting can provide complementary emissions data and improve sector-level carbon intensity metrics. In many cases, these environmental reporting requirements are mandated by governments collecting installation-level emissions data. For example, the United States Environmental Protection Agency (EPA (United States), 2023[109]) requires reporting of on-site fuel use and process emissions, as well as production data for some specific sectors. In the case of cement production installations, where both types of reporting are required, the data are used to calculate the distribution of carbon intensities for the sector (EPA (United States), 2019[110]). This reporting is restricted to only the direct measurement approach, CEMS, under which the flow of emissions and carbon content of cement is measured directly at the installation. The EU Emissions Trading System and Carbon Border Adjustment Mechanism, for example, also require emission reporting for a range of EITE sectors, in accordance with rigorous monitoring and reporting, and accreditation and verification regulations.[8] The emissions data at the sector-level can be used to inform national inventory reporting but can also be used directly for sector analysis. For example, Mura (2021[111]) provides a dataset that reports emissions per unit of GDP in detailed EU regions, using only installation-level data and GDP statistics. These sector-level carbon intensities are used as a proxy for industrial decarbonisation pathways.

Governments can mandate a common framework for measuring and reporting emissions intensities from installations. This can be an advantage compared with industry body and other private sector initiatives that report emissions intensities for their membership and do not necessarily have full industry coverage or a common framework. Government-led frameworks allow for more consistent coverage and reporting from installations. While the direct reporting of installations to governments is distinct from how government construct their national inventory submissions, many governments that use the IPCC's Tier 3 approach draw on direct emissions data at the installation-level in their national inventory submissions that improve estimates (EPA (United States), 2022[112]).

Even among government-mandated reporting programmes, monitoring and verification can vary (see Table 3.2). Moreover, not all countries have such systems in place, although coverage is increasing. For instance, regarding ETS, at the start of 2023, there were 28 operational systems across the world, in jurisdictions representing 55% of global GDP (ICAP, 2023[113]). However, within jurisdictions that have ETSs, often only large (and/or high emitting) installations are included, and emissions coverage of particular sectors and the economy as a whole is partial. In 2021, ETSs covered just 16% of CO2 emissions in the industry sector (OECD, 2023[114]). Aggregating installation-level data for sector-level carbon intensity metrics therefore may result in an incomplete and skewed picture, especially in countries with a large share of smaller installations. To illustrate, Figure 3.1 shows the large dispersion across the share of emissions covered by countries' national ETSs.

Summing-up, using carbon intensity metrics as benchmarks within industries to incentivise decarbonisation in the context of policies such as ETSs requires timely and accurate installation-level data. In many sectors and countries, this type of data is still lacking. There is scope to improve measurement, reporting and verification systems and improve the overall coverage of emissions, as well as the quality and standardisation of data collection methods.

[8] Sectors covered by the EU Emissions Trading System include power, heavy industry and civil aviation as well as buildings, road and other industry, as of 2023 under EU Emissions Trading System 2 (European Commission (European Union), 2023[257]).

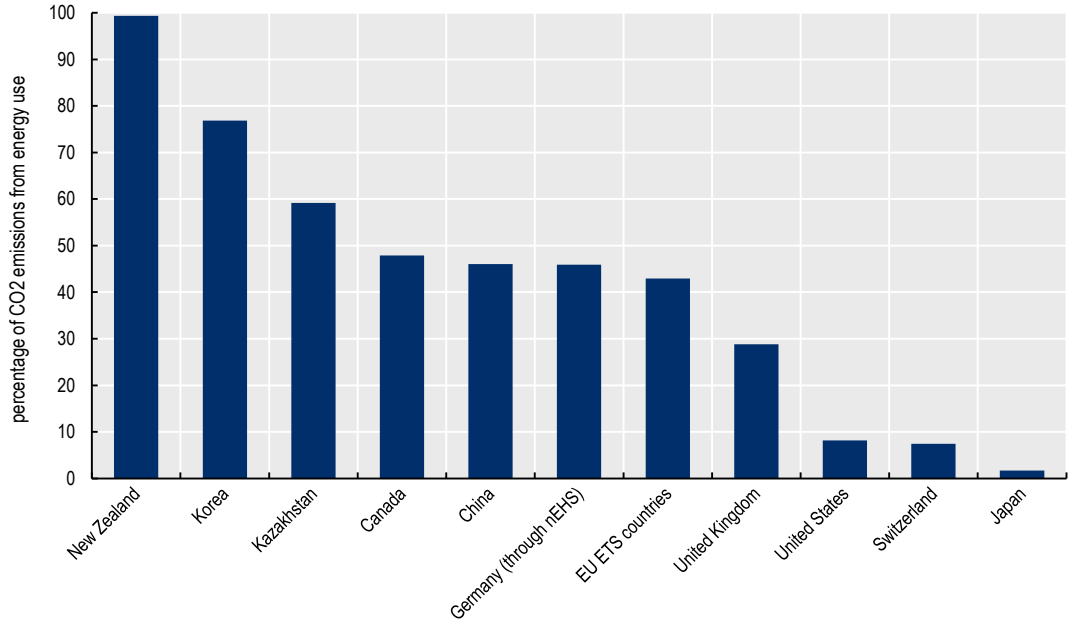
Table 3.2. Selected emission measurement methods across carbon pricing instruments and government-mandated reporting programmes

	Chile green tax	EU ETS	Mexico RENE	US EPA
Application	Obligated entities can choose between methodologies. In general, most obligated entities apply CEMS to CO_2, NO_x, and SO_2. If it is not possible or too costly to install CEMS, alternative methodologies are generally applied.	Obligated entities are free to choose between calculation and direct measurement for CO_2. For N_2O the application of CEMS is required unless it concerns unabated emissions of N_2O from adipic acid, glyoxal and glyoxylic acid production and it is not technically feasible. CEMS is also required for transferred CO_2.	For facilities where it is not technically feasible to apply calculation-based methodologies, CEMS can be used. Only a very limited number of companies have used CEMS.	Rules specify when to use CEMS.* When alternative methodologies are allowed in addition to CEMS, obligated entities must demonstrate that these methodologies have the same precision, reliability, accessibility, and timeliness as a certified CEMS.
PEMS allowed?	Yes	No	No	Yes
Methodology	Measurement of hourly average concentration and hourly average flow rate. Obligated entity is responsible for aggregating hourly averages to emissions per emission point and eventually to total emissions. Specific requirements apply to determining humidity.	Determination based on hourly average concentration and the hourly average flow rate. The obligated entity is responsible for collecting and aggregating to total emissions The tier approach is applicable to CEMS. An uncertainty assessment must be carried out to demonstrate compliance with tier requirements. Specific requirements apply to application of CEMS in the determination of N_2O emissions and transfer of CO_2 emissions.	Hourly average concentration and flow gas rate is determined through CEMS. The obligated entity is responsible for aggregating the data to total emissions. Concentration is multiplied by flow rate and a conversion factor, taking into account moisture correction.	Determination is based on hourly average concentration and hourly average flow rate. Data is reported automatically to regulator for monitoring purposes. Specific requirements apply to determination of emissions and heat input based measured values. Requirements differ depending on the type of emissions measured. Requirements also specify when to take into account the moisture content of the stack.

Note: *If a unit is coal-fired or combusts any type of solid fuel, CEMS is in general applied to all parameters. If a unit is oil or gas fired or if it combusts very low sulphur fuels, alternative methodologies may be applied.
Source: (World Bank and Partnership for Market Readiness, 2020, p. 127[115])

Figure 3.1. Shares of CO_2 emissions from energy use priced by emissions trading schemes

Countries or supranational jurisdictions having an ETS with positive permit prices, 2021



Note: The share presented for Germany separately from the rest of EU ETS countries refers to the share covered by its national ETS. The share presented for EU ETS countries is the total share over all EU ETS countries covered in the ECR database. The EU ETS applies to all EU countries as well as Iceland, Liechtenstein and Norway. The ECR database does not cover Bulgaria, Croatia, Liechtenstein, Malta and Romania. Mexico's pilot ETS is not presented because prices were null in 2021. Canada, China, Japan and the United States each have sub-national ETSs, and the country-level share of emissions covered by these systems (along with the national ETS for China) are presented.
Source: (OECD, 2023[114])

Industry bodies' efforts to report sector-level carbon intensity data

In an effort to harmonise reporting on emissions intensity, some industry bodies generate sector-level carbon intensity metrics from data collected and reported by their members. These metrics are most commonly emissions (including process emissions) and energy use per unit of output. To a large extent, industry bodies make use of and directly contribute to the development of existing international standards for calculating emissions from installations, including the GHG Protocol and ISO standards (see Box 3.5). By requiring their members to implement specific standards, industry bodies support the widespread adoption of common approaches to calculating sector-level metrics. These are informed by sector-specific technical expertise, making it easier for installations to implement the methods. Thus, industry bodies can minimise the proliferation of inconsistent and/or non-fit-for-purpose data collection and reporting efforts and provide an additional sector-level carbon intensity data source. International fora, such as the Climate Club, are working to strengthen emission measurement and reporting mechanisms and can further support the alignment of industry efforts (Climate Club, 2024[116]).

Box 3.5. International emissions accounting and reporting standards

GHG Protocol

The GHG Protocol Corporate Accounting and Reporting Standards, a joint initiative from the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), provide a set of accounting standards and guidelines for entities (e.g. installations, firms, government agencies) to measure and report their emissions. It aims to reduce the burden of compiling emission inventories and improve the consistency and transparency of emissions accounting and reporting practices. The GHG Protocol provides comprehensive and precise standards and guidelines for measuring Scope 1, 2 and 3 emissions from seven GHGs (CO_2, CH_4, HFCs, PFCs, SF_6 and NF_3). Entities that use the GHG Protocol do not report the WRI or WBCSD but use these methods and formats to report to other compatible legal or voluntary emissions reporting bodies.

ISO

The International Organization for Standardization is an independent, non-governmental international organisation composed of representatives from member countries' national standards bodies. ISO develops technical standards across a range of topics such as quality, safety, technology and environmental impact – including emissions accounting and reporting (see key examples in Figure 4.1). The standards provide detailed guidance, taking account of the technical complexity and product-specific considerations to promote the harmonisation of emissions accounting within and across sectors. ISO does not receive data from reporting entities, but its standards are often used by other industry and governmental initiatives. The WTO Technical Barriers to Trade Agreement strongly encourage to base measures on international standards, where available, to avoid regulatory fragmentation and facilitate trade. In this context, ISO standards can play a key role.

Source: (WRI and WBCSD, 2023[117]; International Organization for Standardization, 2024[118])

There are critical differences between the products and production processes of subsectors, which warrant tailored approaches deviating from existing international standards (see Box 3.6). As a result, there remains substantial variation in guidance for calculating carbon intensity metrics by industry bodies (e.g. in direct versus indirect methods, emissions coverage and definitions). Depending on the intended use of the metrics (e.g. for ETSs, installation- rather than product-level data may be sufficient), further harmonisation or an overall improvement in data quality may be needed. There are also data gaps in certain sectors and geographic regions where engagement with industry bodies by installations is lower, meaning sector-level aggregates may not be representative. Further progress is needed to strike the balance between harmonising methods across sectors, while also allowing for variation to account for sector-specific considerations such that installation-level data can be used in aggregation to complement other sources of sector-level carbon intensity data.

The World Steel Association, for example, has developed methodological guidelines for its members to measure and report emissions data. These are based on a combination of existing standards from the ISO, the GHG Protocol and the IPCC Guidelines (World Steel Association, 2023[119]) The World Steel Association's guidelines were later used as the basis to develop the ISO 14404 series – the international standard for calculating CO_2 emission intensity from iron and steel production, which provides specific methods for different types of steel installations and includes definitions for materials and energy flows, as well as emission factors (ISO, 2023[120]). With additional data and computations (see Box 3.6), the World Steel Association reports the carbon intensity of its members, which in 2022, consisted of 62 steel companies covering 24% of global crude steel production (World Steel Association, 2023[119]).

Other industry bodies, such as ResponsibleSteel, rely more on existing recognised standards to report carbon intensity metrics. ResponsibleSteel, a voluntary accreditation organisation, awards certification (known as the ResponsibleSteel International Standard) to members based on achieving a specified level of emissions intensity for steel products (ResponsibleSteel, 2022[121]). Approved standards for measuring emissions intensity include the GHG Protocol, ISO 14404 and the EN 19694 – the European Standard for calculating GHG emissions performance in the steel industry, which also provides specific guidelines for different steel production processes (World Trade Organization, 2023[15]). At the start of 2024, ResponsibleSteel's membership accounted for 15% of global steel production (ResponsibleSteel, 2018[122]).

There are, however, important differences even among guidelines used within the same industry. For example, ResponsibleSteel certification covers all emissions from extraction, preparation, processing and transportation of input material to final crude products leaving the facility, while the World Steel Association excludes emissions associated with raw material extraction, sorting, and transportation (World Trade Organization, 2023[15]). In addition, ResponsibleSteel covers CO_2, N_2O and CH_4 emissions, while the World Steel Association focuses only on CO_2 (World Trade Organization, 2023[15]). These differences undermine comparability of carbon intensity metrics from different industry bodies within the same sector and manifest in large variation in the emissions coverage of carbon intensity metrics.

Some industry bodies, such as the International Aluminium Institute, take a different approach and calculate carbon intensity metrics indirectly. This involves collecting electricity and energy use data from their members and applying emissions factors, rather than directly measuring emissions at the installation-level (see Box 3.6). As such, guidelines by the International Aluminium Institute instruct members on data sources for emissions factors and calculation approaches, rather than direct emissions measurement methods. Given that the majority of emissions from aluminium production stem from electricity use, this indirect approach reflects the specific production processes of the aluminium sector (International Aluminium Institute, 2023[123]). Collectively, the various intensity metrics provided by the International Aluminium Institute cover 80% of global aluminium sector emissions (International Aluminium Institute, 2023[123]).

Similar to the International Aluminium Institute, the Global Cement and Concrete Association also takes an indirect approach to providing sector-level carbon intensity metrics. Their approach is compatible with the IPCC Guidelines and in line with the GHG Protocol (WBCSD, 2011[124]). However, similar to other industry bodies, the Global Cement and Concrete Association recommends an adjustment of the IPCC approach to tailor it to the unique production processes of cement and concrete (see Box 3.6). The Global Cement and Concrete Association calculate a range of carbon intensity metrics, even at the product-level, including for clinker and cement, representing 80% of the global concrete industry outside of China (Global Cement and Concrete Association, 2024[125]).

Overall, there is still large variation in approaches to measuring and reporting carbon intensity data, even within narrowly defined sectors. To a large extent, this variation reflects the specific production processes of different sectors and determines the scope, methods and precision of carbon intensity metrics across sub-sectors and products. Further coordination among industry bodies can help to ensure that flexible, tailored approaches exist to ease the burden of emissions measuring and reporting on installations, and to prevent the proliferation of additional approaches. Progress towards harmonising methods will have to account for critical sector-specific considerations, as well as the specific needs of firms in developing countries. Existing international standard-setting bodies, such as the GHG Protocol and ISO, could collaborate with other international fora, such as the Industrial Deep Decarbonisation Initiative (IDDI), the Climate Club, G20 and G7 – in consultation with private sector stakeholders - to develop or, mandate international organisations to develop, principles aimed at achieving greater harmonisation in approaches. Over time and with guidance, industry bodies could require their members to implement such standards, promoting the adoption of standardised carbon intensity metrics.

Box 3.6. Measuring and reporting carbon intensity metrics from installations. Selected examples of industry bodies' tailored methodologies:

The World Steel Association

Following the World Steel Association's guidelines, installations can measure their emissions by providing their own measured data on carbon content and net calorific values as well as emission factors, which is recommended, or use default values developed by a panel of experts, drawing on data from the World Steel Association itself, the IEA, IPCC and ISSF (Janjua and Maciel, 2022[126]). The World Steel Association then aggregates the emissions data along with data on the output of tonnes of crude steel cast to calculate a sector-level average emission intensity. The global average is weighted, based on the split between different plant types, such as blast furnace and scrap-based electric arc furnace global steel production. In addition, the World Steel Association reports energy intensity and material efficiencies, which provide more detail for the interpretation of the emissions intensity. For example, a reduction in emission intensities can come from productivity improvements (fewer inputs used) or from a change in fuel type (switching from coal to hydrogen).

International Aluminium Institute

Installations following the International Aluminium Institute's guidelines calculate their emissions using different data sources for different parts of the production process. To calculate emissions from the smelting process, electricity data (measured in kWh/tonne) is converted to tonnes of CO_2e using national and regional emission factors from the IEA, process emissions are calculated using Sphera's Life Cycle Assessment Database[9] and electricity transmission figures from the IPCC Guidelines (International Aluminium Institute, 2023[123]). Sphera's Life Cycle Assessment Database, which is built on, to a large extent, primary data collection that is compliant to ISO 14040 – the international standard providing guidelines for life cycle assessment – and the European Commissions' Environmental Footprint Database (Greenhouse Gas Protocol, 2023[127]). Emissions from refining processes are calculated by converting energy use data (measured in MJ/tonne) to CO_2e emissions using global fuel emission factors also published in the GaBi Database (International Aluminium Institute, 2023[123]). Process emissions are calculated using given emissions factors (measured in tonnes of CO_2e/tonne of aluminium). The International Aluminium Institute provides a range of carbon intensity metrics (measured in tonnes of CO_2e per tonne of primary aluminium), also split by processes (including mining, refining, anode production, electrolysis and casting). The various metrics include all sources of emissions from direct GHG emissions, electricity use, thermal energy, transport and ancillary materials.

Global Cement and Concrete Association

The Global Cement and Concrete Association follows the IPCC Guidelines yet recommends alternative measurement methods where the Guidelines are unsuitable for the specific production processes of the cement and concrete sector. Specifically, Tier 3 of the IPCC Guidelines for reporting emissions based on raw materials requires the monitoring of the chemical composition of inputs, which is impractical in cement production due to the large number of inputs and because these are usually homogenised before and during the grinding process (WBCSD, 2011[124]). Thus, the Global Cement and Concrete Association details an alternative method based on the amount of raw meal consumed in the kiln, which is usually monitored in the cement and concrete sector for compliance with quality control. For the calcination of raw material, the Global Cement and Concrete Association offers the choice to use a raw meal-based method or a clinker-based output method, depending on the data

[9] Formerly known as the GaBi-Software Database.

collection capabilities of members. These methods are further broken down into a simple and more detailed option.

Source: (Janjua and Maciel, 2022[126]; World Steel Association, 2023[119]; International Aluminium Institute, 2023[123]; Greenhouse Gas Protocol, 2023[127]; WBCSD, 2011[124]).

Additional initiatives by international benchmarking entities

In addition to industry bodies, there are other initiatives that aggregate data to assess the progress of various sectors in terms of carbon intensity. These use various approaches to calculating carbon intensity metrics, using a range of data sources. Three such initiatives are: the Transition Pathway Initiative, the State of Climate Action report series, and the Global Efficiency Intelligence:

- **The Transition Pathway Initiative (TPI) aims to evaluate how the transition to a low-carbon economy looks for high-emitting sectors such as cement, steel and aluminium** (Dietz et al., 2021[128]). Their key indicator benchmarks high-emitting companies against an emissions intensity pathway that aligns with achieving the Paris Agreement. The main data sources used to compute the pathways are from the IEA and publicly available company data. For each sector, however, the data is adjusted to obtain a measure of total emissions. For instance, for the cement sector, the TPI aligns emissions data from the IEA and defines emissions intensity using the Global Cement and Concrete Association's definition. This involves converting total cement output into cementitious product for the denominator, as well as subtracting CO_2 emissions from on-site power generation emissions and CO_2 emissions from the use of alternative fuels from total Scope 1 emissions for the numerator (Dietz, Hastreiter and Jahn, 2021[129]). Other similar adjustments are made for other sectors, such as aluminium and steel, to align with established guidelines for sector-specific production processes.
- **Systems Change Lab also reports sector-level carbon intensity metrics in their State of Climate Action report series** (Boehm et al., 2022[130]). Following a very similar approach to the TPI, they compute sector-specific pathways, modelling the current trend of a sector's carbon intensity (measured in kg CO_2 per tonne of product) against the trend required to achieve the Paris Agreement. For the most part, their approach relies on data from industry bodies such as the Global Cement and Concrete Association, World Steel Association and others, as well as non-profit initiatives such as the Climate Action Tracker (NewClimate Institute and Climate Analytics, 2024[131]).
- **The Global Efficiency Intelligence has conducted sector-specific studies aiming to benchmark the energy and CO_2 emission intensity of key industries including steel, aluminium and cement** (Hasanbeigi, 2022[132]; Hasanbeigi, Springer and Shi, 2022[133]; Hasanbeigi et al., 2019[134]). Similar to the TPI, depending on the sector, different data sources and methodological adjustments are combined. For instance, for steel, emissions data from the IEA's Energy Balances and production data from the World Steel Association are used to calculate the energy intensity of across 16 major steel producing countries, representing 87% of global production in 2019 (Hasanbeigi, 2022[132]). This metric is then converted in CO_2 emission intensity (measured in total CO_2 per tonne of crude steel) using fuel emission factors from the IPCC and electricity grid emission factors from Carbon Footprint (Carbon Footprint, 2020[135]).

Novel approaches have also been emerging for estimating sector-level carbon intensity metrics. Often, installation and granular sector-level data are not available due to concerns about revealing trade secrets or misusing these data (see Section 4). In addition, data from energy use reported by governments often comes with lags of two to four years and from sources that may not be independent or lack common methodologies. Novel approaches to computing carbon intensity metrics are helping to tackle these challenges and ease the calculation of product-level carbon intensity metrics (see Box 3.7). These

approaches come with limitations, but they could ensure more consistency between sector and product-level metrics. Comparing metrics from both direct and indirect methods, when available, can shed light on the reliability and cost-accuracy trade-off between both types of measurement and provide information on the desirability for extending the use indirect measurements.

Box 3.7. A novel approach to computing carbon intensity: satellite data

Climate TRACE uses a novel approach combining satellites with infrared technology and machine learning to measure output by installations and applying emission factors to estimate carbon intensities and total emissions. Data are aggregated at the sector-level and, in the case of steel, can be produced with a one-month lag. The main strength of this approach is that it can provide close to real-time output data. Climate TRACE collects only minimal data from firms (Ben m'barek, Phillpott and De Daniloff, 2022[136]). Instead, it makes use of several public datasets including from the World Steel Organisation's estimates of emissions intensities, IEA Energy Balance data, and various sector-level emissions data sources for calculation and validation. In comparison to primary data collection methods, this offers a faster and cheaper alternative to computing carbon intensity metrics. Although the aim is to estimate emissions at the installation-level, Climate TRACE also validates results by aggregating to a sector-level and comparing with other sector-level data.

Novel approaches such as that of Climate TRACE still have limitations – in this case, as a result of indirect measurement of emissions. The quality of the data is dependent on the frequency and resolution of satellites that are in operation and can therefore be less accurate when primary emissions data exists. There are several sources of emissions, particularly those arising from indoor fossil fuel use and soil carbon which cannot be captured well, or at all, by satellite imaging. In fact, the sources of emissions which are captured best under this approach are often those where credible direct emission data collection exists although remain complimentary (Roberts, 2020[137]).

Source: Authors.

Installation-level data are helpful, but more granular and timely data are needed

Governments, industry bodies and other organisations' initiatives have resulted in broad collection of different sources and methods to compute or facilitate the computation of carbon intensity metrics. More coordination and harmonisation among these initiatives would strengthen complementarities among them, avoid duplication and reduce costs.

Governments have begun collecting GHG emissions data in more detail, mainly for the reporting of national inventories. These initiatives can provide reliable and timely sector-level aggregates and benchmarks against which more granular sector- and product-level carbon intensity metrics can be compared. In addition, they can facilitate the computation of carbon intensity metrics by providing fall-back values when more granular data is missing or not developed yet. Government systems for collecting GHG emissions can play an important role in promoting the widespread adoption of harmonised standards and implementing effective monitoring, reporting and verification systems.

Industry bodies can also play a key role in developing guidelines for computing carbon intensity metrics based on their sector-specific expertise. Such expertise is necessary to collect data covering narrowly defined sectors (e.g. cement, steel and aluminium) and develop guidelines to compute carbon intensity metrics that take into consideration the specific circumstances and characteristics of each sector, while ensuring consistency with existing and commonly used international standards. Evaluation of carbon intensity at the product level (see Section 4) can benefit from sector-level statistics, such as sectoral averages and distribution across installations (e.g. to assess for outliers and opportunities for targeted

policy interventions). Sector-specific methods, as well as national and international standards, require a balance between harmonisation while still allowing for flexibility to reflect sector-specific circumstances and reporting units' (e.g. installations, firms) individual data collection and reporting capacities.

In addition to government and industry body reporting initiatives, other entities have been developing novel approaches to fill data gaps using new technologies, such as satellite imaging and machine learning. These initiatives are an opportunity to deploy new tools and methods to fill existing data gaps at the sector and installation-level, improving sector-level carbon intensity metrics. There is scope to broaden and develop these initiatives further as a complementary data source to existing emissions data collection and reporting efforts. This requires ensuring consistency with current standards.

More coordination and harmonisation of government, industry body and other efforts can ultimately yield more accurate, timelier and granular data and carbon intensity metrics. Sector-level metrics remain essential, but installation- and/or product-level metrics also provide more disaggregated metrics and valuable information on the distribution of carbon intensities within a sector, going beyond the simple average. Such information can help policy design tracking of decarbonisation approaches, given it can unmask potentially large variations in the carbon intensities of products within the same sector which are otherwise disguised in sector-level metrics. Installation-level data and novel approaches can also provide more accurate and timely data to inform sector-level metrics, but ultimately, product-level metrics and standards are needed to further improve data on carbon intensities.

4 Product-level carbon intensity metrics

Key Messages

- Governments could play an important role in ensuring that product-level carbon intensity metric methodologies align across sectors and countries. Cross-sectoral standards, complemented by sector and where necessary product-specific guidance, can improve the quality and compatibility of carbon accounting systems. In many cases, such as in steel, pre-existing private-sector methodologies provide a good starting point.
- Using site and supplier-specific primary data will generally yield the highest accuracy, but there is a trade-off between accuracy and resource requirements. Rules to allocate emissions from multi-product installations to individual products are key to computing product-level carbon intensity metrics relying on primary data.
- The verification and assurance of carbon emissions data, including Scope 3 emissions, are critical for the reliability of carbon intensity metrics at the product-, site- and firm-level. However, the absence of a widely adopted international standard for emissions verification and the optional nature of such verification practices in many jurisdictions impair reliable comparisons of carbon accounting across industries and countries. The European Union's (EU) efforts to implement a common and mandatory EU-wide standard for assuring sustainability reporting, and the proposed global sustainability assurance standard by the International Auditing and Assurance Standards Board, are first steps towards addressing these challenges.
- Sharing carbon intensity information along the supply chain faces significant economic, technical, legal, and regulatory barriers. Better integration of government and private sector initiatives aimed at overcoming these barriers would expedite the development of interoperable GHG accounting and reporting standards, and secure data-sharing platforms.

This section discusses key challenges associated with computing product-level carbon intensity metrics. It first discusses carbon accounting methodologies, including scope and boundary issues, calculation methods and allocation rules for product-level carbon intensity metrics. It then turns to the challenges related to verifying emissions data, before discussing the challenges in sharing these data along the supply chain.

Carbon accounting methodologies

A pyramid of guidelines and standards

Carbon accounting methodologies exist at the firm, installation and product level. While the focus of this section is on the product level, several firm-level (see Box 4.1) and installation-level (see Section 3) guidelines are relevant. Firm-level guidelines inform the verification, reporting and sharing of carbon intensity metrics. Installation-level guidance is important in the context of primary data collection. These complementarities are illustrated by the horizontal dimension of the pyramid shown in Figure 4.1.

Box 4.1. Firm-level carbon intensity metrics

There is growing demand for firms to measure and report the carbon intensity of their business activities to support their alignment with international and national GHG reduction targets. A consistent framework for firm-level carbon intensity metrics can help firms compare themselves to others within relevant sectors and strengthen incentives to innovate and commercialise low-carbon products. By collecting detailed information on emissions, firms can also improve the transparency and credibility of their Environmental, Social and Governance (ESG) commitments for stakeholders (e.g. investors and consumers of end-products). Importantly, reporting of firm-level metrics can serve as a first step to meeting the data and procedural requirements for product-level carbon intensity metrics.

The GHG Protocol's Corporate Accounting and Reporting Standard is the most widely used framework for firm-level emissions monitoring and reporting (WRI and WBCSD, 2023[117]). It provides standards and step-by-step guidance, as well as a number of calculation tools, for firms to account for their Scope 1, 2 and 3 emissions, drawing on the various calculation methods detailed below. The GHG Protocol has also developed more detailed sectors-specific guidance, such as the forthcoming Land Sector and Removals Guidance (WRI and WBCSD, 2024[138]).

Calculation methods

At the firm-level, there are various methodologies to calculate carbon intensity, depending on the scope of emissions and business activity measured. Regarding emissions, firms may measure direct emissions at the installation, or combine activity data (e.g. on energy consumption, vehicle use or fugitive gasses) with default emission factors. For example, the United States Environmental Protection Agency and the United Kingdom Department for Energy Security and Net Zero both publish emission factors (Tarleton, 2023[139]).

Regarding business activity, firms may choose to express their emissions denominated in units of output, revenue from sales, or enterprise value. The revenue methodology is most widely accepted as it provides a proxy of production irrespective of the units of output, which can vary widely across sectors for firms of a similar size in terms of revenue. Using revenue to normalise carbon intensity, however, tends to favour firms with higher prices.

As an alternative to the revenue methodology, firms may denominate their carbon intensity in terms of enterprise value, which better reflects a firm's total activities and assets. This methodology, however, is sensitive to changes in firms' market capitalisation and can inherit equity market volatility, leading to misinterpretation of carbon intensity metrics. For both within and across firm comparisons over time, it can reward a firm's market performance over emissions reductions efforts.

Both the measurement of emissions and business activity are subject to how a firm defines its business entity, which is relevant, in particular, to firms embedded in larger, more complex organisational structures. Taking the equity share approach, a firm reports its emissions and output, sales revenue, or enterprise value according to the firms' share of equity in the operations of its larger organization. Taking

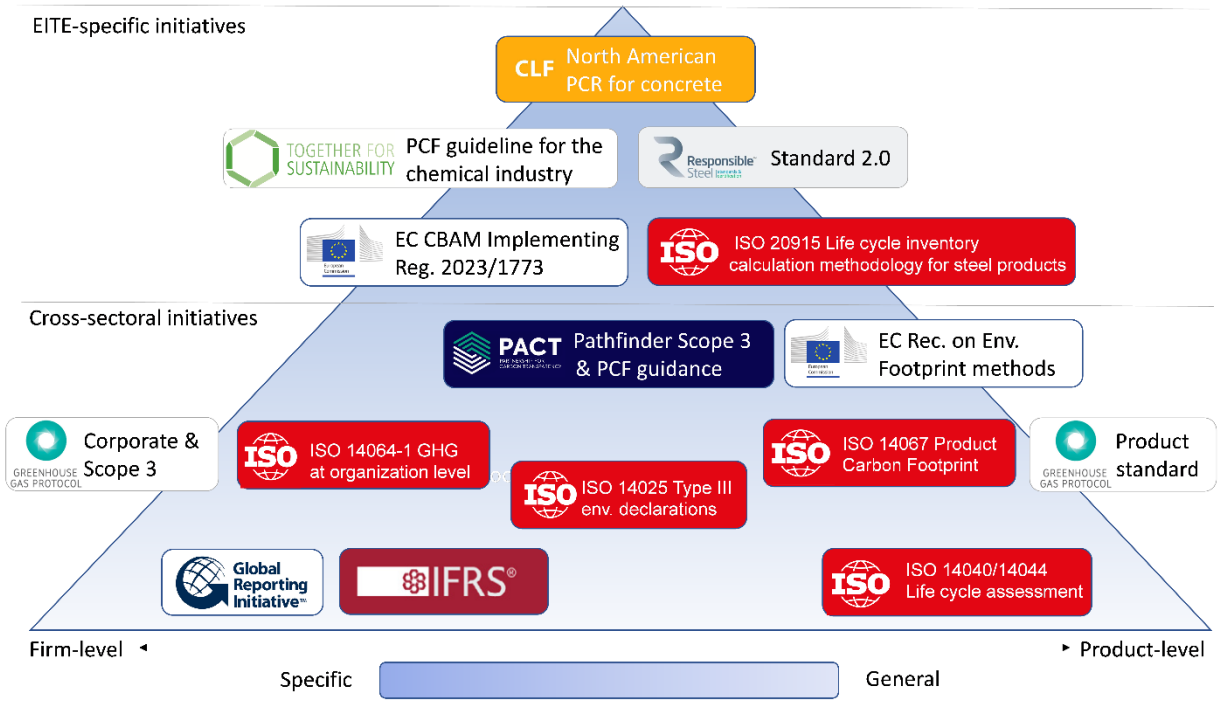
the control approach, a firm reports carbon intensity for the business activities over which it has control, which can be financial or operational. Accordingly, the scope of emissions included in a firm's inventory and the scope of business activity that is considered can vary.

An ongoing OECD project is investigating the relationships between environmental and economic performance of firms using harmonised cross-country micro data. The data cover energy use, emissions, and environmental investments to identify differences in environmental efficiency and responses to policies among firms even within narrowly defined industries. Initial results highlight that even within industries, the dispersion in carbon productivity (defined as revenues per unit of emissions) is five times larger than in labour productivity on average across all sectors.

Source: Authors

Sector-specific carbon accounting methodologies for product-level metrics build on general-purpose guidelines and standards. This is illustrated by the vertical dimension of the pyramid (see Figure 4.1), which places more general methodologies in the lower part and more specific methodologies in the upper part. General purpose methodologies include the GHG Protocol's Product Life Cycle Accounting and Reporting Standard ("product standard"), which in turn refers to IPCC guidance on the calculation of GHG emissions (see Section 3) (IEA, 2023[3]; WBCSD, 2023[4]; Greenhouse Gas Protocol, 2011[5]). In the cross-sectoral accounting methodologies, firms and industry bodies retain some flexibility to make methodological choices to meet sector-specific needs. This is necessary as reporting entities need to take into account sector-specific production processes and other characteristics. However, this flexibility can reduce comparability of carbon accounting methodologies between sectors.

Figure 4.1. Carbon accounting methodologies relevant for EITE industries



Source: Own analysis building on OECD work on food chains (OECD/BIAC/WEF, 2023[140])

Sector-specific, product-level guidance that is consistent with general-purpose methodologies can improve the quality and compatibility of carbon accounting methodologies. In many cases, such as in steel, pre-existing private-sector methodologies provide a good starting point (see Section 3).[10] Sector-specific methodologies, such as the work of Together for Sustainability on chemicals and plastics – both private-sector-led initiatives – and product category rules (PCRs)[11] provide detailed rules, requirements, and guidelines at the level of a specific product category. PCRs establish the methodology for a product's life cycle assessments (LCA) in order to develop environmental product declarations (EPDs).[12] They often cover specific geographic regions, such as the North American PCR for cement (Carbon Leadership Forum, 2012[141]). EPDs are increasingly being used as the basis of low carbon procurement policies (e.g. in the United States in the context of the Inflation Reduction Act (US EPA, 2024[142])). EPDs are the dominant reporting format for cement and concrete, and for steel construction projects (Industrial Deep Decarbonisation Initiative, 2023[143]).

There can be considerable differences between initiatives covering the same sectors. For example, treating emissions of process scrap differently can change the average footprint of a semi-finished aluminium product by about 200% (Labutong, Liu and Wu, 2023[144]). Similarly, differences between accounting methodologies in the steel sector can "dramatically affect the levels of GHG emissions assigned to steel producers" (Biberman, Toledano and Lei, 2022[145]). The IDDI (Industrial Deep Decarbonisation Initiative, 2023[143]) recently identified key reasons for these differences in the steel, cement and concrete sectors. These include provisions that allow for use of secondary data that may not reflect a product's actual emissions, differences in the stage of the lifecycle at which emissions are reported, allocation rules, and accounting rules for scrap, alternative fuels and carbon capture utilisation and storage (CCUS) (see Box 4.2).

Box 4.2. Key issues driving reporting variance in steel, cement and concrete

The Industrial Deep Decarbonisation Initiative recently reviewed the major standards relevant to steel, cement and concrete and identified seven key issues that drive differences. They are:

- **Data use in emissions reporting**: Many standards allow the use of secondary data for upstream emissions, which can vary significantly across sources and may not reflect the actual emissions of a product.
- **Reporting at common lifecycle stage**: Products undergo several 'finishing' steps after the production of steel or cement. Because product-level reporting blends these numbers, some stakeholders have called for reporting at a common step to enable greater comparability between products.
- **Allocation of emissions to co-outputs**: Industrial processes can result in several outputs, or 'co-outputs,' that may be allocated a portion of emissions from a particular process, thereby

[10] For example, the World Steel Association developed a product-based LCA methodology in the 1990s, which is still valid and used today and formed the basis of ISO 20915. Another relevant initiative is the Global Steel Climate Council that seeks to develop a low-emission steel standard that accurately accounts for carbon emissions regardless of the production methods.

[11] This report uses the term PCR, as in ISO 14025. Note that PCRs are referred to as Product Rules in the GHG Protocol Product Life Cycle Accounting and Reporting Standard and as Supplementary Requirements in PAS 2050 standard.

[12] The website of the international EPD system already has a library of more than 100 PCRs with information on the corresponding product category in the Central Product Classification (CPC) system of the UN. EPDs include but are not limited to climate impacts.

reducing the emissions allocated to the primary product. This is particularly relevant for steelmaking where blast furnace slag is a key co-output and frequently sold to cement producers.

- **Accounting for utilisation of scrap in steel**: Steel is a highly recyclable material and most steel contains some proportion of scrap. A key question arises on whether and how to assign emissions to scrap as an input into steelmaking, accounting for its future recyclability and any emissions incurred in original production.[13]
- **Accounting for the use of alternative fuels**: Alternative fuels refer to biogenic matter or other waste products such as plastics, tires, or medical waste that can be used as energy sources in cement and steel production. It is critical to align on how producers should account for the emissions that result from the use of these fuels.
- **Accounting for CCUS**: Carbon capture is a crucial emissions abatement lever in the cement and steel industries. However, major European Standards (EN) and ISO standards do not yet provide a pathway for producers to claim a reduction in direct emissions through carbon capture and sequestration. Additionally, standards must also determine the extent to which producers can claim emissions abatement for carbon used in different products and processes rather than stored geologically.
- **Permissibility of alternative chain of custody (CoC) models**: Industrial producers are increasingly entertaining new approaches to lifecycle assessment and reporting, such as mass balance or book and claim, to capture value more effectively from investments in decarbonisation. Several questions remain unanswered about the degree to which these approaches should be accepted, and the guidelines needed to govern them.[14]

Source: IDDI (2023[143]).

Comparability issues can lead to allocative inefficiencies. For instance, more carbon-efficient products may fail to secure a green premium in the market because less carbon-efficient products obtain similar carbon intensity "scores" by choosing a more favourable accounting metric. This could have knock-on effects across the market as cleaner firms might respond by choosing methodologies that underestimate the real carbon intensity of their products to remain competitive. This concerns both the comparability between products from the same sector and between products from different sectors if they are substitutable (e.g. aluminium cans and plastic bottles for beverages).

Differences across GHG accounting methodologies have spurred initiatives to enhance the comparability and compatibility of carbon accounting methodologies. Both private and public initiatives seek to address inconsistencies in existing rules. The PACT Pathfinder Framework, further discussed below, is an example of a cross-sectoral initiative and also provides an instruction for how sectoral guidance fits in (WBCSD, 2023[4]). Horizon Zero and Together for Sustainability are examples of private sector initiatives developing sector-specific, product-level emissions reporting guidance to bring clarity to voluntary GHG reporting (Labutong, Liu and Wu, 2023[144]; Together for Sustainability, 2022[146]; Together for Sustainbility, 2024[147]). The European Commission has been working towards harmonised rules for the evaluation of carbon footprints and other life cycle environmental impacts both at the level of products/services (Product Environmental Footprint, or PEF) and organisations/sectors (Organisation Environmental Footprint) (European Commission (European Union), 2021[148]). During a pilot phase, Product Environmental Footprint Category Rules (PEFCRs) were tested with more than 300 companies

[13] An example is ISO 20915, a comprehensive standard which provides an option to include or exclude scrap emissions from calculation.

[14] For example, World Steel has developed chain of custody principles and is developing more detailed guidelines.

and 2 000 stakeholders in different areas, including food, feed, batteries and detergents.[15] PEFCRs are being developed on a larger scale and may become codified in EU law (WBCSD, 2023[4]).

Challenges in developing and implementing common standards can be overcome through government initiatives. These challenges are compounded as GHG accounting challenges may be sector- or product-specific. Hence, harmonised standards should be broadly applicable yet able to accommodate specificities relevant to sectors or products. Governments could decide to make the application of guidelines mandatory. They could also play a coordinating role to make sure that methodologies are aligned across sectors and countries, including through active participation in the relevant international fora. Collaboration in for example the G20, IFCMA or UNFCCC, could help in this regard.

Scope and boundary issues

Product-level carbon intensity metrics draw on lifecycle assessment (LCA) methods to quantify the GHG emissions associated with a product at different stages of its lifecycle. The traditional approach to lifecycle assessment is Attributional LCA (ALCA), which attributes a share of observed emissions to an individual product. An alternative approach is the Consequential LCA (CLCA), which uses economic models to estimate emissions taking into account the various behavioural and economic feedbacks that happen as a result of expanding the production and use of the product (Rajagopal, Vanderghem and MacLean, 2017[16]). ALCA-based methods are more easily applicable to a large set of individual products than CLCA-based estimates as the latter require model simulations for each individual product, generating additional uncertainty due to modelling assumptions (Rajagopal, 2013[149]). CLCA has been used to carry out impact assessments of biofuel policies inter alia accounting for indirect land use change (e.g. to determine feedstock eligibility for biofuel production in the context of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)) (Prussi et al., 2021[150]).

Whether a full lifecycle assessment or more limited approaches are appropriate depends on the circumstances. Full lifecycle (i.e. cradle-to-grave) approaches can help to design products in a way that reduces their end-of-use emissions by considering products' end-of-life issues such as recycling. However, they require strong assumptions particularly for downstream emissions (Meinrenken et al., 2020[151]). Metrics calculated based on lifecycle standards therefore often take a more limited approach (e.g. the 'cradle-to-gate' approach to focus on Scope 1, Scope 2, and upstream Scope 3 emissions, such as methane emissions from coal mining for steel production). This differs from 'cradle-to-grave' approaches because it does not include downstream emissions from the use of the product, nor includes emissions involved in the products' disposal. Domestic carbon pricing systems and policy instruments addressing carbon leakage and competitiveness concerns, such as border carbon adjustment mechanisms, typically do not take a full lifecycle perspective (OECD, 2020[14]).[16]

Computing product-level metrics requires information both from within and outside the firm or plant. While a firm can in principle measure the direct GHG emissions from the processes that it owns or controls (Scope 1) and compute carbon intensity metrics for the products it produces (using some pre-defined methodology), it cannot directly measure the carbon intensity of the inputs it sources. Upstream

[15] PEFCRs (Product Environmental Footprint Category Rules) and OEFSRs (Organisation Environmental Footprint Sectoral Rules) are developed building on PEF/OEF to further specify methodological rules for product groups and sectors. The method is already being used in different voluntary (such as Ecolabels) and mandatory policy instruments (such as the recent EU Battery Regulation). In the development of the Environmental Footprint methods, the European Commission is also working on improving data, modelling rules and impact assessment methods, also addressing needs of SMEs.

[16] The EU CBAM is more limited in scope than the 'cradle-to-gate' approaches as it, for example, does not apply to upstream transportation emissions, which also facilitates the work of customs authorities.

Scope 3 emissions are indirect GHG emissions that occur in the supply chain prior to the processes owned or controlled by the firm and include upstream transportation emissions. Scope 2 are energy inputs, such as electricity purchased from the grid, used during production. Downstream Scope 3 emissions are indirect GHG emissions that occur in the supply chain following the processes owned or controlled by the firm.

Narrowing the range of emissions considered can facilitate the computation of product-level carbon intensity metrics and the verification, reporting, and sharing of data, but it can also reduce comparability. Focusing on Scope 1 emissions, for instance, is rarely appropriate as the boundaries of firms producing similar products can vary widely, depending on, for example, whether electricity and heat is produced on-site (Scope 1) or purchased from electricity and heat networks (Scope 2). This may result in carbon intensity metrics that are not comparable across products of different firms. In particular, there would be a risk of circumvention for certain goods as multi-facility firms can artificially split sites or divert elements of the production process to their lower-emissions subsidiaries to reduce their recorded emissions. Widening the emissions scope (e.g. including certain Scope 3 emissions) helps address such issues.

Different methods for allocating Scope 2 emissions from electricity are inconsistent. As EITE industries are often major electricity users, rules for allocating Scope 2 emissions from electricity can make a difference. In general, there are two methods to allocate such emissions. The first is the location-based method based on the average emissions intensity of grids on which energy consumption occurs. The second is the market-based method whereby emission factors are derived from contractual instruments, which may include energy attribute certificates and direct contracts as per GHG Protocol's Scope 2 guidance. As for the methods used for Scope 1 and Scope 3 accounting (Greenhouse Gas Protocol, 2024[152]), these methods do not necessarily reflect the marginal effect of production on emissions from the electricity sector.

The temporal scope of the assessment can have material implications for carbon intensity metrics as emissions intensities may vary significantly over time across facilities. Calculating carbon intensity metrics involves choosing a time horizon. Greenhouses, for instance, tend to require more heating in the cold season, but seasonal differences are averaged out when using annual data for heating-related emissions. Another example is the carbon intensity of electricity inputs, which can vary depending on weather conditions (e.g. wind, sunshine) and time of use. To date, metrics are typically calculated annually. Increasing the granularity of the time horizon brings greater precision. The benefits of a more granular time horizon need be compared with the higher costs of the data collection it will entail. To the extent that data is simply cyclical, assessments can draw on approaches developed to deal with cyclicality in related applications, such as commodity pricing time series analysis.

Increasing the granularity of the time horizon brings greater precision, but it also involves additional administrative and investment costs. A more granular time horizon can be more accurate where the availability of green inputs fluctuates over time (e.g. green power). However, if one were to require hourly electricity carbon intensity data for each individual product, this could lead to large differences in the carbon intensity of electricity-intensive products, such as green hydrogen, depending on when the hydrogen was produced. For the production of green hydrogen, for example, granular (e.g. hourly) matching requirements for low-carbon electricity could impact the business case of electrolyser investments. In particular, Ruhnau and Schiele (2023[153]) argue that requiring hourly data leads investors to oversize wind turbines, hydrogen electrolysers, and hydrogen storage, leading to underutilised assets.

Even when emissions are perfectly measured, comparing the carbon footprint of individual products is challenging because outputs may not be directly comparable (see Table 4.1). For instance, a new processing technique may enhance a material's strength, thus lowering the amount of it needed to produce a certain product relative to the conventional processing technique (Department of Energy (United States), 2022[154]; Roychand et al., 2023[155]). In this case, the less material-intensive and stronger product could also be the less carbon-intensive choice, even if it were to have higher emissions

per declared unit (i.e. its physical quantity, such as tonnes of steel). Additionally expressing emissions relative to a product's functional unit, such as the amount of steel, in kg, needed to produce an automotive B-pillar that meets all relevant structural and safety requirements over a vehicle lifetime of 200 000 kilometres travelled, would allow for comparing such partial substitutes (Rajagopal, Vanderghem and MacLean, 2017[16]). Functional unit approaches are not necessarily the only way to solve such comparability issues. Declared unit approaches would be a key input for addressing these issues.

Table 4.1. Pros and cons of different ways of output measurement

	Definition	Advantage	Disadvantage	Example
Declared unit	Physical quantity of a product	Does not require knowledge of the eventual end use of a product (for intermediate products). No need to specify a specific function (for products with several potential functions)	Cannot be compared across products with different attributes (lifetime, etc.)	The amount of steel, in kg
Functional unit	Quantity of a product on the basis of the performance it delivers in its end-use application	Enables comparisons across different products or systems have different attributes (lifetime, etc.) but serve the same function	Need to specify a function (for products with several potential functions) Requires knowledge of the eventual end use of a product	The amount of steel, in kg, needed to produce an automotive B-pillar that meets all relevant structural and safety requirements over a vehicle lifetime of 200,000 kilometres travelled

Source: Own analysis based on (WBCSD, 2023[4]) (Department of Energy (United States), 2022[154]).

Trade-offs among calculation methods

There are three main types of calculation methods of product-level carbon intensity metrics (see Table 4.2). First, the spend-based method involves multiplying company expenditures on a given product or input by an emission intensity factor of these activities (WBCSD, 2023[4]) (e.g. based on input output tables) (Steubing et al., 2022[156]). As discussed in Section 3, the use of appropriate deflators is key to avoid biased estimates. Second, the average data method relies on multiplying primary activity data (e.g. on material weight, fuel consumption) with activity-specific emission factors based on industry averages (Finnveden et al., 2009[157]; Ben m'barek, Phillpott and De Daniloff, 2022[136]). Third, the primary data method draws on data directly measured, collected, and calculated at each stage of the supply chain (WBCSD, 2023[4]) (e.g. using the installation-level methods discussed in Section 3).

No single method fits all applications and contexts. When selecting a calculation method for computing product-level carbon emissions, there is a trade-off between accuracy and resource requirements. For instance, practitioners may reserve more resource-intensive methods for those inputs that have large impacts on the overall carbon intensity of the product. Administrative costs imply that certain approaches are currently not realistic across countries and firms with low administrative capacity. Less resource-intensive methods can therefore be useful in a transitional period while capacity is being developed for using primary data and where resource-intensive methods would pose an undue burden on certain groups, such as SMEs and many firms from developing countries. However, long-term decarbonisation incentives could be compromised by using less accurate methods masking the performance of individual products (see Table 4.2). Specifically, this would be the case if using default values led to lower carbon intensity than that resulting from using primary data.

Table 4.2. Trade-offs between calculation methods for product-level carbon intensity metrics

	Granularity	Maintains decarbonisation incentives	Resource cost on reporting party	Administrative burden on suppliers	Requires data sharing and verification along the supply chain
Spend-based methods	Low	Low	Low	Low	No
Average-data methods	Medium-to-high	Low	Low-medium	Low	No
Primary data methods	High	High	High	High	Yes
Hybrid approaches	Low-to-high	Low-to-high	Low-to-high	Medium	Maybe

Source: Authors.

The least resource demanding method will often be the spend-based method. This method can be instructive to prioritise data collection efforts. Spend-based calculation methods are relatively straightforward to implement as firms routinely collect financial data on different purchasing categories. However, the accuracy of the spend-based method tends to be relatively low as financial information is a crude proxy for emissions and prices fluctuate based on drivers that are unrelated to carbon intensity. In addition, data based on input-output tables is typically only available for relatively aggregate product categories (see Section 3). The increasing availability of such data at more disaggregated levels can enhance the accuracy of spend-based method (Steubing et al., 2022[156]).

The average-data method will typically be more precise than the spend-based method. Average data can, for instance, be found in national or regional LCA inventory databases based on publicly funded projects, or on websites of international business associations (see Section 3) (Finnveden et al., 2009[157]). Like the spend-based method, the average data method can help "to pinpoint environmental hotspots in complex value chains" (Hellweg and Milà i Canals, 2014[158]). Average data methods are also being considered for the development of default values under the EU CBAM, in case site-specific data are not available.[17] However, the use of industry averages hides differences in carbon intensities among products from the same sector. As a result, buyers will not be in a position to select the best performing supplier for any given product and to track progress of individual suppliers.[18] This approach – while useful especially in the absence of more precise primary data (see below) – can thus lead to weak incentives for firms to adopt cleaner-than-average technologies.

Using site and supplier-specific primary data will generally yield the highest accuracy. Primary emissions data (i.e. data directly measured, collected, or calculated, e.g. engineering estimates) that is shared along the supply chain can in principle provide precise emissions data. The use of these data for computing carbon intensity metrics would allow firms to tackle emissions reduction at the most effective point in the supply chain. Using more accurate data can enable firms to reduce upstream Scope 3 emissions by switching to less carbon-intensive suppliers (provided the relevant information is shared along the supply chains as discussed below). However, relying on site and supplier-specific primary data comes at the cost of establishing protocols and the necessary infrastructure to collect, monitor, verify and share such data along the supply chain. An increasing number of private and public actors are moving

[17] A recent example by the Joint Research Centre outlines an example methodology to compute product-level emissions intensity for the iron and steel industries relying entirely on publicly available sources (Koolen and Vidovic, 2022[232]). The approach draws on publicly available data from the IEA (IEA, 2023[78]; IEA, 2022[80]) and specific data and knowledge of production process to assign emissions to different products.

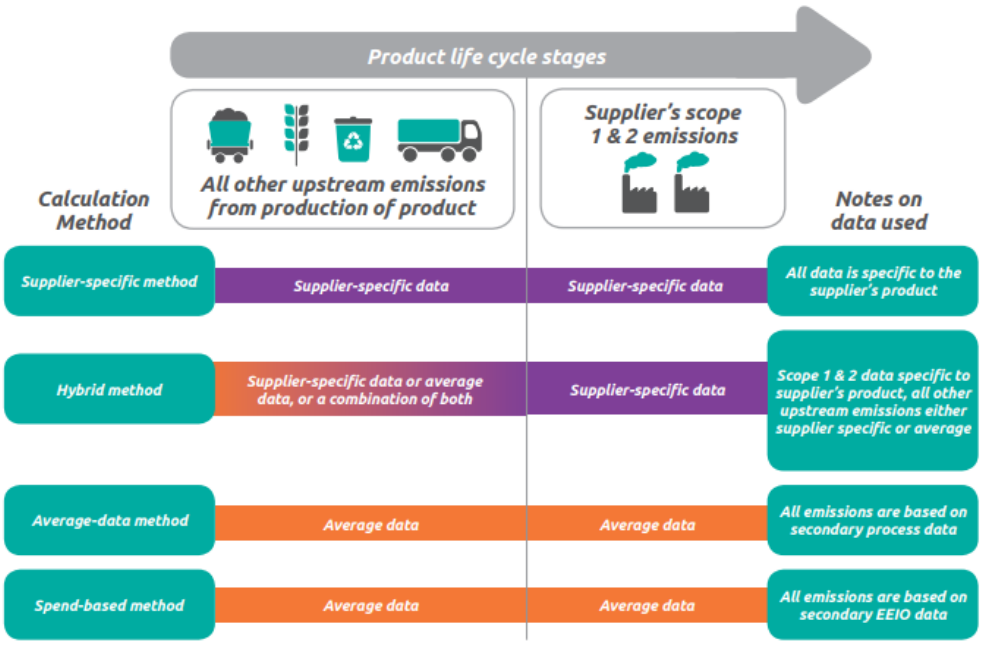
[18] A step forward is to use country-specific industry data, but this still does not allow one to distinguish between more efficient producers within a given country.

ahead despite these challenges and are developing increasingly robust and precise activity data to increase the granularity and quality of emissions data (e.g. Schneider Electric (2022[159])).

The challenges associated with primary data collection differ between sectors and countries due to variations in their emission profiles and global supply chain integration. Some industries, such as electricity generation and manufacturing, typically have higher levels of Scope 1 and 2 emissions from their direct use of energy, making it easier to collect (primary) emission data for the bulk of their emissions. For instance, cement and concrete producers have significant Scope 1 and 2 emissions resulting from their high energy use and the chemical reaction that occurs during cement production. In contrast, firms operating in sectors with complex and fragmented global supply chains face more difficulties in collecting (primary) emission data as Scope 2 and 3 emissions will dominate. The motor vehicle industry, for instance, is characterised by internationally fragmented and complex supply chains which involve numerous actors and activities across the globe, traditionally resulting in relatively large Scope 3 emissions. Furthermore, data collection may be complicated for sectors with more diffuse emission sources. The agriculture sector, for instance, faces diffuse emissions sources (e.g. from land use, fertiliser use, manure management, etc.), and data collection is complicated due to variations in soil quality, fertiliser use, and crop rotation.

Combining methods in a hybrid way is an option to lower costs and circumvent data limitations (see Figure 4.2). Yet, in these cases, care must be taken to avoid double-counting or undercounting emissions and opportunistic behaviour. For instance, a firm could use the primary data method for Scope 1 and 2 emissions, but the average-data method for Scope 3 emissions from suppliers even when supplier-specific data are available because this combination could lower the reported carbon intensity of the product.

Figure 4.2. Different data types used for different calculation methods



Source: (World Resources Institute and World Business Council for Sustainable Development, 2013[160])

Both the public and private sectors (e.g. industry associations) can play an enabling role by increasing the provision of publicly available emissions and carbon intensity data. Governments, for instance, could engage actively in the relevant committees of the International Organization for Standardization (ISO) whilst also encouraging industries and other stakeholders to participate in efforts to improve measurement methodologies (IEA, 2023[3]). Governments and their agencies could – in collaboration with relevant industry stakeholders – develop country-specific default values to be used if more specific data are not available (Life Cycle Initiative & UNEP, 2020[161]).[19] When regulating the use of default values, care should be taken to encourage information disclosure by firms (e.g. by basing default values on the carbon intensity of the least efficient firms in an industry).

Both the public and private sectors (e.g. industry associations) can help alleviate capacity constraints facing SMEs in calculating carbon intensity metrics. Through knowledge sharing initiatives, SMEs can gain access to best practices and expertise from larger firms, enabling them to improve their capabilities in data collection, measurement, and reporting. Private-sector-led initiatives can contribute to this knowledge sharing by actively engaging in partnerships and collaborations with SMEs, for instance by providing tools and training programmes. Governments can promote knowledge sharing by reducing training costs for firms and promoting the benefits for workplace training, for instance through tax incentives or subsidy schemes. Furthermore, governments can develop, with the help of industry associations, educational programs and resources specifically designed for SMEs, providing guidance on carbon footprint measurement methodologies, reporting frameworks, and available support mechanisms.

Allocation rules for multi-product installations

Rules to allocate emissions from multi-product installations to individual products are key for computing product-level carbon intensity metrics relying on primary data. Such rules require data and information on firms' operations. The experience of competition authorities and network regulators in the context of multi-product firms may be valuable in this respect (Liston, 1993[162]; Laffont and Tirole, 1990[62]). A major source of primary data is installation-level data that can be collected for a variety of reasons beyond the computation of carbon intensity metrics, such as complying with data collection and reporting requirements in emissions trading systems (see Section 3). However, as many installations produce more than one product, allocating emissions to products require rules (see Table 4.3). To prevent firms choosing whichever method minimises the reported carbon intensity metric and ensure comparability, industries using a particular co-output need to align on a single approach (Industrial Deep Decarbonisation Initiative, 2023[143]).[20] Clear guidelines from governments developed in co-operation with industry and accounting bodies could specify what methods should be used in different circumstances. Both public guidance (e.g. the European Commission's Product Environmental Footprint Category Rules (PEFCR) (European Commission (European Union), 2021[148])) and private sector initiatives can be helpful (e.g. the Pathfinder Framework (WBCSD, 2023[4])).

Table 4.3. Allocation methods presented by GHG Protocol

Method	Definition
Physical allocation	Allocating the inputs and emissions of the system based on an underlying physical relationship between the quantity of product and co-product and the quantity of emissions generated
Economic allocation	Allocating the inputs and emissions to the product and co-product(s) based on the market value of each when

[19] The Global LCA Data Access network (GLAD) (2024[265]) provides a directory of LCA datasets from around the world.

[20] The IDDI describes the allocation methods used across steel and cement producers, inter alia finding regional differences in the choice of method.

	they exit the common process
Other relationships	Allocating the inputs and emissions to the product and co-products(s) based on established and justifiable relationships other than physical or economic

Source: GHG Protocol as reported in WBCSD (2023[4])

Verifying, reporting and sharing carbon intensity information along the supply chain

Calculating product-level carbon intensity metrics taking into account Scope 3 emissions involves verifying and sharing data along the supply chain. The following subsections first outline the challenges related to verifying emission data along the supply chain. They then discuss the economic, technical, legal, and regulatory barriers in sharing these data along the supply chain, including costs associated with fragmented reporting standards, and the private and public initiatives that have emerged to address them. These initiatives are focussed on the firm level but can serve as a first step to achieving the data and procedural requirements for product-level carbon intensity metrics (see Box 4.1).

Challenges in verifying and assuring the quality of the data along the supply chain

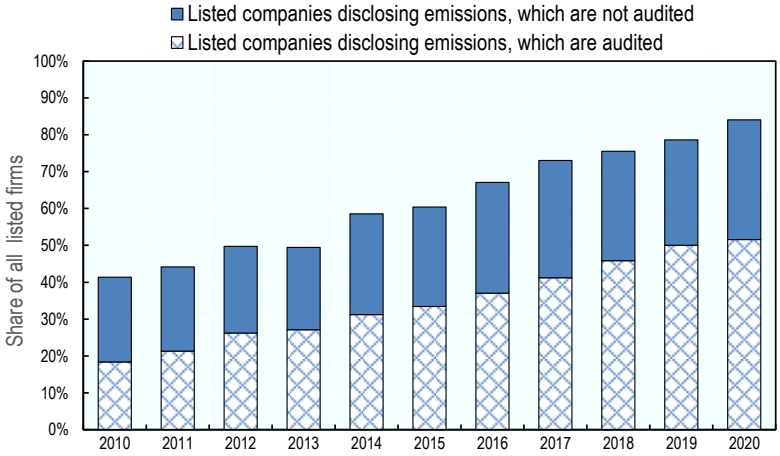
Companies can ensure the accuracy of emissions data through independent verification and assurance. Independent verifiers help ensure that emission data are complete, accurate, and consistent with relevant standards. The GHG Protocol stipulates that this assurance process can be undertaken internally or, to increase credibility, through a third-party. Furthermore, there are two levels of assurance: reasonable and limited. The former requires a deeper evaluation, including tests on internal controls, data sampling and underlying evidence, while the latter focuses mainly on reviewing the process for compiling information. The costs of third-party assurance can be significant. The US Security and Exchange Commission estimated that the costs of limited assurance ranges from USD 30 000 – 60 000, and from USD 75 000 – 145 000 for large companies (SEC, 2022[163]). The costs of reasonable assurance are estimated to be about 50% higher.

In contrast to firms' financial reporting, the assurance and verification of emission accounting and reporting remain optional in many jurisdictions. Nonetheless, verification of corporate-level emissions has increased in recent years among the biggest companies within the EU and the United States (see Figure 4.3), driven by, for instance, public scrutiny and regulatory requirements (e.g. compliance with emissions trading systems). However, the verification of corporate-level emissions is not yet widespread, and only 60% of the biggest European and American companies disclosing emissions verified their emission data in 2020. Compared to corporate-level emissions, the verification of product-level emissions is less developed, pointing to challenges in achieving widespread verification of product-level emissions. This includes the shortage of verification bodies and verifiers.[21]

[21] For instance, the ANSI National Accreditation Board (ANAB) (2024[266]) list only two eligible programme operators of Eco Labeling And Environmental Product Declarations

Figure 4.3. Disclosure of emissions data and the share of audited disclosures

Companies listed in the S&P 500 (US) and STOXXX 600 Europe (EU), percentages



Note: Emissions disclosure of one of the three emission scopes.
Source: ECB (2022[164]).

The lack of an assurance requirement threatens the credibility of the emissions data shared and disclosed by firms. This thwarts efforts to compute reliable and comparable product-level carbon intensity metrics and may lead to misreporting, as illustrated by recent research covering the oil and gas sector (García Vega et al., 2023[165]). Furthermore, the multitude of verification standards reflects the absence of a widely adopted and implemented international standard. This breeds uncertainty about the quality and scope of verification processes across different countries. To tackle these challenges, initiatives have been proposed to establish mandatory standards for assuring sustainability reporting, develop guidelines for verifying the emissions of imported goods, and create a global standard for sustainability assurance. Box 4.3 discusses examples of such initiatives.

Box 4.3. Selected initiatives on verification and assurance of sustainability information

The European Union (EU) has recently implemented regulations to ensure the accuracy and reliability of sustainability reporting and the verification of embedded emissions. These rules are part of the Corporate Sustainability Reporting Directive (CSRD) and the Carbon Border Adjustment Mechanism (CBAM). Furthermore, the International Auditing and Assurance Standards Board (IAASB) has recently proposed a global sustainability assurance standard.

Corporate Sustainability Reporting Directive (CSRD)

The CSRD mandates that all sustainability reports must be certified by an accredited auditor, but its implementation and the different categories of companies concerned depend on several criteria. Large European and non-European companies listed on EU regulated markets, for instance, are now required to follow assurance rules, as of January 1st, 2024, if they have more than 500 employees and a turnover exceeding EUR 40 million (or a balance sheet over EUR 20 million). SMEs listed on regulated European markets (except micro-undertakings) need to follow assurance rules from January 1st, 2026, onwards (with a 2-year op-out period). The CSRD replaces the Non-Financial Reporting Directive (NFRD) of 2014, in which verification was optional.

The EU takes a progressive approach in implementing the new assurance rules, starting with a limited assurance requirement, which may escalate to a reasonable assurance requirement. This gradual

strategy allows for the development of the assurance market and a phased cost increase for reporting entities, given that reasonable assurance engagements are more costly than limited ones.

EU member states can use their own assurance standards as long as the European Commission has not established equivalent standards. However, the CSRD encourages using the Committee of European Auditing Oversight Bodies' guidelines for sustainability reporting assurance, pending the Commission's adoption of standards covering the same topic.

Carbon Border Adjustment Mechanism (CBAM)

The CBAM is designed to prevent carbon leakage by ensuring equivalent carbon pricing between imported goods and goods produced within the EU subject to the EU Emissions Trading System. Key to the CBAM's functioning and effectiveness is a rigorous assurance and verification system, which guarantees the reliability of imported goods' declared emissions. The CBAM's transition phase began in October 2023, and verification rules will apply from 2026. Verification of total embedded emissions will be based on the following principles:

- **Professional scepticism**: Verifiers approach the verification process with a sceptical mindset.
- **Reasonable assurance**: Verifiers ensure that the verification report is free from material misstatements and material non-conformities regarding the calculation of embedded emissions.
- **Mandatory installation visits:** Verifiers are required to conduct installation visits, unless specific criteria for waiving the visit are met.
- **Materiality thresholds**: Verifiers use thresholds to determine the materiality of misstatements or non-conformities.

Furthermore, the verification report should include essential details such as the identification of production installations, the reporting period, quantification of each type of declared goods produced, emissions quantification, an explanation of how the installation's emissions are allocated to different types of goods, and comprehensive descriptions of complex goods and their associated emissions. Specific rules including the accreditation of the verifiers will be detailed in implementing regulation yet to be published.

International Auditing and Assurance Standards Board (IAASB)

The IAASB has proposed an International Standard on Sustainability Assurance (ISSA) 5000, designed to provide a global baseline for all sustainability assurance engagements (i.e. reasonable and limited). It will apply to sustainability information reported across any sustainability topic and prepared under multiple sustainability reporting frameworks (e.g. the IFRS Sustainability Disclosure Standards, or the European Sustainability Reporting Standards, etc.).

The proposed standard is a principles-based standard, focused on principles or outcomes rather than procedures or steps. This approach supports the scalability and comprehensiveness of the standard by limiting possible exceptions from the principles and ensuring applicability across all types of entities and industries. The final standard will be issued before the end of 2024.

Source: (European Parliament and Council of the European Union, 2022[166]; European Parliament and Council of the European Union, 2023[167]; IAASB, 2024[168])

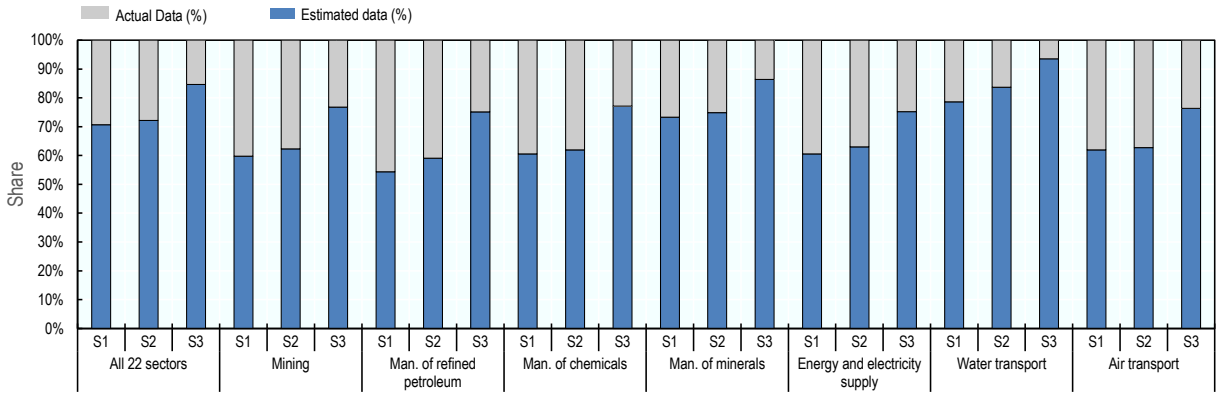
Challenges in sharing emission data along the supply chain

The computation of product-level carbon intensity metrics that include Scope 3 emissions requires a firm to collect information on emissions and activity data not directly owned or controlled by it. Scope 1 and 2 emissions of one firm are the Scope 3 emissions of another firm downstream in the supply

chain. There exist a range of economic, technical, legal, and regulatory challenges hampering the sharing of emission data along supply chains (Stenzel and Waichman, 2023[169]). Consequently, the bulk of Scope 3 emissions measurement currently relies, more than for Scope 1 and 2 emissions, on proxies (such as default values) rather than actual data (see Figure 4.4). Furthermore, the use of proxies versus actual data varies across sectors, indicating sector-specific differences in the severity of these challenges.

Figure 4.4. Relative use of actual data vs. proxies for the measurement of Scope 1-3 emissions

European banks' use of proxies for Scope 1-3 emissions of their customers



Source: ECB (2022[170])
Note: S1. S2, and S3 refer to Scope 1, Scope 2, and Scope 3 emissions respectively.

Companies may be reluctant to share carbon intensity information due to the risk of sharing trade secrets and potential adverse impacts on their business. For instance, in the manufacturing sector, revealing emissions data could hint at energy usage, cost structures and other production details. The severity of this problem may differ among sectors depending on the extent to which energy and process data may reveal key information on businesses' operations. In 2022, a survey among German manufacturing firms found that 42% of them worry about losing innovative or competitively relevant knowledge if data is shared or locked into one data platform (EFI (Germany), 2022[171]; Stenzel and Waichman, 2023[169]). On the other hand, only 31% of ICT companies and knowledge-intensive service providers (e.g. legal and tax consultancy, auditing, marketing, etc.) shared the same concern.

Contractual and regulatory barriers may also be significant obstacles to sharing emission data. Firms could, for instance, encounter contractual restrictions when re-sharing data received from their suppliers who often wish to retain control over who will access their emission data. Additionally, OECD (2022[172]) analysis shows that the number of data localisation measures (i.e. measures that restrict data flows across borders to not lose control over the data) is increasing and becoming more restrictive. Countries often justify these restrictions by the need to safeguard digital security, intellectual property rights, national security, and uphold law enforcement. These measures can also restrict the cross-border flows of emission data, with implications for supply chains spanning different countries (Stenzel and Waichman, 2023[169]). Furthermore, data sharing among firms may be impeded by competition law, as Scope 3 emissions data could include competition-relevant information (OECD, 2019[173]). Due to these barriers, firms are left to decide on a case-by-case basis which data can be shared for what purpose, increasing monitoring and transaction costs (European Commission (European Union), 2018[174]; Stenzel and Waichman, 2023[169]).

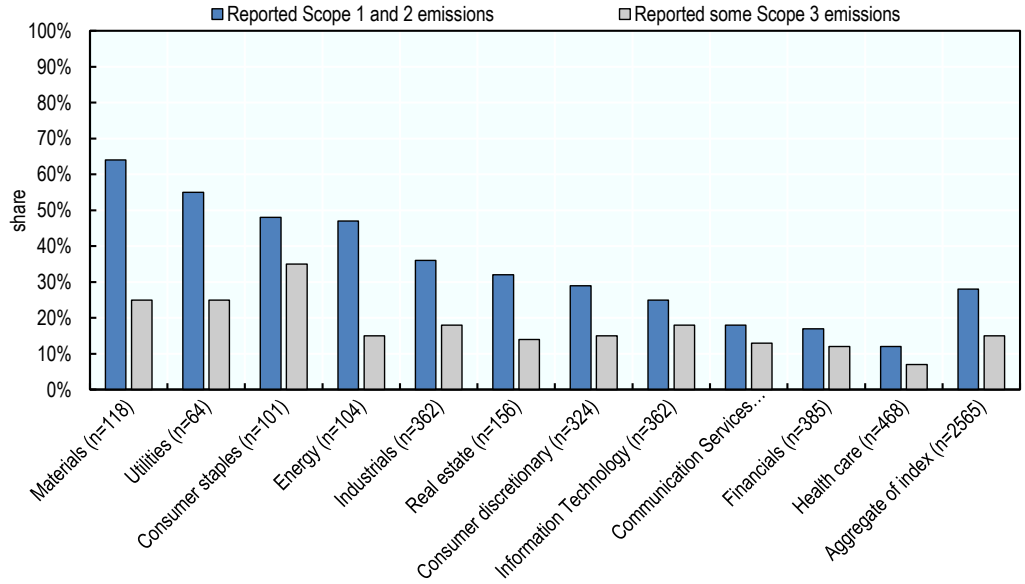
The absence in many countries of a mandatory requirement for Scope 3 emissions reporting may generate a wait-and-see attitude and delay efforts to measure Scope 3 emissions. While the GHG Protocol, a voluntary framework, guides firms to report their Scope 1 and Scope 2 emissions, it only

recommends reporting on Scope 3 emissions. The GHG Protocol divides Scope 3 emissions into 15 sub-categories, granting firms the autonomy to establish their own reporting boundary. This includes the flexibility to select which of these 15 sub-categories they will disclose, contingent on applying the principles of relevance, completeness, accuracy, and consistency. Thus, corporate reporting on Scope 3 emissions is generally sparse and varies by industry, relevant Scope 3 category, and firm size. Higher disclosure rates are found in emission-intensive sectors (see Figure 4.5), upstream Scope 3 categories (MSCI, 2020[175]), and large-cap companies (ISS, 2022[176]).

The absence of mandatory reporting for Scope 3 emissions may also encourage firms to outsource carbon-intensive production to reduce their Scope 1 emissions. Unclear messages from governments or standard-setters on future regulations or requirements may discourage companies from investing in a reporting infrastructure (e.g. information-gathering processes) (Kauffmann, Tébar Less and Teichmann, 2012[177]).

Figure 4.5. Current climate-related disclosures on selected topics by US companies

Scope 1-3 disclosure of US-listed companies in the MSCI USA Investable Market index as of March 2022



Note: The S&P 500 index tracks the largest 500 publicly traded companies in the United States. Russell 3000 has 1 000 large and 2 000 small-cap stocks. The MSCI USA Investable Market Index (IMI) is designed to measure the performance of the large, mid and small cap segments of the US market. With 2,470 constituents, the index covers approximately 99% of the free float-adjusted market capitalization in the US.
Source: (Cote and Watanabe, 2022[178])

Lack of interoperability poses another significant hurdle to emission data sharing along supply chains. The challenge of strengthening interoperability of Scope 3 emission data is twofold. First, there is a lack of harmonised GHG accounting and reporting standards (methodological interoperability). Second, there is an absence of common guidelines on data attributes and a common technical infrastructure for data exchange (technical interoperability). Methodological interoperability would ensure comparable data even if collected through different reporting standards. Technical operability would allow for reducing transaction costs and operational inefficiencies (e.g. due to filling in different surveys or spreadsheets to share emission data). The lack of methodological and technical interoperability may be especially burdensome for export-intensive companies operating across multiple jurisdictions, and for SMEs. The latter often do not have the financial resources for the upfront investments in a data collection and sharing system, and the in-house expertise to prepare the Scope 3 emissions data (OECD, 2019[173]). This situation

is further compounded in developing and low-income countries, which typically have less capacity to address these interoperability challenges compared to developed nations.

Overcoming the challenges related to sharing emission data

Several private and public initiatives have emerged recently seeking to address the challenges hampering the sharing of emission data along the supply chain. This subsection sheds light on some of them, highlighting initiatives aimed at resolving methodological interoperability and data confidentiality challenges, and government actions addressing contractual and regulatory obstacles to data sharing.

Initiatives to overcome methodological interoperability challenges

Several private and public sector initiatives have emerged to promote and enhance consistency in GHG accounting (i.e. data collection and measurement) and GHG disclosures. Ensuring these efforts span the complete GHG accounting and reporting process would yield benefits beyond cost-effectiveness. Harmonisation of verification and accreditation standards, for instance, would result in enhanced credibility of (Scope 3) emission data, improving confidence among firms, consumers, and investors. Harmonising GHG accounting and disclosure standards, in turn, would make these standards more objective, thereby increasing the comparability and consistency of product-level carbon intensity metrics across different industries and regions. In addition, such harmonisation could ensure a level playing field for competition, provided these efforts comply with criteria of transparency and inclusiveness (to prevent domination by large market players). While the rise of private and public initiatives underlines the growing commitment to this harmonisation effort, global coordination remains vital to magnify the effectiveness of these initiatives.

Efforts to promote GHG disclosure primarily focus on firm-level rather than product-level emissions. However, recent initiatives that mandate the reporting of Scope 3 emissions could reinforce corporate accountability, thereby encouraging firms to calculate product-level metrics to identify the products contributing most to their emissions. This process necessitates collaboration with supply chain partners to gather and share the necessary data to enable more targeted and effective reduction of Scope 3 emissions.

The initiatives covering GHG accounting and sustainability disclosure fall broadly into two categories (Siew, 2015[179]):

- **Sustainability reporting and GHG accounting standards**: Often developed by governments or standard-setters, they define formal requirements or specifications to consistently measure (at the product level) and report (at the firm level) emissions data.
- **Sustainability frameworks**: They provide more flexible guidelines, including best practices and tools (e.g. ESG software, a reporting platform, etc.) to help companies identify, measure and report their emissions.

Sustainability reporting and GHG accounting standards

The growing consensus towards harmonising sustainability reporting standards has spawned many initiatives in this area. However, they target diverse adopter groups, vary in focus on environmental, social, or economic aspects, and propose diverse requirements for disclosing Scope 3 emissions and carbon intensity metrics (see Table 4.4). The Task Force for Climate-related Financial Disclosures (TCFD) set the stage in 2017 with recommendations for clear, comparable, and consistent sustainability information. Building on this groundwork, the International Sustainability Standards Board (ISSB) issued in June 2023 standards on general sustainability-related and climate-related disclosure to support a comprehensive global baseline. Moreover, individual jurisdictions, such as the EU and the United States, have recently established disclosure requirements. Both requirements draw significantly on the TCFD's recommendations but show differences in some key areas, as highlighted below.

Table 4.4. Selected initiatives providing sustainability reporting standards

Name of the international standard	Date of release	Creator/sponsor	Requirements for Scope 3 emissions	Requirements for carbon intensity
IFRS Sustainability Disclosure Standards (IFRS S1 and S2)	2023	Created by the International Sustainability Standards Board (ISSB), to help meet the demand for 'high quality, transparent, reliable and comparable reporting by companies on climate and other environmental, social and governance (ESG) matters.'	Requires entities to disclose their Scope 3 emissions, subject to the general, single materiality assessment based on the definition included in the standards. An entity is also required to disclose the categories of upstream or downstream activities from the GHG Protocol that are included in the Scope 3 emissions calculation.	It does not explicitly require entities to disclose a single standardised intensity metric because, as noted by the ISSB, the relevant denominator often depends on industry-specific circumstances. However, an entity is required to disclose an emissions intensity metric if that information is material or if the entity's management uses such a metric to manage the entity's climate-related risks and opportunities, or both.
European Sustainability Reporting Standards (ESRS)	2023	Prepared by the European Financial Reporting Advisory Group (EFRAG), a private association established in 2001 to provide technical advice to the European Commission in the form of draft EU Sustainability Reporting Standards on climate and other environmental, social and governance (ESG) matters.	Requires entities to disclose Scope 3 emissions from each significant Scope 3 category, subject to the general, double materiality assessment based on the definition included in the standards. The disclosure should consider the principles, requirements and guidance provided by the GHG Protocol. Entities with less than 750 employees may omit the datapoints on Scope 3 emissions and total GHG emissions for the first year of preparation of their sustainability statement.	Requires companies to disclose their total (over all three Scopes) GHG emissions intensity based on net revenue, subject to the general materiality assessment based on the definition set by the standards.
Rules to Enhance and Standardize Climate-Related Disclosures for Investors	2023	The U.S. Securities and Exchange Commission (SEC), an independent agency of the United States federal government, adopted amendments to its rules under the Securities Act of 1933 ("Securities Act") and Securities Exchange Act of 1934 ("Exchange Act") regarding companies' provision of certain climate-related information in their statements and annual reports.	Requires larger companies (e.g. those with an aggregate worldwide market value of equity of USD 75 billion or more) to disclose Scope 1 and Scope 2 emissions if such emissions are material. The disclosure of Scope 3 emissions is not required.	The disclosure of GHG intensity metrics is not required.
Task Force on Climate-related Financial Disclosures (TCFD) Guidance on Metrics, Targets, and Transition Plans	2021	The Financial Stability Board (FSB) of the G20 created the TCFD to develop recommendations on the types of information that companies should disclose to support investors, lenders, and insurance underwriters in appropriately assessing and pricing a specific set of risks related to climate change. These	Recommends all organisations to disclose absolute Scope 1 and Scope 2 emissions independent of a materiality assessment. The disclosure of Scope 3 emissions is subject to materiality.	The disclosure of GHG intensity metrics is not required, except for specific industries in the financial sector, such as insurance and asset owners. For all other industries, the Task Force defined seven metric categories (e.g. GHG Emissions, Transitional Risks, Physical Risks, etc.) rather than specific metrics, recognising companies may define relevant metrics for their respective

		recommendations were published in 2017. In 2021, the Task Force developed guidance on metrics, targets, and transition plans to reflect evolution in disclosure since 2017. On October 12, 2023, the TCFD indicated that it has fulfilled its remit and disbanded. The IFRS Foundation will take over responsibility to monitor the progress of companies' climate-related disclosures.		industries differently for a given category. In the category GHG Emissions, the weighted average carbon intensity is named as an example of a metric that companies may apply.
Global Reporting Initiative (GRI) Standards	2021 (Universal Standards) 2023 (*draft* Topic Standard for Climate Change Exposure)	The Global Reporting Initiative (GRI) is an international independent organisation that provides voluntary guidelines and standards for sustainability reporting. Its aim is to provide organisations with a standardised method for reporting on their environmental, social, and governance (ESG) performance	An organisation that has determined Climate Change to be a material topic is required to report their Scope 3 emissions according to the 15 Scope 3 categories as set out by the GHG Protocol.	An organisation that has determined Climate Change to be a material topic is required to report GHG emissions intensity ratios, including the specific metrics used as denominators. This metric can vary depending on the organisation's activities, such as using 'tons of product produced' or 'full-time equivalent employee (FTE)' as denominator. Types of GHG emissions included in the intensity ratio(s) should be reported, whether they are Scope 1, Scope 2, or Scope 3 emissions.

Note: The information on Scope 3 emissions and Carbon Intensity metrics for GRI is based on a draft topical standard for Climate Change exposure and is currently still subject to comments. Hence, the draft may change before official publication.
Source: relevant (draft) standards of the relevant organisation or government body.

Some of the recently adopted sustainability standards differ in their requirements for Scope 3 emissions disclosure, emission measurement, and carbon intensity calculation methods. For instance, the sustainability standards of the EU (ESRS), the International Sustainability Standards Board (ISSB), and Global Reporting Initiative (GRI) require companies to disclose Scope 3 emissions if material (in addition to disclosing Scope 1 and 2 emissions), whereas the U.S. Securities and Exchange Commission (SEC) does not mandate Scope 3 emissions reporting. In terms of calculating GHG emissions, the SEC allows for the use of methods other than the GHG Protocol, provided companies describe the used framework or standard. In contrast, the IFRS standards adhere strictly to the GHG Protocol unless a regulatory authority demands an alternative method. Furthermore, standards vary in their approach to calculating intensity metrics; some provide general guidance, whereas others, like the EU's, specify methods based on companies' net revenue. Box 4.4 discusses the European Sustainability Reporting Standards (ESRS) and its requirements in more detail.

Box 4.4. The European Union's European Sustainability Reporting Standards (ESRS)

One of the key pillars of the EU Corporate Sustainability Reporting Directive (CSRD) is the European Sustainability Reporting Standards (ESRS), which companies subject to the CSRD will need to integrate in their reporting from 2025. These standards, tailored to EU policies, were developed by the European Financial Reporting Advisory Group (EFRAG) in partnership with relevant stakeholders. The European standards complement and contribute to international standardisation initiatives such as those led by International Sustainability Standards Board and the Global Reporting Initiative.

On 31 July 2023, the European Commission formally adopted twelve ESRS, spanning two cross-cutting standards (ESRS 1 and ESRS 2), and ten topical standards including environmental social, and governance issues. ESRS 1 establishes general principles for reporting under ESRS but does not specify specific disclosure requirements. ESRS 2 mandates general disclosures for all companies subject to the CRSD and details necessary information regardless of the sustainability issue addressed. All other standards and their specific disclosure requirements are contingent on a materiality assessment.

The standard on climate change establishes that the disclosure of Scope 3 emissions should detail the percentage of emissions that are calculated with primary data (from suppliers), emissions from each significant Scope 3 category, the reporting boundaries, calculation methods, and any calculation tools applied. In line with the GHG Protocol, Scope 3 categories should include indirect emissions from the consolidated accounting group, associates, joint ventures, unconsolidated subsidiaries, and other relationships where the firm can influence operational activities. Regarding carbon intensity metrics, the standard on climate change establishes that firms shall disclose their firm-level GHG emissions intensity in terms of total GHG emissions (including all three emission Scopes) per net revenue. The results of the GHG emissions intensity calculation should be presented for both the market-based and location-based method.

Source: (European Parliament and Council of the European Union, 2022[166])

The key concept of materiality differs across some of these initiatives, adding importance and urgency to efforts to make standards interoperable. The standards of the ISSB and SEC adopt a single-materiality approach, focusing on the sustainability-related risks and opportunities that could affect a firm's (financial) prospects. In contrast, both the GRI standards and the ESRS adopt a double-materiality perspective. This broader approach not only considers how sustainability issues affect the company (financial materiality) but also how the company's operations impact society and the environment (impact materiality). These varying perspectives determine the extent of reporting obligations, with the EU's framework resulting in more extensive disclosures aimed at a broader range of stakeholders than the ISSB and SEC, which focus on information pertinent to investors' financial decision-making only. However, the ISSB's standards are intended to provide a global baseline and to be compatible with jurisdiction-specific requirements, including those aimed at broad stakeholder groups. Moreover, in January 2024, the IFRS Foundation and GRI detailed interoperability areas for companies to consider when measuring and reporting Scope 1-3 emissions under both GRI and ISSB Standards.

Sustainability frameworks

Numerous sustainability frameworks have recently emerged to provide flexible guidelines to help companies identify, measure, and report their emissions. Among them, the non-profit organisation Carbon Disclosure Project (CDP) provides training services to upskill suppliers (e.g. emission accounting support) and a standard framework for reporting emission data (Scope 1-3) through an online questionnaire. This questionnaire is aligned with the 15 Scope 3 emissions categories outlined by the GHG Protocol, but leaves it to participants to identify relevant categories.[22] Despite these comprehensive efforts, 11 of the 15 categories accounted for only 7% of the total Scope 3 emissions disclosed through CDP in 2022, though some of these 11 categories are emission hotspots for certain sectors (CDP & Capgemini, 2023[180]). This underscores the challenges and resulting incompleteness of Scope 3 emissions reporting across industries and countries. Box 4.5 provides more information about CDP.

The PACT Pathfinder Framework takes a cross-sectoral approach to assist organisations in developing and exchanging product carbon intensity metrics along the supply chain. Established in 2022 through a collaboration between the World Business Council for Sustainable Development (WBCSD) and multiple industry groups, the Pathfinder Framework issues guidance on data collection, verification, measurement, and reporting. A growing number of companies across industries have been adopting the Pathfinder Framework, which is discussed in more detail in Box 4.5.

Box 4.5. Selected frameworks to promote and enhance consistency in GHG accounting and reporting

The Carbon Disclosure Project (CDP)

The Carbon Disclosure Project (CDP) is a global platform enabling companies, cities, states, and regions to report their environmental impact, including GHG emissions, water use, and deforestation. The CDP provides a standardised framework to report emission data through an online questionnaire. Based on this self-reported data, the CDP scores companies with respect to their environmental transparency and action. The CDP also provides companies with specific guidance on the most relevant Scope 3 emission categories per sector. This may help companies to identify emissions hotspots in their supply chain. Furthermore, via its supply chain program, the CDP also assists companies to collect GHG emissions data information from their suppliers. While there is no obligation to report through the CDP, over 5 800 European companies and over 150 European local governments disclose environmental information through the CDP. In recent years, CDP has made efforts to align best practice with other frameworks or standard setters (e.g. GRI).

The Pathfinder framework

The Pathfinder Framework is a collaborative initiative led by the World Business Council for Sustainable Development (WBCSD) and other stakeholders. The Pathfinder Framework provides a standardised approach to Scope 3 emissions accounting and reporting, enabling companies to track and report emissions across their supply chain. The framework includes guidance on data collection, reporting, and verification. It has been adopted by a growing number of companies across industries. The Pathfinder Framework builds on both ISO and GHG Protocol standards and focuses on ‘cradle-to-gate’ emissions only. This has the advantage that it allows reporting firms to focus on emissions that have occurred before a given product is sold onwards. This avoids making assumptions about emissions that

[22] The GHG Protocol outlines 15 distinct Scope 3 categories, including 8 upstream categories (such as purchased goods and services, and business travel) and 7 downstream categories (transportation and distribution, and use of sold products).

depend on a product's downstream use. One of the distinct features of the Pathfinder Framework is that it also provides a technical IT specification that enables companies to securely exchange product-level emissions data across technology solutions and data exchange platforms (as discussed in Box 4.6).

Source: (CDP, 2024[181]; WBCSD, 2024[182])

Private-sector initiatives to overcome technical interoperability and data confidentiality challenges

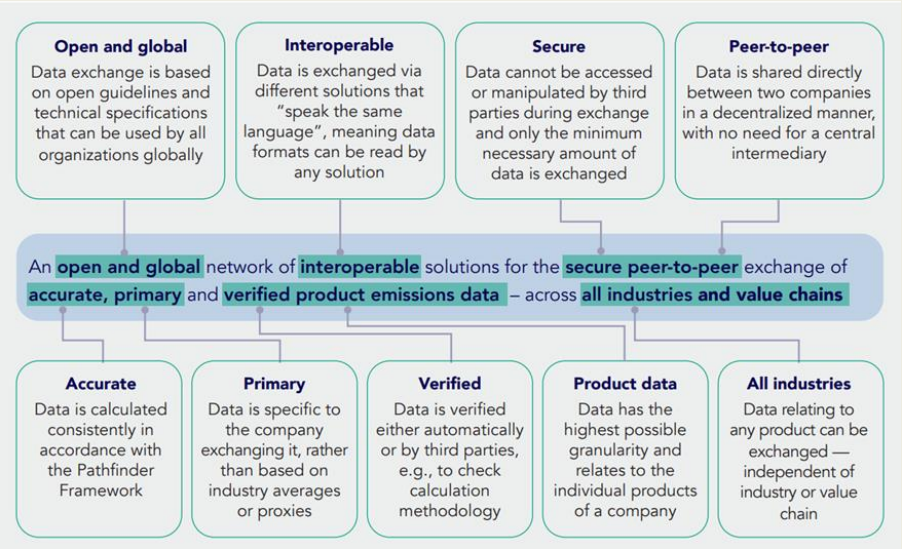
Several private sector initiatives have emerged to solve the issue of technical interoperability while addressing countries' and companies' concerns over data sovereignty and confidentiality. The target group of these initiatives varies, with some having cross-sectoral memberships and an industry-agnostic focus, while others concentrating on specific industries. Furthermore, some initiatives prioritise accessibility by lowering entry barriers, while others seek to foster trust among participants by setting demanding requirements (increasing entry barriers). There are various initiatives working in this area. This subsection focuses on two of them that exemplify the different target groups these initiatives cover and the trade-offs they face between ensuring data privacy and fostering trust, on the one hand, and designing data-sharing platforms with wide accessibility, on the other.

The PACT Pathfinder Network aims to establish a global network for the secure peer-to-peer exchange of product-level carbon intensity data across firms and industries. It was developed as the technological counterpart of the PACT Pathfinder Framework (discussed above) by the WBCSD and the SINE foundation - in collaboration with different stakeholders like technology companies and standard-setting bodies. At the core of the PACT Pathfinder Network is an open technical specification enabling the interoperable exchange of emissions data among organisations and across diverse technology solutions (e.g. emission accounting software). This approach minimises transaction costs for new members to join, allowing for global scalability of the network to connect organisations of different sizes, supply chains and product categories. Box 4.6 discusses the key features of the network in more detail.

Box 4.6. The PACT Pathfinder Network: an open and global network of interoperable solutions for the secure exchange of product-level carbon intensity data

The PACT Pathfinder Network aims at creating a global, interoperable network for the secure and accurate peer-to-peer exchange of emissions data across industries and supply chains. Unlike individual technology solutions, which for instance support organisations in their emissions data management (e.g. storage, calculation, analysis), the Pathfinder Network provides an infrastructure to which different technological solutions can connect to share emission data (Figure 4.6).

Figure 4.6. Key features of the Pathfinder Network initiative



Source: (WBCSD, 2024[182])

Central to the network is an open technical specification, similar to the standardised exchange of emails, which ensures interoperability, transparency and accessibility for firms irrespective of geography, size, or industry-affiliation This approach fosters collaboration and allows for the participation of various stakeholders, including businesses and technology companies, thereby mitigating lock-in risks and minimising transaction costs for new members to join. By leveraging an open-source technology, the network also promotes innovation and allows for continuous improvement and customisation to meet the evolving needs of users.

The network recognises the importance of data sovereignty and confidentiality concerns that countries and companies may have. The network is based on a peer-to-peer exchange of data, allowing for the sharing of data directly between two companies. This decentralised approach also mitigates cybersecurity risk. Additionally, the governance of the network ensures legal and organisational structures for data control, trust, and collaboration and include, for instance, fraud prevention measures.

Source: (WBCSD, 2024[182])

Developing a global network infrastructure, wherein diverse technological solutions can seamlessly interconnect, is a promising avenue. This entails collaboration among firms, technology companies and standard-setting bodies to establish common (industry-specific) guidelines on data exchange and technical specifications. Common guidelines on data exchange, including data attributes, will ensure that data is formatted in a way that is transmissible to and readable by the intended users. In this regard, industry practitioners in life cycle assessments highlight the need for well-defined interfaces and data exchange formats, including sector or even industry wide product-specific (unique) identifiers to allow precise data mapping (Jaeger et al., 2022[183]). Common technical specifications, in turn, will ensure compatibility and seamless communication between different technological solutions (e.g. software and IT systems). This will ensure that companies can still choose the technology solutions which best fit their specific needs.

The adoption of digital technologies is key to ensure data privacy and security within this global network infrastructure. Recent improvements in computing power have made the practical use of

advanced encryption technologies increasingly feasible (WEF, 2019[184]). These technologies, including "zero-knowledge proofs" and "secure multi-party computing," allow firms to engage in data sharing while preserving privacy (Stenzel and Waichman, 2023[169]). For instance, zero-knowledge proofs enable a firm to confirm compliance with specific criteria, such as meeting certain carbon footprint thresholds, without revealing additional sensitive information. Secure multi-party computing protocols facilitate the analysis of combined data (e.g. carbon intensity metrics) without exposing individual inputs (e.g. emission and output data), and ensure data is shared on a need-to-know basis. The integration of these cryptographic measures enhances firms' willingness to share confidential information (Jones and Tonetti, 2020[185]). Additionally, blockchain technology could enhance trust and product traceability by providing a transparent and immutable record of transactions, supporting for instance, initiatives aimed at tracking the lifecycle of products through supply chains. These digital innovations could therefore become instrumental in overcoming data privacy and security hurdles in the secure exchange of emission data.

Beyond the technical aspects of network infrastructure, establishing an open governance framework could support data exchange while respecting companies' rights and promoting responsible behaviour. By guiding the operation of the network infrastructure, open governance frameworks can empower companies to maintain control over their data and support them in building trust with other firms in their supply chains. Extending the analysis by Ostrom (2012[186]) on the economic governance of commons (i.e. common-pool resources, such as ecosystems) to the issues of data sharing, the SINE foundation developed three core values on which such governance frameworks should be built.[23] These include reciprocity (i.e. firms need to rely on reciprocal relationships and mutual benefits), security (i.e. cryptographic measures can ensure the safe exchange of data) and openness (i.e. open and interoperable software solutions decrease efforts for new members to join and existing members to leave, increasing the scalability of the network). Implementing these core values may contribute to an open, secure, and fast network infrastructure (or in the spirit of Ostrom's work, a "data commons") for sharing product-level carbon intensity data. A notable example of this approach is the PACT Pathfinder Network (discussed above), which leverages these principles in its operations.

Catena-X seeks to develop an agile, secure data-sharing platform focusing on the automotive supply chain. It was initiated as a consortium of leading automotive companies, and collaborates with manufacturers, suppliers, and dealers, with a special focus on integrating SMEs. Catena-X adopts a decentralised, peer-to-peer approach for data exchange, akin to the PACT Pathfinder Network. Its technical foundation rests on a data connector that must be installed at each participant's site, serving as a gatekeeper for incoming and outgoing data. This setup enables automated negotiations of data usage contracts between participants through the data connector. Such a mechanism protects data ownership, as companies can specify the parameters of how and when to share data, with whom and under what conditions. Alongside the technical infrastructure, Catena-X has developed a Governance Framework. This framework outlines the requirements and responsibilities of participants and sets industry-specific standards, such as carbon footprint methodologies and data attributes. To engage with Catena-X, companies must undergo an audit to ensure compliance with its standards. While this audit and the required data connector raise entry barriers, it also strengthens trust and transparency within the platform.

Government initiatives to address contractual and regulatory challenges to data sharing

Various governments worldwide have enacted regulations to facilitate the free exchange of data between governments or federal states, the private and public sector, or along supply chains. An

[23] The SINE Foundation is a non-profit organisation founded by academic experts and entrepreneurs. SINE aims to design and implement tools for lasting data collaboration — delivered as ready-to-use governance tools and Open-Source software.

example of a jurisdiction that recently enacted legislations to facilitate data exchange across borders and supply chains is the EU, informed by its February 2020 European strategy for data.

While these legislative initiatives do not explicitly focus on emissions data, they create a supportive framework for data sharing in general. They also offer a means to navigate around issues such as digital security, intellectual property rights, national security, and competition law that may pose challenges to sharing emissions data. Table 4.5 provides a concise overview of the key provisions of the selected EU initiatives and their potential impacts on emission data sharing. Box 4.7, in turn, discusses these initiatives and their potential impacts in more detail.

Table 4.5. Selected EU legislative initiatives and their potential impact on emission data sharing

Initiative	Key provisions	Potential impact on emission data sharing
Free Flow of Non-Personal Data Regulation (2018)	Prohibits data localisation requirements for non-personal data within the EU, unless justified on grounds of public security.	Could facilitate the cross-border flow of emissions data within the EU, as emissions data is typically non-personal.
Data Governance Act (2022)	Encourages voluntary data sharing in neutral 'data spaces'; includes rules for data intermediaries to ensure trustworthiness; aims to improve availability, quality, and interoperability of data.	Enhances data-sharing mechanisms, potentially encouraging firms to share emissions data in a secure and trustful environment like 'green data spaces'.
Data Act (2023)	Addresses usage rights of data in the digital economy; promotes fair and balanced data-sharing contracts; mandates sharing of certain data in high public interest situations.	Could mitigate contractual and legal uncertainties in sharing emissions data; may promote sharing of emissions data in high public interest situations.

Source: Regulations of the EU published in the Official Journal of the European Union.

Box 4.7. Key EU legislative initiatives for data sharing

The EU has launched different primary legislative initiatives to enhance data sharing and access. These legislative initiatives aim at creating a supportive framework for data sharing in general, which may also facilitate the sharing of emissions data.

Free Flow of Non-Personal Data Regulation

The Free Flow of Non-Personal Data Regulation was adopted in 2018 to, among others, counter data localisation requirements within the EU. It restricts Member States from imposing such requirements for non-personal data, barring justifications on grounds of public security. The objective of this regulation is to ensure that data can be stored and processed anywhere within the EU, thereby lifting any barriers on data mobility. Given that emissions data is typically non-personal, this regulation could potentially ease the cross-border flow of such data.

The Data Governance Act

Effective from June 2022, with a 15-month grace period, this Act focuses on increasing the availability and reliability of data and fostering trust in data intermediaries. The Act envisions a data-sharing model where companies voluntarily share their data in 'data spaces'. These data spaces aim to make data easy to find, accessible, interoperable and re-usable, while ensuring a high level of cybersecurity. The data spaces can be cross-sectoral, sector-specific, or purpose-specific, such as a 'green data space',

The data spaces also include governance structures, compatible with relevant EU legislation, which set rights and obligations for data access and processing. The Act also outlines rules for data intermediaries

to ensure that they operate as trustworthy organisers of data sharing within the common European data spaces.

The Data Act

The Data Act, adopted in November 2023, aims to address issues relating to the usage rights of data generated in the digital economy. The new legislation includes measures to help businesses negotiate fair and balanced data-sharing contracts with stronger counterparts. Clauses deemed 'unfair', like those stating that a company can unilaterally interpret the terms of the contract, will not be binding on European enterprises. These measures aim to protect EU companies from unfair agreements and protect SMEs.

The new law also aims to ensure an adequate level of protection of trade secrets and intellectual property rights. To prevent possible abusive behaviour, it also provided safeguards for exceptional circumstances and dispute settlement mechanisms.

In addition, the Data Act will enable users of connected products (e.g. cars, medical and fitness devices, industrial equipment) and related services (e.g. an application to control light brightness or to set refrigerator temperatures) to access the data that they co-create by using the products or services.

By setting clearer rules for data access and usage, and by promoting fair practices, the Data Act could help to alleviate the contractual and legal uncertainties that firms face when sharing emissions data along their supply chains.

Source: (European Parliament and Council of the European Union, 2023[187]; European Parliament and Council of the European Union, 2022[188]; European Parliament and Council of the European Union, 2018[189])

5 Principles to guide the development of carbon intensity metrics and the design of policies based on them

Key Messages

- Uncoordinated efforts to increase the use of carbon intensity metrics risk economic distortions that weaken competition, fragment supply chains and diminish innovation incentives.
- As a first step towards greater coordination, countries could adopt principles like ensuring proportionality, promoting innovation and competition, and fostering interoperability. These principles are consistent with those of the UNFCCC and can underpin the development and use of carbon intensity metrics in policies while helping to minimise economic distortions.
- As a "safe space" for peer exchange and mutual learning, the IFCMA can play a key role in establishing common, consistent and effective approaches.

This section puts forward economic principles that countries interested in further developing carbon intensity metrics and introducing policies based on them may wish to consider. Further efforts to develop and promote the use of more granular and timely carbon intensity metrics based on these principles could help to minimise economic distortions. These distortions may arise due to duplication in data collection efforts, differences and inconsistencies in computation methods, and high administration and compliance costs for firms. Failure to adhere to the principles is likely to weaken competition, fragment supply chains and stifle innovation incentives. This can make it harder to achieve the ambitious decarbonisation targets countries have set.

The proposed principles are consistent with the UNFCCC principles (UN General Assembly, 1992[190]) **of common but differentiated responsibilities and respective capabilities (CBDR-RC), sustainable development, international co-operation and open international economic systems.** They are:

- **Ensuring proportionality**: striking a balance between accuracy and resource requirements, which may differ across sectors, products and use cases;
- **Promoting innovation and competition**: enhancing innovation incentives to decarbonise production processes and preserving open markets and a level playing field at national and international levels;
- **Fostering interoperability**: developing processes, methods and infrastructure in different regions, countries, sectors or products that share common foundations and can "speak" with each other to avoid multiple reporting requirements and increasing firms reporting costs.

The IFCMA could further develop these principles and propose guidance to promote concrete action towards common, consistent and effective approaches. As a "safe space" for peer exchange

and mutual learning, the IFCMA could bring together different country and private sector perspectives to support common understanding on these issues and make progress while ensuring compliance with international economic and trade rules, and being respectful of countries' differences in economic structure. The work to further develop these principles and guide concrete actions will also need to recognise trade-offs that could arise from them and seek to establish more granular versions of these principles relevant to either the computation of carbon intensity metrics, the implementation of policies based on these metrics, or both. Implementing these principles would need to be a gradual process that recognises the capabilities of different countries.

Ensuring proportionality

Proportionality is a core regulatory principle. Its aim is to limit government action to what is necessary to deliver specific policy goals (Angeloni, 2018[191]). It involves tailoring policies to avoid excessive compliance costs or regulatory burdens that could unduly dampen competitive positions without a clear justification (Lautenschläger, 2017[192]). Such burdens can be disproportionally heavy for small business, thereby potentially reducing market entry and competition (OECD, 2019[193]).

Proportionality is often enshrined in regulation. For example, in the banking sector, the Basel Framework allows for a degree of proportionality**.** It provides options to implement simpler standardised approaches, recognising that financial systems are heterogeneous and that a one-size-fits-all approach may not be best (Basel Committee on Banking Supervision, 2022[194]) In insurance regulation, the application of a proportional approach seeks to increase the diversity of market participants and develop the industry (Restoy, 2018[195]). The G20/OECD Principles of Corporate Governance also outline the responsibility of policy makers to ensure regulatory frameworks are flexible and proportional (OECD, 2018[196]). The OECD's Best Practice Principles on Regulatory Impact Assessment and the Recommendation of the Council on Competition Assessment point to the importance of independent oversight for adopting proportional approaches early in the policy-development stage (OECD, 2020[197]; OECD, 2019[198]). In the case of the EU, the principle of proportionality has been explicitly recognised in the main legal instruments for the application of EU Competition Law (competition issues are discussed below).

Policies that require the calculation of carbon intensity metrics may require different levels of accuracy or frequency. As discussed in Section 2, taxes or subsidies whose eligibility depend on the level of carbon intensity metrics of goods or firms are likely to require a high level of accuracy and frequency of recalculation as tax or subsidy payments will depend on such metrics. Carbon intensity metrics to track aggregate decarbonisation progress or provide general information may not need the same level of accuracy or frequency of recalculation.

Tailoring accuracy requirements to the intended use case would help reduce the cost of policy implementation align with a proportional approach. The proportion of emissions by scope will vary by product or product category (see Section 4). For example, in the financial services sector, the percentage of emissions coming from Scope 3 sources can be almost double that arising from Scope 1 and 2 sources, whereas for cement it can be less (World Business Council for Sustainable Development, 2016[199]). Moreover, many factors (e.g. seasonal variations in power demand) can lead to differences in the carbon intensity of two identical products coming off the same supply chain at different times of the year. Highly accurate carbon intensity metrics must account for all emission scope categories and variances in the metric for each individual unit being produced, but high accuracy can be unnecessary for many use cases. A proportional approach would help to avoid unnecessary costs for firms.

The implementation of policies that require the calculation of carbon intensity metrics can impact firms in different ways. Generally, the greater the accuracy, granularity and recalculation frequency required, the higher firms' compliance costs. Larger, higher-capacity firms are more likely to be able to

comply with strict and exacting regulatory requirements than SMEs, start-ups or firms in developing countries.

Firm characteristic-specific regulatory requirements (i.e. asymmetries in regulatory requirements) may help preserve and enhance competition in cases where firms have different levels of capacity to meet such requirements. Such design features would diminish the risks of market exclusion for firms that are initially unable to meet regulatory requirements, such as the computation of product-level carbon intensity metrics using primary data or producing products with a carbon intensity below a certain threshold. Larger firms are also more likely to have a higher impact on emissions, which may justify a different treatment. Such arrangements could be temporary to give firms time to invest and build the necessary capacity. Examples of asymmetries in regulatory requirements include the EU Digital Markets Act, where obligations are triggered when a digital platform is assigned a "gatekeeper" status (i.e. if the platform provides an important gateway between businesses and consumers in relation to core platform services like internet search). Similarly, all EU telecoms regulation imposes different obligations for those with significant market power. Additionally, the 2022 Sarbanes-Oxley Act in the United States includes differentiated requirements for financial record keeping and reporting depending on the size of the firm and the industry it operates in being regulated. More broadly, most emissions trading systems (ETS) have a cut-off size of covered installations, so that small-scale emitters either do not have to comply with ETS rules or can do so in a simplified manner.

Derogations can be used to help ease the burden of computing carbon intensity metrics on firms, especially SMEs and those based in developing countries. Governments could consider requiring some firms to compute accurate carbon intensity metrics only for specific products. One approach could be to use materiality criteria and require accurate computation only for those products that account for a large share of a firm's total emissions, while allowing for the use of default values, assumptions, or extrapolation for other products. Such an approach is consistent with one taken to corporates' climate disclosures (OECD, 2018[196]). To be effective, the approach would need to ensure it provides a fair estimate of carbon intensity metrics based on default values whilst maintaining firms' incentives to decarbonise (OECD, 2023[200]). Moreover, mandatory Scope 3 emission reporting for larger firms can act as a catalyst, encouraging these companies to work with and support their suppliers (especially SMEs, through for instance upskilling programme, sharing data infrastructure and know-how) in collecting and sharing the necessary data along the supply chains. However, mandating such reporting risks facilitating collusion (as discussed further below). Additionally, governments could consider providing further derogations allowing for the use of default values in specific cases, such as the calculation of emissions relating to end-of-life treatment of sold products (i.e. Scope 3 – Category 12 of the GHG Protocol). Derogations could be applied based on aspects of a given policy other than carbon intensity metrics such as in the case of the United Kingdom's ETS (see Box 5.1).

Box 5.1. UK Emissions Trading Scheme (UK ETS) for Hospitals or Small Emitters (HSE) scheme.

The UK ETS HSE scheme is designed to relieve some of the compliance burden of the UK ETS on specific installations. Under the HSE scheme, installations have annual emissions targets assigned to them by the regulator instead of having to surrender allowances.

Eligibility

Operators providing services to hospitals can apply if at least 85% of the heat produced by the installation in a scheme year is used by or supplied to one or more hospitals.

Installations emitting less than 25 000 tonnes of CO_2e each scheme year in the relevant period and having a total rated thermal input of less than 35 megawatts (MW) in the relevant period (if applicable), can be classed as small emitters and can thus apply.

Scheme Terms

For every scheme year for which an eligible installation is under the HSE scheme, it must ensure that the installation's reportable emissions do not exceed that year's emissions target. Targets are included in the hospital or small emitter permit based on the installation's historic emissions, multiplied by an annual reduction factor.

Where firms do not have full year of emissions data when their installation becomes an HSE, their initial target will be based upon an estimate of forecasted emissions. When a full year of emissions data is available, the regulator will calculate targets for the remainder of the relevant allocation period.

If the installation's reportable emissions are less than their target, this can be banked for future years.

Source: (UK Government, Scottish Government, Welsh Government, and the Department of Agriculture, Environment and Rural Affairs for Northern Ireland, 2023[201])

In general, segmentation of firms based on their characteristics can help ensure any derogations are fairly applied. Following the example of the banking system (Basel Committee on Banking Supervision, 2022[194]), firms could be categorised by their size, emissions profile, capability, the range of products they produce, and whether these products have any alternatives (Greenhouse Gas Protocol, 2011[5]). Whilst regulatory stability and predictability tend to create favourable operating environments for firms, regular reviews can help systems from becoming outdated (OECD, 2023[200]). As with any other regulation, authorities may revise the scope and range of proportionate approaches and asymmetries in regulatory requirements based on the evolution and progress made in the carbon intensity reporting systems and calculation methods, and as firms' capabilities evolve and improve. Derogations may become less necessary over time and could be subject to sunset clauses.

The goal of proportionality and asymmetries in requirements is to adapt to the conditions and capabilities of regulated firms without compromising the overall policy objective. Therefore, in the context of the net-zero transition they should be viewed as a transitional stage in the adoption of standards which are to be applied more widely and with a higher level of stringency over time. (Restoy, 2018[202]). Transition periods can also help to safeguard competition as firms build the capacity to comply with regulations. The inclusion of transition periods in policies give firms time to understand relevant legislation and make the necessary adjustments to their business models and supply chains. This is particularly important for policies with cross-border impacts, as firms in developing countries may need time to adjust.

Regulators and government agencies need to have the capacity to ensure effective oversight of policies that use carbon intensity metrics. Derogations and requirements differing across firms may reduce compliance costs but increase the cost to monitor such a regime. Regulators may also face challenges due to information gaps and uncertainties about technological developments. Overall, regulators' capacity is likely to differ across countries. For example, in the EU, there already exists a system of determining the best technologies available for emissions reduction through an exchange of technical information between experts from industry, EU Member State authorities, research institutes and NGOs (IEA, 2017[203]). How to best allocate the burden sharing between private and public entities is an important issue that could be explored in the IFCMA's future work.

Promoting competition and innovation

Competition is a key driver of growth and rising living standards. It benefits consumers by promoting lower prices, higher product quality and enhancing innovation. Competitive markets generate incentives for firms to carry out product and process innovation as they seek to maximise profits and survive (OECD, 2023[204]; OECD, 2023[200]). Competition also enables consumers to select the products and services that best meet their needs (OECD, 2008[205]). Moreover, the challenge of reaching net zero requires innovation as many of the technologies required to deliver emissions reductions do not yet exist or are not mature enough for commercialisation (IEA, 2021[206]).

Regulations and policies aimed at lowering the carbon intensity of goods and sectors could potentially diminish competitive pressure and innovation incentives. Many policies may innately foster innovation and competition. On the other hand, certain policy approaches may do the opposite. For instance, some regulations relating to carbon intensities may involve high compliance costs (as analysed above), thus curtailing resources for research and development activities, especially for small firms and start-ups. Such high compliance costs may also act as barriers to entry, reducing competition for incumbents and entrenching their dominant position. Incumbents can also lobby for rules and approaches that favour their established production methods and business interests to the detriment of competition and disruptive innovation. Well-designed regulations can help reduce these compliance costs, as outlined in this report. Overly prescriptive regulations can reduce risk taking as firms may avoid experimenting with new ideas and products that may not comply with regulations or increase the costs of doing so. If regulations mandate or are based on specific technologies or production processes, established firms might mostly focus on compliance, forsaking the development of alternative technologies or production methods that could achieve the same policy goal more easily. Technology developments and the macroeconomic environment can require changes to regulations to avoid them becoming outdated. On the other hand, frequent changes can brew uncertainty, weakening investment and innovation incentives. A fixed schedule to review policies and regulations could help strike a balance between these two opposing considerations.

Output-based regulation and performance standards may be better suited to drive innovation than input-based regulations as they require monitoring numerous inputs into the production process (Poudineh, Peng and Mirnezami, 2020[207]). Standards and policies that promote the development and use of – or are based on – product-level carbon intensity metrics need to be designed in ways to protect and enhance innovation and competition. Output-based regulations, including performance standards, allow companies more operational flexibility to achieve the desired aim (e.g. lower carbon intensity) than prescriptive input-based regulation by adapting production processes and developing new products (OECD, 2023[200]). Experience from the United States on output-based regulations for combined heat and power plants and on hearing aid sales points in this direction (Revesz, Richard L., 2023[208]; Environmental Protection Agency Combined Heat and Power Partnership (United States), 2014[209]). Both output-based and input-based regulations aiming at lowering products' carbon intensity require the development of clear and transparent methodologies for the computation of carbon intensity metrics and the collection of data to compute them.

Policy guidance from governments that is product-specific and allows for the use of functional units would promote comparability and thus competition. Such an approach would, for example, recognise that builders may face trade-offs using timber, concrete and steel as structural materials in the construction sector. Comparable carbon intensity metrics based on a product's functional unit can help firms to decide what to produce while preserving competition in the market. "Function-based" carbon intensity metrics (see Section 4 discussion on functional units) would be akin to performance standards based on products' functionality and would guarantee entry as long as the function provided by the products meet the agreed standard.

Undertaking competition assessments prior to the implementation of regulations and guidelines concerning carbon intensity metrics could help to minimise negative impacts on competition. In line with OECD (2019[198]) guidance, governments should assess whether new policies may either limit the number or range of suppliers, limit the ability of or reduce the incentive for suppliers to compete, or limit the choices and information available to customers. For instance, public procurement rules based on product-specific characteristics (e.g. carbon intensity below a certain threshold) have the effect of limiting the range of potential suppliers and ability of some firms to compete. These adverse effects on competition would need to be assessed taking into consideration the overall policy goals of lowering the carbon intensity of production (e.g. decarbonising steel, cement production) and absolute emissions.

Actions to safeguard competition should also balance considerations for innovation incentives. In general, where a new policy or regulation relating to carbon intensity poses a tangible risk to competition (e.g. the calculation and disclosure of product-level metrics may limit entry into markets), governments might consider whether the benefits of the policy outweigh the harm to competition (OECD, 2019[210]). In some cases, a slight modification to the design of a regulation (e.g. by allowing new entrants to use default values for a period of time) can substantially enhance competition while still delivering the main policy goals (Revesz, Richard L., 2023[208]).[24] A dynamic competition approach to assess market structure and its long term effects on competition and innovation (Petit, Heiden and Schrepel, 2024[211]; OECD, 2023[200]) can better combine the aim of safeguarding competitive pressures with other policy goals (e.g. reducing emission intensity, which demands significant and additional innovation efforts).

The basis of promoting competition is preventing abuse of market power. Market power may arise because of various reasons and be used by firms in different ways. Not all occurrences of market may be anti-competitive, especially if innovation and higher product quality are the source of market power. Where there is a likelihood that a firm's market power may be significant, competition authorities can monitor them more closely for any potential abuses of market power (Department for Digital, Culture, Media & Sport and Department for Business, Energy and Industrial Strategy (United Kingdom), 2021[212]).

Initiatives and regulations aiming at facilitating the sharing of emissions data should strive to ensure that data transparency necessary to compute carbon intensity metrics does not undermine competition. The computation of carbon intensity metrics requires the sharing of emission data. Data transparency is generally beneficial to competition, bolstering allocative and productive efficiency, and enlarging consumer choices. However, in some instances data transparency can facilitate tacit collusion among competitors. In concentrated markets, it can enable firms to tacitly collude to increase prices, share or allocate markets. It can also make it easier for co-operating firms to detect and therefore punish deviating firms (OECD, 2010[213]). Governments could monitor these risks and take appropriate action where merited.

Interoperability of methods, systems and infrastructure

Interoperability is the ability of a system or a product to work with other systems or products without any special effort required from the user (Miller, 2000[214]). In a digital context, interoperability is the ability of systems to combine and use data from various sources with ease, coherence and efficiency (OECD, 2023[215]). Similarly, in the context of carbon intensity metrics, interoperability would facilitate the combination and use of data from various sources and ensure correct comparisons.

For carbon intensity metrics the challenge of strengthening interoperability is twofold (see Section 4). First, methodological interoperability would ensure comparable data even if collected through different reporting standards. Second, technical interoperability would allow for reducing transaction costs and

[24] See the "Illustrative policies and ways of mitigating their negative effects on competition" table in the guidance from Canada for some good examples of potential mitigations (Competition Bureau Canada, 2020[31]).

operational inefficiencies (e.g. due to filling in different surveys or spreadsheets to share emission data). The OECD Recommendation of the Council on Enhancing Access to and Sharing of Data (OECD, 2021[216]) outlines actions to achieve interoperability, which the IFCMA could explore in future work.

Policy design that ensures interoperability can promote consumer choice and allows for more flexibility in production choices. For example, when the United States Federal Highway Administration set standards for electric vehicle chargers funded by the Bipartisan Infrastructure Law, it required those chargers to have consistent plug types, power levels, and application accessibility (Revesz, Richard L., 2023[208]). Interoperability across methods, systems, and infrastructure for carbon intensity metrics is crucial to ensure consumers can compare different products and limit firms' compliance costs when accessing different markets. Interoperability also promotes increased competition by reducing entry barriers for new firms by giving them the ability to pick from a series of approaches that suit them best without compromising the reliability and comparability of carbon intensity metrics (Scott Morton et al., 2021[217]).

Interoperability of methods and standards to compute carbon intensity metrics would prevent them from becoming an obstacle to international trade and supply chains (White et al., 2021[218]). Efforts of several public and private sector organisations to strengthen methodological and technical interoperability underlines the growing commitment to facilitate the computation and use of product-level carbon intensity metrics (see Section 4). However, they also risk resulting in multiple and inconsistent approaches. Improved coordination among these initiatives is vital to ensure and magnify their effectiveness.

Drawing upon the experience of existing public sector and private sector efforts could help to progress towards international or interoperable reporting standards. Through coordinated efforts, countries can work together to identify divergences in approaches and draw upon the experience of existing efforts to agree on a way forward towards the potential development of reporting standards in the future. Examples of recent public and private sector efforts in this direction include the guidance being developed for the UK and the EU's respective Carbon Border Adjustment Mechanisms, the French low emission vehicle subsidy schemes (see Box 2.1), the establishment of a common global approach to food labelling (see Box 2.7), and the development of the ISSB standards aiming aim to provide a global baseline for company reporting on sustainability (see Section 4).

Governments could build on existing domestic and foreign public sector efforts, instead of starting from scratch. In most countries, the private sector has taken a lead in designing approaches for the reporting of carbon intensity metrics. However, as efforts towards mitigating emissions increase, governments have begun to develop and implement policies that require the measurement of carbon intensity (see Section 2). To avoid further fragmentation and mitigate the risk of disproportionate economic distortions, governments could build on existing approaches, particularly those from key export markets, to maximize interoperability (World Economic Forum, 2023[219]; Deconinck, Jansen and Barisone, 2023[7]). This means that when regulators or policymakers are designing a use case for carbon intensity metrics, they should consider how it can dovetail into other initiatives or drive concordance between different initiatives.

Guidance on the calculation of product-level carbon intensity metrics would help promote interoperability of methods and comparability. Section 4 has underlined that carbon intensity calculations require product and process-specific information. For example, computing the carbon intensity of steel made from a blast furnace and an electric-arc furnace require different sets of information and data specific to these production processes. Relying only on broad catch-all guidance would defer a number of accounting decisions to firms, resulting in hard-to-compare metrics. Specific guidance would help promote comparability and avoid inconsistent approaches even for identical products – supporting the interoperability of methods. However, overarching guidance can be useful in providing principles and

general approaches applicable to broad sectors, as done recently for the chemical industry (Together for Sustainbility, 2024[147]).

Governments could work with domestic and multinational industry groups involved across each product's supply chain to co-operate and agree on approaches to solve methodological challenges. Section 4 outlined the range of private sector actors that are working to resolve methodological and data sharing issues across their respective areas of expertise. In this context, governments could play a convening role or even mandate a standard on which there is widespread agreement (Gasser and Palfrey, 2008[220]). Government involvement may also be required to bring together all parties with an interest in the production of a strategic and highly complex (multi-input) good.

Given the centrality of the Harmonized Tariff System (HTS) to trade, countries could align product classification for their carbon intensity computation with this system, thus reducing fragmentation and fostering interoperability of methods. Where required, trading partners could work through multilateral or plurilateral fora and via bilateral relationships to agree on more granular classifications going beyond the six-digit level (e.g. to the eight, nine, or ten-digit level) to facilitate alignment of HS codes with product-level carbon intensities (Reid, 2022[221]; World Trade Organisation (WTO), 2021[222]).

Interoperability among reporting systems could promote consistency between product-level metrics and national emissions reporting frameworks. In the long term, carbon intensity metrics could aim to be consistent with or based on national emissions reporting frameworks to reduce inconsistencies and double counting. National emissions reporting frameworks (see Section 2) have been established as part of an international architecture resulting in a broadly comparable and consistent approach. If product-level carbon intensity metrics are treated as separate from national emissions reporting frameworks there is a risk that inconsistencies and double counting could arise. Such issues could also reduce public confidence in the metrics. Consistency would mean that if the output of each of the main polluting products in a country was multiplied by its carbon intensity and added up, this would account for a large share of country's reported total emissions (after accounting for methodological differences between national and product-level metrics, e.g. territorial emissions for national aggregates, versus life-cycle assessment for product-level metrics). Innovations in methodologies and the use of common sources of data could help in this respect.

Policies could encourage the use of primary data and the standardisation and sharing of Scope 3 emissions data, while taking into account proportionality considerations. For example, whilst transport related emissions can be an important determinant of the overall carbon intensity for certain products, policies should not be based on the assumption that buying locally is the lowest carbon approach. There may be cases where less climate ambitious countries use relatively less emissions-intensive production processes compared to high climate ambition countries. Policies should not impose additional non-relevant aspects that impact firms' decisions on whether and how to source inputs and whether sell domestically or abroad.

Calculating product-level carbon intensity metrics requires co-operation along the supply chain. A firm wanting to provide their clients with a statement of a good's product-level carbon intensity will need to bring together data from all preceding steps of the supply chain. Whilst larger firms may be able to impose contractual obligations to extract this information from their suppliers, smaller firms may struggle to gain traction. Clear rules for co-operation (e.g. the establishment of an open governance framework – see Section 4) would be useful to define responsibilities for sharing activity and emissions data along the supply chains and calculating product-level carbon intensity metrics. The increased usage of smart micro-sensors to measure air quality in France has posed similar interoperability challenges to those relevant for carbon intensity. Adopting the same rules for data collection, storage, and aggregation (irrespective of the brands of the air-quality sensors used) and establishing an Air Quality Sensor certification by an association – with the involvement of the French National Institute for Industrial Environment and Risks (INERIS) and the

French National Laboratory of Metrology and Testing (LNE) – has resulted in air quality measures comparable across cities and regions (Orange, 2022[223]; INERIS (France), 2023[224]).

As co-operation among actors along supply chains may be difficult, governments could consider how to promote the disclosure of emissions and activity data along the supply chain. If each actor within any given supply chain computed and systematically disclosed relevant Scope 1-3 emissions data for their products, this would make computation of carbon intensity metrics along the supply chain easier. Such a modular approach would mean that any firm at the final stage of the supply chain (before the product reaches the consumer), could compute and share a carbon intensity metric with the consumer. For such a system to take effect, governments would need to define a legal responsibility and/or provide financial incentives. Given the challenges of international supply chains, government may also need to work with each other to promote cross-border firm-level disclosure.

6 Further work and next steps

This report has been developed in line with the IFCMA's Terms of Reference, which call on the Secretariat to explore methodologies for computing carbon intensity metrics at the sector and product levels. It has drawn together the main use cases for carbon intensity metrics, the challenges in computing sector-level metrics and their role as a backstop for product-level metrics, the challenges in computing product-level metrics, and the challenges in sharing and verifying information across a supply chain. The data challenges identified in this report provide motivation for additional inquiry. Specifically, how the integrity of the data used for product-level carbon intensity metrics can be verified. Further, the implications of multilateral trade policies using different carbon intensity product-metric methodologies or incorrect or incomplete data need to be explored.

In early 2025, a companion paper will follow this report delving deeper into some of the methodological issues this report has raised. Whilst the scope of this report originally envisaged undertaking further study into methodologies and data sources, data availability challenges have meant that this more detailed work has only recently commenced. Accordingly, the companion paper to this report will delve into these aspects seeking to identify and facilitate the use of scalable methodologies for carbon intensity metrics.

Whilst no further work beyond the report and companion paper is foreseen for the IFCMA's Carbon Intensity Workstream (ICIW) as part of the terms of reference, this report has highlighted areas of further work to promote the widespread computation and use of product-level carbon intensity metrics. These areas of further work can be categorised into exploring data sources, measurement and calculation methods, convergence of public and private sector initiatives and capacity building, and supporting policy design development that is proportional, pro-competition and undergirding trade and cross-border investment.

Exploring data sources, measurement and calculation methods

Further investigation of the methodologies for calculating carbon intensity metrics are a key step to reaching a common understanding of priority areas for international collaboration. Such investigation could include the calculation of carbon intensity metrics using different data sources to better understand how different data collection and computation methodologies affect carbon intensity metrics and their comparability. Such work could go hand in hand with assessing avenues for improving data measurement, reporting, and verification frameworks. A cross-cutting issue that would merit further study is how to compare functionally similar products.

Convergence of public and private sector initiatives and capacity building

Further work could actively promote exchanges and collaboration amongst governments, industry bodies, and other private-sector initiatives to pave the way towards consistent and interoperable approaches to measure and report on carbon intensity metrics. This type of analysis could initially focus on some priority products or narrow sectors with the view to expand the analysis to others.

Collaboration between the public and private sectors in this area could also facilitate effective capacity building in developing countries and Small Island Developing States (SIDS) to ensure methodologies to compute carbon intensity metrics are inclusive. In this respect, the IFCMA could take stock of country needs relating to expanding and enhancing the computation of carbon intensity. Moreover, it could enable the sharing of experiences in setting up data collection and computation systems, thus fostering mutual learning.

Supporting policy development that is proportional, pro-competition and undergirding trade and cross-border investment

Carbon intensity metrics have many potential applications that could be explored further. Section 2 has outlined existing and innovative use cases of carbon intensity metrics and pointed to policy tools that embody such use cases. This discussion opens avenues for more detailed investigations as to how carbon intensity metrics can be used in policy design and implementation that takes into account the desire to avoid imposing disproportionate costs to firms (especially to low-capacity firms, i.e. SMEs and firms in developing countries) and impairing competition at the national and international levels.

Next Steps

These above areas are outlined to foster a collaborative dialogue on potential future work. The intention is to gather insights and suggestions from IFCMA delegates to refine these ideas further. As part of this process, an Informal Focus Group (IFG) discussion was held with interested IFCMA delegates on 9th July 2024 to scope out future workstreams for the second phase of the ICIW. Following this IFG, the Secretariat is preparing a proposal for the IFCMA that will be tabled for consideration and approval before the end of 2024.

7 Glossary

Term	Description
Basel Framework	The Basel Framework is the full set of standards of the Basel Committee on Banking Supervision (BCBS), which is the primary global standard setter for the prudential regulation of banks. See https://www.bis.org/basel_framework/
CBAM	Carbon Border Adjustment Mechanism (by the European Union)
CEMS	Continuous Emissions Monitoring System
Climate TRACE	Climate TRACE is a non-profit coalition of organisations using artificial intelligence and machine learning technologies to track and build a timely and openly accessible inventory of global GHG emissions. See https://climatetrace.org/
EITE	Emissions-Intensive Trade-Exposed Sectors. Defined in this paper as aluminium, cement, clinker and lime, steel, refining, certain chemicals, and nitrogenous fertilisers following (OECD, 2015[225]).
EPP	Environmentally Preferable Products: Products that have a reduced effect on human health and the environment when compared with competing products that serve the same purpose.
ESG	Environmental, Social, and Governance
ETS	Emissions Trading Schemes
GHG Protocol	The Greenhouse Gas Protocol is a partnership of the WRI and WBCD. It establishes comprehensive global standardised frameworks to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions. See https://ghgprotocol.org/
Global Cement and Concrete Association	The Global Cement and Concrete Association is an international not-for-profit association, working with its members to reduce the impacts of cement production and promote concrete as sustainable, durable and resilient building material. See https://gccassociation.org/
Global Efficiency Intelligence	Global Efficiency Intelligence is an energy and environmental consulting and market research firm, focussing on industrial decarbonisation. See https://www.globalefficiencyintel.com/
GPP (IDDI)	The IDDI's Green Public Procurement Campaign aims to incentivise the low and near zero emission production and use of steel, cement and concrete through public procurement activities.

Term	Description
	See https://www.industrialenergyaccelerator.org/the-gpp-pledge/
ICIO	The OECD's Inter-Country Input-Output tables are input-output tables, linked across countries, that depict how much of a sector's output within a given country is used as an input into production processes in another sector, consumed domestically or exported to sectors in other countries. See https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm
ICIW	IFCMA Carbon Intensity Workstream
IDDI	The Clean Energy Ministerial Industrial Deep Decarbonisation Initiative (IDDI) is a global coalition of public and private organisations who are working to stimulate demand for low-carbon industrial materials. See https://www.cleanenergyministerial.org/initiatives-campaigns/industrial-deep-decarbonisation-initiative/
IEA	The IEA is an autonomous inter-governmental organisation within the OECD framework, headed by its Executive Director. The IEA works with governments and industry to shape a secure and sustainable energy future for all. See https://www.iea.org/
IFCMA	The Inclusive Forum on Carbon Mitigation Approaches (IFCMA) is the OECD's flagship initiative designed to help optimise the global impact of emissions reduction efforts around the world through better data and information sharing, evidence-based mutual learning and inclusive multilateral dialogue. See https://www.oecd.org/climate-change/inclusive-forum-on-carbon-mitigation-approaches/
IFG	Informal Focus Group discussions under the IFCMA
International Aluminium Institute	The International Aluminium Institute is an international association and aims, together with its members, to promote a wider understanding of the aluminium industry and the potential benefits of its use in sustainable applications. See https://international-aluminium.org/
IPCC	The Intergovernmental Panel on Climate Change, created by the United Nations Environment Programme and the World Meteorological Organization, is a scientific body that assesses the state of knowledge of climate change, its impacts and future risks and potential for adaptation and mitigation. See https://www.ipcc.ch/
ISIC	The International Standard Industrial Classification of All Economic Activities is the international reference classification of economic activities, used for the collection and reporting of statistics according to such activities. See https://unstats.un.org/unsd/classifications/Econ/isic
ISO	The International Organization for Standardization is an independent, non-governmental international organisation that is composed of representatives from member countries' national standards bodies and develops technical standards across topics such as quality, safety, technology and environmental impact. See https://www.iso.org/home.html
MPS	Mandatory regulatory Product Standards impose legal ceilings on the emissions intensity of domestic production and imports for products in scope.

Term	Description
NDC	Nationally Determined Contributions are how each country outlines and communicates their post-2020 climate actions under the Paris Agreement. See https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs
NCV	Net Calorific Value
OECD	The Organisation for Economic Co-operation and Development (OECD) is an international organisation that works to build better policies for better lives. See https://www.oecd.org/
PACT	The Partnership for Carbon Transparency is a WBCSD-led group of companies and organisations working together to develop a global and open network for the secure peer-to-peer exchange of accurate, primary and verified product emissions data. See https://www.carbon-transparency.com/
PEMS	Predictive Emissions Monitoring System
ResponsibleSteel	ResponsibleSteel is an international not-for-profit standard and certification initiative, promoting the socially and environmentally responsible production of net-zero steel. See https://www.responsiblesteel.org/
SME	Small and Medium-sized Enterprises
Systems Change Lab	Systems Change Lab is a collaborative initiative climate, monitoring, learning from and mobilising action towards the transformational shifts requires to meet global biodiversity and sustainability targets. The online platform provides open access data across a range of indicators. See https://systemschangelab.org/
TCFD	The Financial Stability Board (FSB) created the Task Force on Climate-related Financial Disclosures to develop recommendations on the types of information that companies should disclose to support investors, lenders, and insurance underwriters in appropriately assessing and pricing a specific set of risks —risks related to climate change. See https://www.fsb-tcfd.org/
$TECO_2$	The OECD's Trade in Embodied CO_2 database combines the OECD's Inter-Country Input-Output database with statistics on CO_2 emissions from fuel combustion and other industry statistics to produce a set of indicators that reveal patterns of CO_2 consumption compared to CO_2 production (via resident industry or household emissions) across the world. See https://www.oecd.org/industry/ind/carbondioxideemissionsembodiedininternationaltrade.htm
TESSD	The Trade and Environmental Sustainability Structured Discussions. Were announced in November 2022 by fifty WTO members as a way to intensify work on trade and environmental sustainability at the WTO and complement the work of the Committee on Trade and Environment. See https://www.wto.org/english/tratop_e/tessd_e/tessd_e.htm
TiVA	The OECD's Trade in Value Added database provides indicators derived from the OECD's Inter-Country Input-Output tables that describe the value added by individual countries in the

Term	Description
	production of goods and services that are consumed worldwide. See https://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm
Tracking Clean Energy Progress Report (IEA)	The IEA's Tracking Clean Energy Progress (TCEP) assesses recent developments for over 50 components of the energy system that are critical for clean energy transitions. The components assessed include sectors, subsectors, technologies, infrastructure and cross-cutting strategies. See https://www.iea.org/reports/tracking-clean-energy-progress-2023
Transition Pathway Initiative	The Transition Pathway Initiative is an international, asset-owner led initiative, based in the London School of Economics and Political Science, that assesses companies' preparedness for the transition to a low-carbon economy. See https://www.transitionpathwayinitiative.org/
UNFCCC	The United Nations Framework Convention on Climate Change entered into force on 21 March 1994 and has a near-universal membership. Its ultimate aim is to prevent "dangerous" human interference with the climate system. See https://unfccc.int/process-and-meetings/what-is-the-united-nations-framework-convention-on-climate-change
VPS	Voluntary regulatory Product Standards operate in the same way as MPSs but are not backed by a legal obligation.
WBCSD	Established in 1995, the World Business Council for Sustainable Development (WBCSD) brings together transformational organizations to form a global community that shifts the systems they work within towards a better future. See https://www.wbcsd.org
World Steel Association	The World Steel Association (World Steel) is an international non-profit organisation, providing leadership on strategic issues impacting the steel industry, particularly focussing on economic, environmental and social sustainability. See https://worldsteel.org/
WRI	Founded in 1982, the World Resources Institute works globally and in focus countries to meet people's essential needs; to protect and restore nature; and to stabilize the climate and build resilient communities. It aims to fundamentally transform the way the world produces and uses food and energy and designs its cities to create a better future for all. See https://www.wri.org

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