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Empowering carbon accounting: from data to action

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Executive summary

There is increasing demand for reliable and readily available information to manage the environmental impact of human behaviour. In particular, enabling rational decision making across the whole spectrum of climate policies requires **measuring the carbon content of economic activities**. The term refers to direct and indirect emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) created during the production of goods or services.

The measurement and disclosure of carbon content would benefit many stakeholders, including companies (to move towards more climate-friendly production processes), consumers (to better understand the environmental consequences of their purchases), investors (to redirect financial resources towards climate-friendly investments), banks (to better assess climate risk) and authorities (to take appropriate policies). It is a **necessary condition for rational, environmentally-oriented decision-making**.

Carbon content information is needed at three levels: first, at the aggregate level, with reliable statistics by country and economic sector; second, at the company level; and, third, at the product level. However, there is currently a lack of harmonised, global, and comprehensive data to properly measure the carbon content of economic activities. One key reason is that available information typically fails to take the global supply chain into account.

How should one proceed to enhance the measurement of the carbon content of economic activities and improve emissions tracking throughout the whole production process? **The starting point is the information that is disclosed by companies** about their direct emissions, on a voluntary or mandatory basis. This provides the foundation necessary to ensure the recording and reporting of the environmental impact of economic activities – with data that should be duly analysed, verified, audited and shared with relevant authorities or also the public at large.

The next step is to adequately measure upstream indirect emissions, which requires more than the simple disclosure at the level of entities. The objective should be to track carbon emissions across the whole supply chain, from the level of raw materials to the final products. This should ideally be done in real-time and in an accurate and verifiable manner, to create comparable and consistent figures. Moreover, the approach is to be cumulative across the network of producers, requiring effective communication among input providers (eg to avoid double-counting) or the development of adequate methodologies – such as the E-liability approach already adopted by a number of companies to estimate their upstream carbon emissions.

The third step is to ensure the proper integration of company- and product-level data in the overall statistical framework for analysing economic activities. Official statisticians, as custodians of publicly available data, have a key role to play in this endeavour. Macroeconomic statistics can provide estimates where no adequate microdata is available from input providers; in addition, official statisticians can set up examples of best practices for data compilation and ensuring the quality of the granular information collected. On the other hand, the availability and disclosure of better micro data has the potential to enhance the quality of the macro indicators that constitute the corner stone of official statistics.

Implementation of the three above steps would allow the **development of an adequate and effective global carbon accounting framework** that provides accurate, credible and verifiable data across the global economy. The accounts produced should be comparable and consistent, calling for strong quality assurance processes and close international collaboration.

A number of initiatives are under way to achieve this objective, with the aim of supporting both corporate decision-making and policy actions. First, the further development of air emissions accounts (AEAs) and input-output modelling is useful to track carbon emissions throughout the value chain, as well as their interactions with the broader economy. Second, global standards are being refined to enhance the disclosure of carbon information and develop adequate statistical classifications and taxonomies, not least to enhance the consistency between micro- and macro-level information. Lastly, important international work has been initiated to address the most pressing data gaps related to the link between carbon emissions and economic activities.

The success of these initiatives will **require close collaboration and innovation by all parties involved**. Many obstacles remain but the issues posed by climate change call for swift policy actions to overcome data gaps. Central banks, as statistical producers as well as users of data to support their specific policy mandates on financial stability, monetary policy and reserve management, are important stakeholders from this perspective. They can be instrumental in spurring the establishment of the statistical infrastructure necessary to better measure the impact on climate change, building on a comprehensive and consistent carbon accounting framework.

Central banks will benefit in this endeavour from the network of the Irving Fisher Committee on Central Bank Statistics (IFC) to foster joint and complementary work of the various stakeholders involved in carbon accounting, support the provision of harmonised and reliable information, and thereby contribute to an international solution for addressing the global phenomenon of climate change and its regional impacts. In particular, the Committee can play a useful role in sharing experience and best practices, keeping central banks informed about ongoing relevant initiatives, and taking stock of existing data sources and future plans – with a number of specific action points being pursued accordingly.

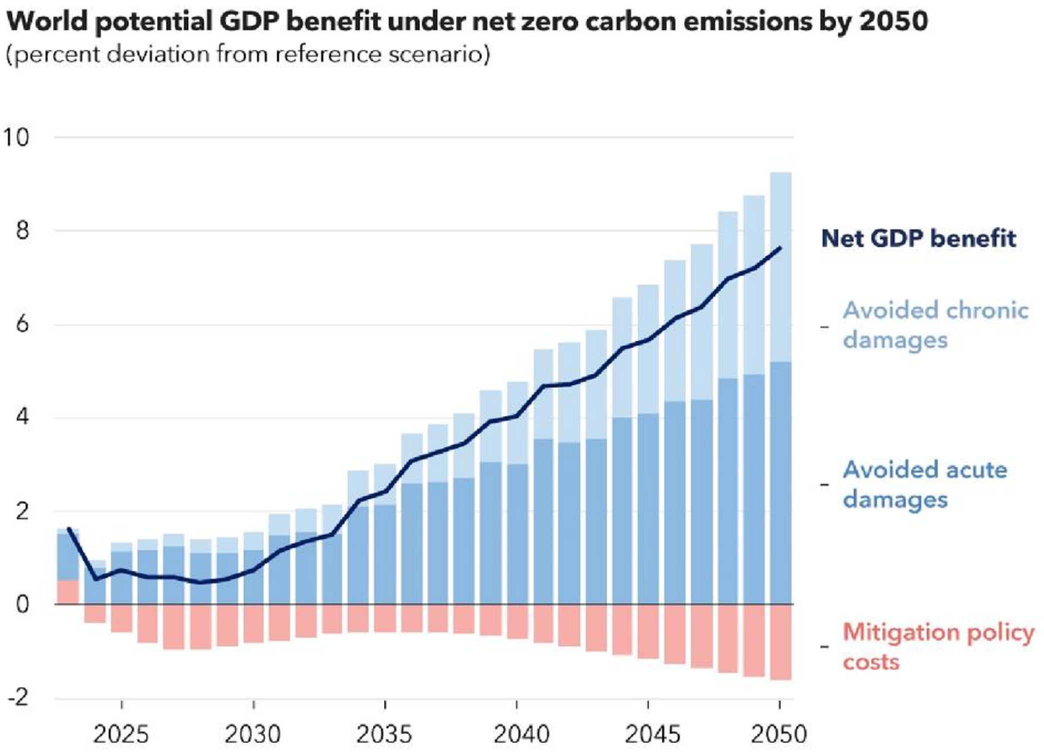
1. Introduction: the need for carbon content data

There is **increasing demand for suitable and reliable information to manage the environmental impact of human behaviour**. In particular, evidence-based decision-making to address the challenges posed by climate change requires a better knowledge of the so-called carbon content of economic activities. The term refers to the sum of (1) the direct emissions of carbon dioxide (CO_2) and comparable GHGs in the course of the production of goods or services by a company and (2) the associated upstream indirect emissions, ie the direct emissions of the suppliers of the inputs used by the company.

Gaining better and deeper qualitative and quantitative insights on carbon content is critical for at least two reasons. First, climate change poses a significant threat to the global environmental, economic, and, at large, social systems. Direct consequences, already severe, are expected to become worse, while the costs of mitigation are high. This creates evident trade-offs, as the long-run damages resulting from inaction would clearly outweigh the costs of taking immediate measures to address climate risks – indeed, tangible macroeconomic benefits can be expected from an orderly transition to a low-carbon economy (Graph 1). Second, calibrating policy measures requires adequate, consistent and reliable quantitative information on carbon content of economic activities. The climate transition will fundamentally require the replacement of a portion of the world's capital stock, necessitating substantial investments that will be constrained by aggregate savings. Consequently, global production and consumption may need to change markedly, leading to potentially acute political and social challenges (eg industry closures, forced displacement).

Currently, **there is a lack of harmonised, global and comprehensive statistics to properly measure the carbon content of economic activities**. On the one hand, there are obvious data gaps to be filled. For example, many companies fail to provide accurate data on their carbon emissions, and when such information is available, it is often based on rough estimates. These shortcomings impact not only firm-level measures of both direct and indirect emissions, but also macro-level aggregate statistics. On the other hand, consistent and coherent methodological frameworks are still missing. Despite their ongoing efforts, reporting institutions, accountants, standard setters and statisticians tend to use inconsistent data at the product, company and industry level, not least due to different objectives.

An orderly transition would bring strong economic benefits — Graph 1



Source: IMF at Hamburg workshop on carbon content measurement, NGFS (2023).

A number of major initiatives are under way to provide better data (NGFS (2024)). First, international standards are being refined to include the provision of carbon information. This is critical to better inform decision-making for corporates, for instance in the design of less carbon-intensive products. In particular, the International Sustainability Standards Board (ISSB) has issued its inaugural global accounting standards on sustainability-related disclosures in capital markets, with the objective of addressing the need for precise carbon content and GHG emissions information at the corporate level. Likewise, new environmental, social, and governance (ESG) reporting requirements, such as the Corporate Sustainability Reporting Directive (CSRD) in the European Union (EU), will lead to the disclosure of better information. More broadly, important international work is progressing to develop methodologies and address the most pressing data gaps (see for a recent example UNECE (2024a)). The ongoing development of aggregate statistics at the national, regional and international levels will foster a better understanding of the interactions between carbon emissions and economic activities – a noteworthy example being the third phase of the Data Gaps Initiative (DGI-3) endorsed by the G20 (IMF et al (2023)).

To take stock of these efforts, an **international workshop** on "Carbon content measurement for products, organisations and aggregates: creating a sound basis for decision making" was organised in

Hamburg, Germany on 21-23 February 2024.[2] It provided a promising opportunity to involve industry specialists, official statisticians, academics, standard-setters, central banks and international organisations for sharing experience and reflecting on potential actions to address the challenges posed by the measurement of carbon content.

A crucial starting point is the principle that "*only what gets measured gets managed*", as highlighted by Bo Li, Deputy Managing Director of the International Monetary Fund (IMF). Relevant data need to be trustworthy, accurate, reliable, consistent, interoperable across countries and readily available.

The development of such carbon content measures at the product, company, industry, and country levels would **benefit many stakeholders**, including:

- *companies* – to move towards more climate-friendly production processes;
- *consumers* – to better understand the consequences of their purchase of a particular product;
- *investors* – to redirect financial resources towards climate-friendly investments;
- *banks* – to better assess climate risk in their portfolios; and
- *authorities* – including central banks and regulators (IFC (2021)), to make more appropriate, evidence-based policies.

The diverse backgrounds of these stakeholders put **a premium on cooperation in developing widely applicable best practices** that can be replicated in other jurisdictions and foster common partnerships to support global measures. It also necessitates overcoming differences in the taxonomies and concepts involved and developing a generally accepted international carbon accounting framework. Such a framework is essential to facilitate rational decision-making across the wide range of parties involved. Without it, there is a significant risk that policies addressing the impact of climate change would remain ineffective.

A comprehensive way forward should thus comprise three main objectives: (i) the accurate measurement of "direct" carbon emissions; (ii) the capturing of upstream "indirect" carbon emissions along the supply chain; and (iii) the establishment of recognised best practices in carbon accounting.

This report aims to shed light on these various issues. It starts with an introduction to carbon content (Section 2) and distinguishes between the concepts of disclosure (Section 3) and accounting (Section 4) for measuring it. It then discusses the compilation of emissions accounts and input-output tables to ensure the proper integration of carbon accounts in the overall macroeconomic framework for analysing economic activities (Section 5) and reviews the various ways of gathering related data (Section 6). Finally, looking forward, it highlights the role and the contribution of official statisticians – especially within central banks with the support of the IFC – to making progress (Section 7).

2. Carbon content – conceptual issues

Carbon content[3] is fundamentally a recursive concept. It corresponds to the sum of direct emissions attributed to the manufacturing of a product and the carbon content of all inputs involved in it, ie the

2 The event was organised by the IMF, the BIS and its IFC Committee, Eurostat, the Deutsche Bundesbank, the Central Bank of Chile and the University of Oxford Blavatnik School of Government.

3 The term of "carbon content" is preferred in this Report to avoid a narrow interpretation, as it encompasses the national and sectoral levels as well as the company and the product levels. Referring to products, a similar concept is labelled "embedded emissions" in recent legislation (see EU (2023), especially Annex IV).

upstream indirect emissions. Indirect emissions are the result of direct emissions in a chain of prior production processes, and production interlinkages are thus key for their consistent measurement.

A first step for measuring carbon content is to use the information disclosed by companies about their direct emissions, whether on a voluntary or mandatory basis. The second step is to adequately measure their upstream indirect emissions, which requires more than the simple disclosure at the entity level. The objective should be to track carbon emissions throughout the entire production chain, from raw materials to final products. This needs to be done in a timely (ideally real-time), accurate and verifiable manner to create comparable and consistent figures. The approach must be cumulative across the network of producers, necessitating in theory perfect communication among input providers.

However, as it stands, **product-level carbon content information typically fails to propagate along supply chains**. In general, most businesses calculating their own carbon content typically rely on approximations rather than direct supplier information, requiring repeated estimates throughout the entire supply chain. On their part, official statisticians do not rely on primary company data or direct measurements. Instead, they often have to turn to alternative estimates based on macroeconomic indicators and technological assumptions.

How should one proceed to enhance the measurement of the carbon content in economic activities and improve emissions tracking throughout the entire production process? **One obvious solution is to leverage practices already developed elsewhere**. For instance, consumers can read essential nutritional information, such as calories/kilojoules and fat content, printed on food packaging. To produce this information, food manufacturers do not need to conduct multiple biochemical analyses, as they know the nutritional content of their ingredients or receive this information from their suppliers. These suppliers, in turn, obtain this information, as needed, from their own suppliers. The same principle applies to the calculation of the production costs of a product, which involves identifying and adding up the respective input costs. Information about nutrients in the first example and about prices and costs in the second is passed on along the supply chain. Box A details how a similar approach could work, in an iterative way, for assessing carbon content along the production chain.[4]

3. Measuring carbon content: disclosure

The information disclosed by companies about their emissions provides the foundation necessary to ensure the recording and reporting of the environmental impact of economic activities – with data that should be duly analysed, verified, audited and shared with relevant authorities or even the public at large. The primary goal of firms disclosing these data is often to inform their stakeholders – eg shareholders, lenders – about their environmental performance. More broadly, this information can be used by policymakers, investors and regulators to support an evidence-based transition to a low-carbon economy. There are several international disclosure initiatives underway to collect and disseminate company-level carbon emissions data.

Firm-level disclosure can be voluntary or mandatory (or quasi-mandatory). It has become an essential element of the broader data ecosystem used for the reporting of carbon emissions at different levels, ie products, firms, sectoral / national and international (Graph 2). In this context, the GHG Protocol

[4] One important feature is that carbon content information would need to cover both final products (the scope of household consumption) and intermediate products (whose demand depends on firms' decisions).

Corporate Standard launched in 1998 has been one of the most widely used frameworks by companies to measure and report their emissions according to an agreed template (Box B).[5]

Box A

A statistical framework for measuring carbon content①

The issue: measuring both direct and indirect carbon emissions

In production planning, every process is defined by a *bill of material* (BoM) that specifies all inputs, plus a *route sheet* that explains how to combine them. A complex production process can thus be decomposed into several stages and formalised along the following lines:

- the requirement coefficient a_{ik} is the quantity of good i that is required per unit of product *k*;
- the amount of greenhouse gas (GHG) emitted directly, as part of the production process of product *k*, is d_k ;
- the scalar c_i is the carbon content of good i, the quantity of GHG that is emitted for the production of one unit over the value chain.

The carbon content of product *k* is then given as the sum of direct and upstream indirect emissions, as detailed in equation (1):

$$c_k = d_k + \sum_i c_i a_{ik} \qquad (1)$$

The above expression is both general and encompassing, ie it relates to products and activities and – for a given time span – to enterprises and sectors as well. Moreover, equation (1) helps to understand the challenges associated with the gathering and processing of information on carbon content. Upstream indirect emissions are the direct emissions at earlier stages of the value chain; in other words, product carbon contents are interdependent, as they depend on the carbon contents of all production inputs. For actual computation, all the c_i corresponding to the BoM of product *k* are required. If these are known (which is the ideal situation), one can calculate the carbon content of product *k* in a straightforward way using the direct emissions and the BoM. This is like computing the energy content of food: it is enough that producers know the composition of their product and the carbon content of the ingredients.

The "chicken and egg" problem

In practice, one does not generally know all of the c_i. But one can use equation (1) recursively to compute the carbon content involved, going up the value chain from more complex intermediate inputs to primary and primitive inputs. This insight is not new and derives from the linear production planning and input-output (IO) analysis pioneered by Wassily Leontief.②

Analytically, the carbon content of all products can be determined simultaneously, by defining:

- all product carbon contents c_i (in a column vector **c**);
- all direct emissions d_i per unit of output (vector **d**); and
- all the coefficients a_{ik} for the requirements of product *k* in the production of output *i*, arranged in the matrix **A** covering all products *k* = 1 to *N*, with

[5] The GHG Protocol provides the world's most widely used greenhouse gas accounting standards designed as a framework for businesses, governments and other entities. The standards include in particular the corporate standard, the corporate value chain (scope 3) standard and the product life cycle accounting and reporting standard (the "product standard"). For GHG scope 1 and 2 emissions, see WRI and WBCSD (2004). For scope 3 emissions, see in addition the two closely related standards for enterprise-level and product-level disclosure (WRI and WBCSD (2011a, 2011b, 2013).

$$\mathbf{A} = \begin{pmatrix} a_{11} & \cdots & a_{N1} \\ \vdots & \ddots & \vdots \\ a_{1N} & \cdots & a_{NN} \end{pmatrix}$$

Equation (1) can then be written:

$$\mathbf{c}' = \mathbf{d}' + \mathbf{c}'\mathbf{A}$$

Reordering and solving for **c**, one obtains:

$$\mathbf{c}' = \mathbf{d}'(\mathbf{I} - \mathbf{A})^{-1} \quad (2)$$

Equation (2) shows that the carbon content of each product k results from the direct emissions related to its own production and the direct emissions of all the intermediate goods used for it. The matrix $(\mathbf{I} - \mathbf{A})^{-1}$ is known as the Leontief inverse of the system of interlinkages in production, as defined by the BoMs.

The above is the general approach for measuring the carbon contents in the economic system. For products with short and linear value chains, good approximations may exist without solving the entire system. And in a not too distant future, one may think of using this relationship directly, as electronic billing is gaining importance in an increasing number of jurisdictions and computing becomes ever more powerful.

Given the limited information available today, however, solving for carbon contents at the micro level is not feasible. Von Kalckreuth (2022a) shows analytically that this is not necessary: producers do not need to be aware of all the stages of the value chain (ie to identify all the a_{ik}). What is only needed is to know their own technology and get some preliminary values of the carbon contents of their direct inputs from their immediate suppliers. An iterative process involving suppliers and users of intermediate products will converge to the correct values.

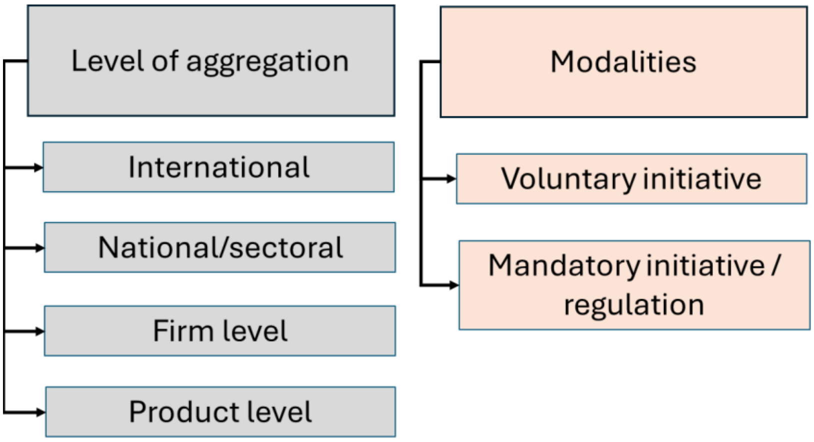
The starting point is therefore to collect initial values on carbon emissions by using information disclosed by suppliers or alternative estimates (eg sectoral averages). If these values are not fully correct initially, iterative use over the value chain will make them so, as the data will be continuously exchanged between producers in an information cascade – just as the price mechanism is able to process an enormous amount of information in a decentralised way. Continuous updating by producers using their private information on own direct emissions and the composition of inputs will progressively correct the impact of improper initial values. The E-liability carbon accounting approach (Kaplan and Ramanna (2021a, 2021b)) is an example for a particular way to organise an information exchange for conducting this type of recursive estimation.

① The content of this Box is adapted from von Kalckreuth (2022a, 2022b). ② Wassily Leontief was awarded the 1973 Nobel Prize for the development of IO analysis and he was indeed the first to apply it to measuring pollution generation associated with inter-industry activity – see Leontief (1970, 1986) as well as Qayum (1994) and Miller and Blair (2022) for subsequent IO analyses. The direct approach in this exposition was first advanced, on a sectoral basis, by Just (1974) and Folk and Hannon (1974). See also Suh (2010) for an extension of IO analysis in the field of industrial ecology.

Voluntary reporting

The first type of reporting is voluntary. In this case, firms decide to disclose internal environmental data without the obligation to comply with external regulations. There can be several reasons underpinning this choice. One driver can be the perceived benefit in terms of the company's reputation, by showing environmental friendliness. Another reason could be to measure the firm's own progress, such as in terms of its carbon footprint. Last but not least, investors and creditors might prefer companies which are transparent in terms of environmental information, as this helps to better capture financial risks.

Several elements contribute to the GHG data ecosystem Graph 2



Sources: IMF; Hamburg workshop on carbon content measurement; authors' presentations.

There is an expanding number of global voluntary carbon emissions disclosure initiatives. A major one is the Carbon Disclosure Project (CDP), which collects, curates and disseminates environmental and climate change data covering companies representing about two thirds of global market capitalisation (with an increase in CDP-related disclosures by 140% during the period 2020–23). The aim is to foster transparency and accountability to better inform investment decisions and support evidence-based policies and regulations. In particular, CDP data are used by the Global Climate Action Portal (GCAP) of the United Nations Framework Convention on Climate Change (UNFCCC). GCAP is an online portal where countries, regions, cities, companies, investors and other organisations can register their commitment to act on climate change. It includes data on mitigation, adaptation, resilience and physical risks. A federated data model is envisaged to facilitate data-sharing and analysis.

Another, more centralised global initiative using CDP data is **the Net-Zero Data Public Utility** (NZDPU). It was launched by the Climate Data Steering Committee (CDSC) to support UN climate objectives, especially by encouraging the private sector to report and disclose data deemed critical for achieving a net-zero economy. It aims to provide a trusted, central source for a core set of private sector climate transition-related company-level data, with three main objectives:

1. Transparency, eg on sources, calculation methodologies, and granularity.
2. Availability in one central place, with free access to all stakeholders through a user-friendly interface.
3. Comparability of the various data models across sources.

The NZDPU puts a premium on collaboration among the different stakeholders not least to limit the reporting burden for companies by avoiding redundant submission processes. It is becoming a key component of the (expanding) global climate data architecture and is designed to be integrated with the UNFCCC's GCAP.

Lastly, **a number of private sector initiatives aim to facilitate the consistent calculation and exchange of information related to carbon emissions, either to the wider public or on a peer-to-peer basis.** For instance, the Partnership for Carbon Transparency (PACT) promotes decarbonisation across value chains by harmonising the calculation and exchange of supplier specific product carbon footprints. In the automotive sector, Catena-X has established an open and interoperable ecosystem to share standardised data in a secure manner.[6]

The objective is to capture the carbon footprint of products along the supply chain by recording and aggregating primary data from every partner involved, with a focus on comparability of the technical standards and calculations involved, data quality verification across industries and proper governance.

Box B

Firms' disclosures in the framework of the Greenhouse Gas (GHG) Protocol

The GHG Protocol is widely used for disclosing and reporting corporate information. This Protocol identifies three types (or "scopes") of carbon emissions and provides explicit guidance for measuring and reporting them at the entity or product levels:

- **Scope 1:** direct emissions from sources that are owned or controlled by a company, such as its production and transportation equipment.
- **Scope 2:** emissions at facilities that generate electricity and heat bought and consumed by the company.
- **Scope 3:** emissions from upstream operations in a company's supply chain (ie from "cradle to gate") plus from downstream activities by the company's customers and end-users.

In the production of good k, let $sc1_k$, $sc2_k$ and $sc3u_k$ be, respectively, scope 1, scope 2 and upstream-only scope 3 emissions. Conceptually, carbon contents as defined in equation (1) are equal to the sum of these three variables, with:

$$c_k = sc1_k + sc2_k + sc3u_k \tag{3}$$

Here:

- $\boldsymbol{sc1_k}$ are the direct emissions d_k in equation (1);
- $\boldsymbol{sc2_k}$ enter equation (1) as the direct emissions $d_j a_{kj}$ at the production facilities of utilities, resulting from energy and heat purchases; and
- $\boldsymbol{sc3u_k}$ is reflected in equation (1) as the indirect emissions $c_i a_{ki}$related to all other inputs (including the indirect emissions of utility companies).

However, it is important to note that equations (1) and (3) are not entirely equivalent. The difference lies in the indirect emissions component, which is accounted for recursively in equation (1) in Box A as it derives from the direct emissions of earlier stages. In contrast, the GHG Protocol measurement concept is not recursive and obliges the producer to gather all the information regarding emissions at earlier production stages.

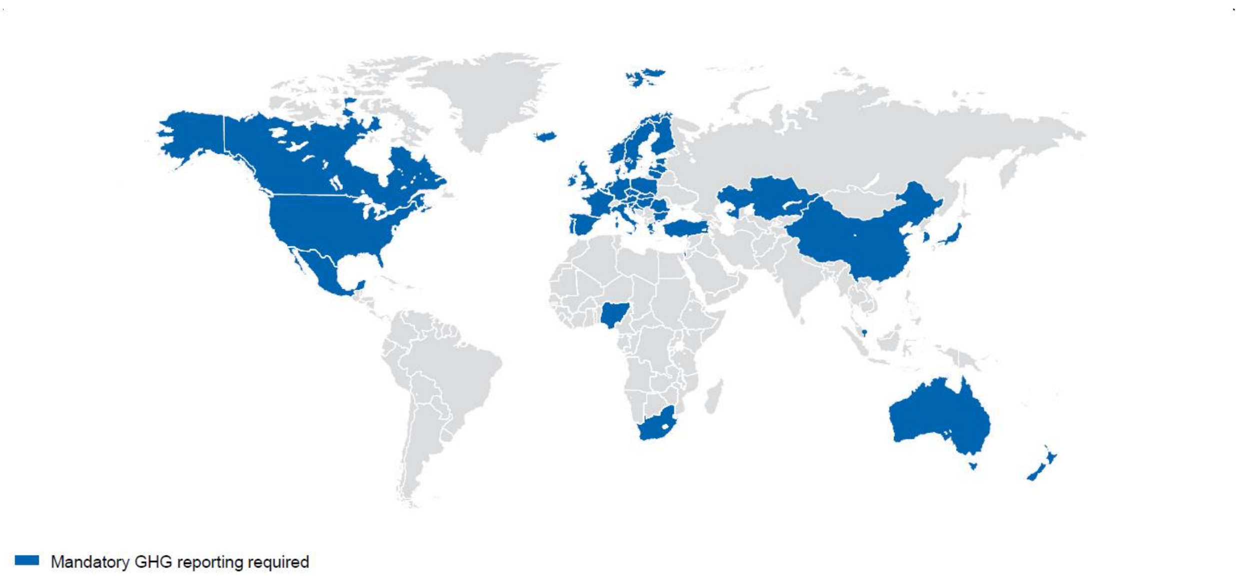
A key lesson of the various voluntary initiatives is the vital role played by metadata (ie the data about the data), as companies may use different measurement techniques to estimate their emissions. Another is the importance of reputational risk, as this can represent a powerful incentive for companies to disclose accurate figures and avoid misreporting. Lastly, one important issue is the development of adequate guidance to support disclosure initiatives. The Intergovernmental Panel on Climate Change (IPCC), the United Nations body for assessing the science related to climate change, has accordingly developed methodology guidelines and established a National GHG Inventories Programme to foster the measurement of carbon emissions at the economic activity level in a comparable way across countries.

6 See www.carbon-transparency.com and catena-x.net/en/.

Mandatory and quasi-mandatory reporting

The second type of reporting is mandatory or quasi-mandatory. In a number of situations, entities are required to disclose environmental data to comply with standards or regulations, including legislation. At present, about 40 countries have mandatory GHG reporting requirements for at least some segments (Graph 3).

Around 40 countries have mandatory GHG reporting requirements   Graph 3



Source: Hamburg workshop on carbon content measurement.

Financial reporting standards play an important role as quasi-mandatory reporting. Although they are not mandatory strictly speaking (as they do not constitute national legislation), they are de facto binding for a large number of companies across the world. A noteworthy example is the International Financial Reporting Standards (IFRS) accounting standards, which correspond to a set of cross-country comparable accounting rules. These standards have been expanded to take into account environmental issues in recent years, with the issuance by the ISSB in 2023 of IFRS S1 and IFRS S2[7] on sustainability-related disclosures in capital markets.

Another key initiative for providing mandatory disclosure data is **the CSRD launched in Europe** in 2022. It requires companies to report digitalised, audited and comparable information on their social and environmental performance. This directive applies to a broad set of large EU companies, including many listed small and medium-sized enterprises and selected foreign companies that generate sales over €150 million in the EU market. As a result, an estimated 50,000 firms are required to disclose data on their environmental impacts. These data are accessible to investors, financiers, customers, suppliers and the public at large.

These (quasi) mandatory initiatives have highlighted the **importance of having an adequate statistical infrastructure in place** to ensure effective disclosure and reporting to authorities, comprising the following main elements:

[7] The new standards can be accessed at the IFRS website; IFRS S2 directly refers to the GHG Protocol with regard to the measurement of carbon emissions.

- A *reference reporting standard* to ensure reporting quality, as is the case with the European Sustainability Reporting Standards.[8]
- A *reporting language*: for instance, EU sustainability reports will use the eXtensible Business Reporting Language (XBRL), a free licence technical standard for exchanging business information, for reporting to the European Securities and Markets Authority (ESMA).
- A *disclosure platform*: as an example, ESMA has been entrusted with developing such a platform for ESG data (with the collection to be organised by 2026) in the context of the EU CSRD. In addition, the European Single Access Point will provide centralised access to publicly available information to facilitate the downloading of the data disclosed by companies and their reuse by interested stakeholders (with a target date of 2027).
- *Flexibility and adaptability:* setting up a disclosure framework takes time and involves many stakeholders.
- Due *consideration of national specificities*: a key point is that there are a number of different national accounting standards around the world; for instance the Generally Accepted Accounting Principles (GAAP) prevail in the United States (instead of the IFRS).

4. Measuring carbon content: accounting

The need for a comprehensive measurement framework…

Ongoing disclosure initiatives facilitate building a necessary foundation for the recording and reporting of the environmental impact of economic activities, enabling data that can be duly analysed, verified, audited and shared with relevant authorities or even the public at large.

Carbon emissions in production processes need to be recorded on a timely basis (ideally in real-time) and in an accurate and verifiable manner to create comparable and consistent carbon accounts across the global economy (Kaplan and Ramanna (2024)). Such encompassing carbon accounts can be regarded as analogue to the existing System of National Accounts (SNA), which is a comprehensive and exhaustive framework for recording economic activities (EC et al (2009)). These accounts would be key to support climate change policies that foster an objective of "geological net zero" for the total carbon emissions on the planet, with consistent breakdowns by jurisdiction and industry (Ramanna (2024)).

Establishing such an ***accounting*** view requires more than the simple ***disclosure*** of carbon emissions at the level of entities. Although the distinction between carbon disclosure and carbon accounting is central, most of the existing carbon initiatives are disclosure-based. Engagement with standard setters is therefore crucial to move towards an accounting regime allowing for an adequate measurement of carbon content at the product level.

Official statisticians can also make a vital contribution, by supplementing missing firm-level information; for example, carbon accounting at the product level requires estimates for "unaccounted" carbon content inputs, which can be imputed from other sources (eg relevant benchmarks, aggregate averages by sectors). Another benefit is that official statisticians can help to formulate a consistent framework, for instance by leveraging the experience gained in the setup of the SNA. This would facilitate

8 This standard was developed by the European Financial Reporting Advisory Group, a private association funded by the European Union to serve the public interest in the field of corporate reporting.

the incorporation of disclosed micro-level carbon content data to infer more comprehensive aggregates that are needed for assessing the macro impact of environmental policies.

Reflecting the above, **the DGI-3 initiative aims indeed to improve reconciliation between granular emissions data and macro statistics**, with a more uniform coverage across countries. In particular, its first recommendation is to develop AEAs (for GHGs) by industry and estimates of National Carbon Footprints by demand category and consistent with macroeconomic indicators such as GDP. This would allow for the development of more detailed sectoral and product breakdowns, not least to better reflect heterogeneous emission intensities and the consequences of using different modes of energy production.

In practice, **an adequate and effective carbon accounting framework should be built upon the following main principles**:

- *Data should be accurate, representationally faithful and verifiable*. Notably, "accuracy" is different from "precision": the main objective is not to know the decimal points associated with specific measurements, but to ensure that fit-for-purpose information represents what it purports to represent. In other words, any carbon accounting report should be within a non-material margin of error.
- A carbon accounting system should *measure realised performance*, not prospective estimates. This is one of the major ways in which accounting differs from disclosure, since company reports can include statements about potential future performance (such as GHG Protocol scope 3 downstream estimates).
- Figures should be *comparable and consistent*. Comparable means that the data of two companies are similar and can be compared. Consistency refers to how a company's data are comparable across time.
- The figures should be presented *in a consolidated way* (ie in net terms at the level of the corporate group reporting its carbon emissions) and collected for the production system in an exhaustive way. This means that, as products pass through the supply chain, their carbon metrics should do the same (flowing from one company's balance sheet to another's) to avoid double-counting. One benefit is that companies would simply rely on the information provided by their immediate suppliers and would not have to know the ramifications of the entire supply chain.
- Consolidated information should also be complemented by estimates based on the *residency concept* underpinning the system of official statistics.[9] The objective is to provide data that are relevant for supporting policy decisions taken by authorities that are located in specific jurisdictions, while group-level disclosed figures typically span across national borders.
- *Quality assurance of the information* is indispensable. This implies that carbon content data at both the product and company levels could be subject to formal auditing, calling for the identification of appropriate standards and clarification of the (internal and external) auditors' role. Yet, this may be challenging in terms of resources – notably for assuring the quality of scope 3 data in the GHG Protocol, which can be complex compared with scopes 1 and 2, as scope 3 includes entire supply chain interlinkages. Hence, alternative ways to develop quality assurance could include active and credible monitoring by interested stakeholders (eg media), not least to raise public awareness and foster reporters' responsibility (see Sun et al (2024)).

[9] National statistics are primarily presented on the basis of the residency of the units that can differ within the same corporate group; an alternative, "nationality-based" approach takes into account the national residency of the controlling parent of the group (Tissot (2016)).

- *International collaboration and coordination* are key to ensuring the use of practices and standards that are comparable across jurisdictions.
- While a unified system across different industries for measuring carbon content is preferable, there is merit in *developing more detailed approaches*, especially for those sectors deemed critical in terms of impact on climate change. Obvious examples include the cement industry, for which the majority of emissions are direct (ie scope 1), as well as the oil and gas industries, in which the bulk of emissions are from combustion.[10] In contrast, it can be useful to set up simple methodologies for modest firms with small carbon footprints. Lastly, the specificities of the government sector should be duly considered.

… supporting cumulative carbon accounting

By design, **any comprehensive carbon cost accounting approach should be cumulative across the network of producers** to ensure that carbon content along the supply chain is taken into account. This is key to tracking emissions data from raw materials to final products. The tasks involved are however complex, as illustrated by the example of a company producing a car door. It needs to account for all upstream emissions involved, comprising the processes of its suppliers, the sources of raw materials (including the extraction of metallurgical coal and iron ore), the transportation of those minerals to a steel producer, the production of sheet steel from the coal, iron ore, and other inputs, and the transportation of that steel to its own production facility (Graph 4).[11]

While the above calculations may be feasible for short and simple supply chains, **it can be quite difficult when dealing with the numerous interlinkages that characterise many modern industrial manufacturing processes**,[12] as producers will typically not know all the inputs in the earlier production stages. In particular, estimating all upstream emissions, especially for companies with long, complex and fragmented multi-jurisdictional value chains, introduces high measurement error, opening the door to biased estimations and potential greenwashing/manipulation. Moreover, measuring emissions at each stage of the value chain, apart from being an inefficient and duplicative process, can result in information that is not comparable. Reflecting these difficulties, the GHG Protocol standards allow for a number of options for estimating scope 3 emissions.

These tasks may however be less daunting than they appear. **Estimations can be relatively straightforward if product-level carbon content information is passed from one supplier to the next producer** (along with similar data from the suppliers' providers). Establishing a cascade of carbon content information along the entire supply chain could be done by leveraging existing financial accounting standards and cost accounting best practices. For instance, carbon content can be calculated in a similar way to production costs at the company level, with the financial accounting information covering all the inputs and expenditures involved in the production process. What is needed is to develop similar types of cost accounting information at the product level to be able to measure the environmental impact of all of the firm's activities and allocate carbon content across products and over time. However, while financial

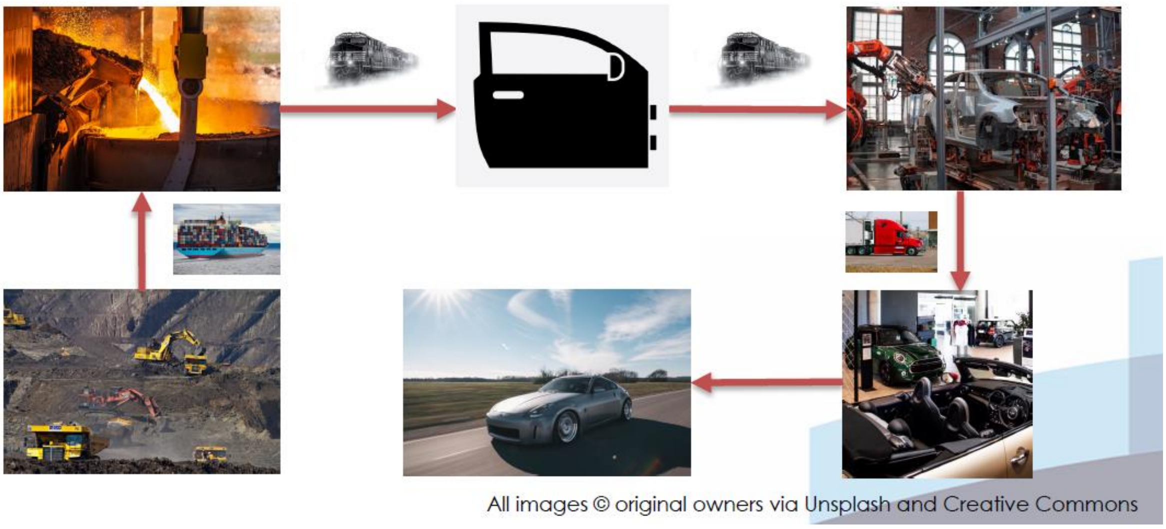
[10] Reflecting these specificities, certain firm-level sources of information have been developed that provide more comparable data for some sectors; cf for instance the Pollutant Release and Transfer Register (PRTR) maintained by United Nations Institute for Training and Research (UNITAR), which provides an open-access database of releases and transfers of harmful chemicals to the environment, comprises useful emissions data for selected industries such as power generation, cement and steel.

[11] Note that the GHG Protocol adds a further complexity by requiring the car door manufacturing company to estimate the impact of downstream activities, including transporting the car door to its customer (the automotive assembly factory), manufacturing the finished car, transporting the car to a showroom and operating the vehicle for perhaps 15 years by the end-user.

[12] One interesting case is the chemical industry: its producers typically know the "formulae" of their inputs and they understand the production processes of their suppliers fairly well (cf the methodology developed by BASF).

accounting is standardised and auditable, cost accounting is not, as companies' practices typically depend on their specific information needs. Hence, common carbon accounting standards should be developed to ensure consistency and interoperability, for instance to allocate carbon content of fixed assets over time, or to handle situations in which carbon content information for inputs is missing. Moreover, there is a need for common, comprehensive and publicly available reference data for aggregate emissions at the country and industry levels to help bridge firm-level gaps. This type of "macro" information embodies the characteristics of a public good, and it should fall to national official statisticians and international organisations to ensure its accessibility and availability.

Calculating cumulatively the specific carbon emissions of a car door producer Graph 4



Source: Ramanna (2024).

A similar approach would also help to better analyse the carbon offset market,[13] which is reportedly characterised by a lack of comprehensive and reliable data. One concern is that a significant part of the reported information on carbon offset offerings may not meet basic accounting standards, making it difficult to distinguish between genuine offset practices and avoidance schemes. For instance, while the carbon dioxide emitted by an aeroplane persists in the atmosphere for around 1000 years, tree planting, the most popular carbon offset method, captures carbon for only around 50 years – possibly representing a fundamental mismatch. Hence, there is a clear risk that misguiding market information can lead companies to buy less expensive but ineffective carbon offsets (Kaplan et al (2023)). These issues call for stronger regulation to ensure adequate accounting and disclosure practices, and in turn for effective climate change mitigation efforts. For instance, greater standardisation, coupled with the availability of digital tools, opens the potential for more efficient, "tokenisation-based" exchanges (by creating a digital representation of the units of carbon content to be offset) in carbon markets. This would increase data transparency and traceability, reducing the risk of double-counting and greenwashing.

[13] Carbon credits, also known as carbon offsets, are permits that allow the owner to emit a certain amount of carbon dioxide or other GHFs. See Advisory Expert Group on National Accounts (2022) for planned enhancements for the recording of emission trading schemes in the SNA.

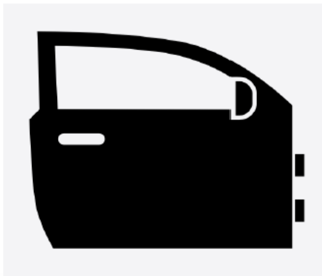
E-liability and related approaches

How should an effective accounting framework be set up to properly record product carbon content at each stage of the value chain? **One option is the environmental-liability (E-liability) approach** (Kaplan and Ramanna (2021a, 2021b)) to tracking firms' total direct and supplier emissions as well as the carbon content of any of their products and services. This approach is inspired by the measurement of value-added in the financial accounts framework, as illustrated in Graph 5. Its objective is to address the problem of multiple-counting and guesstimates in current carbon accounting practices, by allowing companies to produce current (ideally real-time), accurate and auditable data on "cradle-to-gate" emissions at the product level. To this end, one will draw upon the standard principles of financial accounting (eg double-entry accounting) to derive product-based carbon content estimates, using equation (1) in Box A. Cumulative accounting approaches similar to the E-liability concept have been developed in a number of countries.[14]

The E-liability concept: tracking carbon emissions in a way similar to value added — Graph 5

E-liability "enterprise reporting"

E-liability flows	Tons of CO_2
Opening E-liabilities	**3,600**
Add E-liabilities directly produced through operations	2,600
Add E-liabilities acquired from suppliers	39,800
Electricity	*5,600*
Sheet steel	*10,600*
Glass	*5,400*
Fabric and Plastic	*1,200*
Other supplies/components	*4,800*
Capital equipment	*12,200*
Subtract E-liabilities transferred to customers	(32,600)
Closing E-liabilities	**13,400**
Change in E-liabilities during period	*9,800*



Companies can report on the stocks and flows of their E-liabilities just as they report on their stocks and flows of inventory. E-liabilities acquired or produced, but not transferred to customers in each period, are held for future transfer. This feature allows companies to **hold and depreciate GHG emissions from fixed assets** such as plant and equipment.

Source: Ramanna (2024).

There are **five key items to consider in the E-liability approach**, which has already been adopted by a number of companies to estimate their carbon emissions:[15]

1. The measurement (and tokenisation) of all direct emissions of a given firm.
2. The transfer in e-liabilities to this firm from its immediate suppliers.

[14] Cf the "Carbones sur factures" approach under the initiative of Jérôme Cazes in France (Beguin et al (2024)) and the iSumio company in Ireland that provides carbon accounting software (Richter (2024)).

[15] Cf the examples of BMW, Heidelberg Materials and Chevron, among others.

3. The removal of emission offsets purchased by the firm (if any).
4. The allocation of the firm's e-liabilities to all of its products, in the same way as in cost accounting.
5. The transfer of the e-liabilities of the firm's products to its immediate customers.

In practice, companies may not have full access to their suppliers' data and would need to complement them with generally accepted reference data. **This obstacle can be overcome by estimating the global carbon accounts in an iterative way**, using the best available information at each step of this dynamic process as described in Box A. Simulations by von Kalckreuth (2022a) suggest that sufficient accuracy can be achieved after no more than three to five cycles, even if the initial estimates are far off the mark.[16]

5. Air emission accounts and input-output tables

While the proper measurement and tracking of carbon emissions at the product level should be a key objective, **another important issue is to ensure the proper integration of carbon accounts in the overall macroeconomic framework**. At the country level, an obvious starting point is the SNA, which provides an international standard for analysing national production and demand and is characterised by its completeness, coherence and consistency. The SNA also frequently offers the possibilities to integrate other domestic statistical standards, facilitating data use and re-use. Reflecting those qualities, it underpins a wide range of economic flagships indicators, such as GDP.

In practice, a key feature of the SNA is the **provision of "supply and use tables" (SUTs)** that record the production and use of products by industries, integrating multiple data sources and countries' specificities. These tables allow for the compilation of symmetric Leontief-type input-output tables (IOTs), on a product-by-product or industry-by-industry basis. Environmentally extended IOTs can be computed for a better tracking of GHG emissions throughout the value chain and providing useful indications – for instance on how a given change in production will impact the generation of emissions.

A key example is the **inter-country input-output (ICIO) tables** of the Organisation for Economic Co-operation and Development (OECD) which track production, consumption and investment flows within countries as well as external trade flows and can shed light on current environmental issues.[17] For instance, ICIO tables may serve as basis for the estimation of carbon emissions embodied in international trade.

Cross-border relationships are incorporated by developing multi-country IOTs, requiring the set-up of the input-output matrix for M industries in N countries – representing $(M \cdot N)^2$ entries to be estimated. As an example, FIGARO,[18] Eurostat's inter-country IOT , features 46 countries plus the "rest of the world", and 64 industries. Turning to the IMF, it is developing a multi-analytical regional input-output table (MARIO) with an even greater degree of detail (212 economies, 144 industries and 178 products).

[16] This general convergence principle is illustrated by von Kalckreuth (2024) using a simulation based on US micro data. See also Ramanna (2024).

[17] The ICIO tables cover 76 countries and 45 industries and are compiled and disseminated by the OECD; they are available at oecd.org. Frequently, carbon footprints are given in absolute terms (millions of tons) and only for goods for final demand (households/government, investment and exports). While carbon footprints of final demand sums up to the total of direct emissions, this essentially reflects the reassignment of emissions from the industries where carbon is emitted to the industries that produce the final output. From this perspective, a comprehensive carbon accounting framework as presented in Box A also covers intermediate consumption.

[18] FIGARO stands for "full international and global accounts for research in input-output analysis".

Reflecting the above developments, **calculating production-based carbon footprints and total carbon intensities from IOTs and direct emissions sources has become standard** in the literature.[19] An indispensable input for these calculations is the direct emissions by industries as a result of production activities. The Air Emissions Account in the System of Environmental-Economic Accounts (SEEA) are recording the generation of air emissions (including GHG emissions) by resident economic units, ie establishments and households. The SEEA framework is an international statistical standard for measuring the environment and its relation to the economy, developed in relation with the SNA.[20]

Yet, despite ongoing initiatives to develop AEAs, **substantial data gaps remain**, and there are significant differences in the information available across regions (Graph 6). Gathering adequate data has thus become a high priority on the global statistical agenda.

6. Gathering data

From firms' disclosure to carbon accounts

The development of comprehensive carbon accounts requires carbon content **information at the level of products, companies, industries and countries that is *consistent and interoperable*, *accurate*, *available* and *trustworthy and credible***. *Consistent and interoperable* data require common practices, with standard setters playing a critical role in defining inputs, allocation processes and the treatment of carbon content over time. *Accurate* data require high-quality internal reporting of direct emissions and input information; where direct carbon content information is lacking, suitable proxies would be used. Communication devices, such as carbon content on receipts or invoices[21] and data exchange platforms, can promote data *availability*. *Trustworthiness* requires informative and standardised labelling of carbon content on products, with proper verification and auditing ensuring that the data are credible, especially those that are self-reported.

The starting point is to properly **record primary carbon emissions, for which three main methods can be identified**. The first, and most commonly used, is to *estimate* the emissions produced by certain activities. The second, *calculation*, involves understanding the chemical reactions at play in the production process (from inputs to outputs) and derive the emissions generated. The third, *direct monitoring* of emissions into the atmosphere, is arguably the best approach – it can be done by using information provided by monitors attached to smokestacks, proximate sensing and remote sensing, although this can be very costly.

[19] See in particular Miller and Blair (2023), Munksgaard et al (2010), Yamano and Guilhoto (2020), Yamano et al (2023) and also related official definitions in United Nations (2017). Moreover, Desnos et al (2023) provides a description of methods for the computation of carbon intensities.

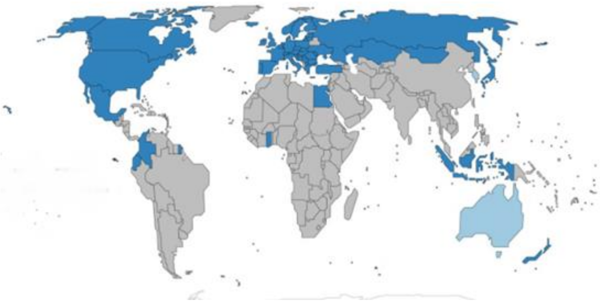
[20] In addition, the SEEA Ecosystem Accounting (SEEA EA) constitutes an integrated and comprehensive statistical framework for organising data on the ecosystem and its linking to economic and other human activity; cf United Nations (2017).

[21] The increasing use of E-Bills to settle transactions between firms could be used to track input-output relations. Such data would provide useful insights to measure the carbon content of products as well as firms' direct carbon emissions (by focussing on bills related to fossil fuel purchases).

There are substantial differences in air emissions data availability across countries

Graph 6

A. Data gaps persist in many countries…



B. … and there are significant regional differences in air emissions data availability

Region	Number of countries compiling AEA		
	Total	G20 + *participating economies*	Non-G20
All countries	50	14	36
Africa	2	0	2
Central, Eastern, Southern and South-Eastern Asia	4	2: IDN, JPN	2
Europe and Northern America	38	8: CAN, FRA, DEU, GBR, ITA, RUS, TUR, USA *3: NLD, ESP, CHE*	27
Latin America and Caribbean	3	1: MEX	2
Oceania	2	0	2
Western Asia	1	0	1

Note: Based on submission of AEA questionnaires, supplemented with information from the SEEA Global Assessment

Panel A: countries in dark blue compile and disseminate air emission accounts (AEA) according to the System of Environmental-Economic Accounting on a regular basis. Countries in light blue have discontinued the compilation of AEA. Countries in grey have not started the implementation of AEA.

Source: IMF calculations based on the UN Global Assessment on Environmental-Economic Accounting and Supporting Statistics.

The next step is to infer proper carbon content data, for instance by using the approaches presented in Box A. This information should ideally be disclosed alongside corporate financial information, not least to ensure the proper integration of carbon accounts in financial and cost accounting. This is important both to promote transparency at the entity level and to support policy at the macro level.

Despite fragmented data sources, new opportunities arise, especially with satellite data

The **current company-level reporting ecosystem, whether mandatory or voluntary, has grown large and complex**, not least because of its constant evolution. This raises a number of important issues, including the proliferation of heterogeneous sources and types of data, which may result in overlaps and duplications. Fragmented sources may also negatively affect data availability and accessibility. Perhaps more fundamentally, uncoordinated data collections may lead to poor comparability, across countries and time. To add more, the quality of reported data can be seriously compromised by falsification of accounts or information asymmetry, especially when reporting is on a voluntary basis (Chung et al (2024)). In the absence of rigorous, harmonised and, in certain cases, mandatory reporting framework, collected data may be of little use and, ultimately, bring no substantial benefit for users.

To cope with these challenges, it is critical to **link and consolidate the information available from different sources and carefully map the various elements involved in the carbon data ecosystem** – including the standard setters, firms covered, reporting frameworks established, types of data collected (eg types of instruments, mix of qualitative and quantitative data) and data distributors. Such a mapping would provide clarity on the degree of compliance (eg voluntary vs mandatory reporting), the type of information collected and reported (emissions data, compliance data and audit information) as well as its degree of accessibility (eg open vs closed, and free vs paid subscription). It would also facilitate the alignment of the various work programmes under way to ensure their complementarity, reduce the reporting burden and enhance the use of information generated and distributed across the data ecosystem. All these elements are crucial to spur the set-up of a consistent and global framework for carbon accounting.

Innovation can also be usefully leveraged, not least considering the opportunities offered by new big data sources and artificial intelligence which allow for an efficient tapping of unstructured information. In particular, one of the most promising technologies is **satellite imagery**, which uses high-resolution information about a large geographical area to monitor global real-time atmospheric emissions, detect regional and sectoral hotspots, estimate firm-level GHG emissions that can usefully complement the data reported by companies and even assess emission changes against reduction targets. Drones and handheld sensors can also provide more precise information, although for smaller geographical areas. But, notwithstanding ongoing efforts – notably with the creation of the Global Statistical Geospatial Framework (UN GGIM (2019)) and the support by some statistical exchange standards,[22] there are still many challenges when to integrating geospatial data within general statistical information (UNECE (2024b)). Fortunately, technological innovation can be expected looking forward to offer new opportunities to integrate ground and satellite information to enhance environmental data coverage, precision, quality and frequency, and to address new demands from users, eg for tracking forest carbon storage and monitoring clean energy transitions.

7. The way ahead

A more sustainable economy requires a consistent and interoperable carbon accounting framework based on a reliable system for measuring and reporting GHG emissions across the value chain. This calls for **collaboration and innovation from all stakeholders involved**. First, companies and auditors have a key role to play to ensure the quality of enterprise data. Second, standard setters are essential to ensure the consistency of micro and statistical macro information, for instance though the use of global statistical classifications such as the International Standard Industrial Classification of All Economic Activities (ISIC) or the Central Product Classification (CPC)). Third, novel types of information sources, especially satellite data, offer new opportunities to fill gaps.

Last but not least, **official statisticians, as producers of publicly available data, have a central part to play in this endeavour**. They have developed in-depth expertise in measuring the flows and stocks of essential macroeconomic variables. This makes them very well-equipped to complement and think beyond existing indicators, such as GDP, by incorporating new metrics on inclusive and sustainable growth and prosperity (MacFeely et al (2024)). As most of environmental data cut across domains and are often generated outside of official statistics, one has to integrate disparate sources to "grow" statistics on the environment (Rancourt (2019)). Leveraging official statisticians' expertise in using new, complementary big data information, such as satellite imagery and micro-level data sets, can bring a fundamental contribution for ensuring the accuracy and consistency of all collected information.[23] This experience can be mobilised to bridge existing carbon-related data gaps, foster better quality and more complete company-level reports, and develop consistent carbon accounts for the global economy. For instance, official statistics can help to estimate scope 2 and upstream scope 3 data where no direct information from the supply chain is available, by making accessible environmentally extended IOTs, providing disaggregated information for industries where emission intensities are heterogeneous, and helping to distinguish between various modes of energy production. Finally, and perhaps more fundamentally, official statisticians can help to ensure that environmental data remain open and accessible to the public, in turn promoting awareness and shared responsibility in achieving carbon neutrality. The provision of more

[22] A key example is the support for modelling and exchanging geospatial data with the version 3.0 of the Statistical Data and Metadata eXchange (cf sdmx.org). For a broad overview on the use of common standards for the integration of geospatial and statistical information, see the recent work from the UNECE INGEST Task Force on Standards Issues (UNECE (2024c)).

[23] Two important statistical committees in Europe – the Committee on Monetary, Financial and Balance of Payments Statistics (CMFB) and the European Committee of Central Balance Sheet Data Offices (ECCBSO) – have taken steps in this direction. In particular, they are monitoring the implications of climate change-related regulatory developments for statistical purposes, including with regard to the collection of company-level data.

transparent, openly available and credible data can be fostered by strong policy requirements, official statisticians' stewardship and effective peer pressure mechanisms.[24]

But **many obstacles remain**. Access to and sharing of micro-level data should be enhanced and made more efficient, not least to minimise reporting burdens. Commonly shared regulation and disclosure standards are still lacking. Moreover, it is essential to ensure that information disclosed by firms adhere to well-established international statistical classifications, eg on products and activities. However, the existing statistical infrastructure presents important shortcomings, and more work is needed to develop global agreed definitions and classifications, especially in the area of climate finance, as well as of product- and firm-level identifiers. . Last and not least, official statisticians too often face resource constraints that hinder their ability to meet the increasing demand for data by users. In this context, the urgency to act swiftly calls for stronger collaboration and innovative solutions, for instance through the integration of cutting-edge digital technology and the development of incentive mechanisms for voluntary carbon reporting.

In view of the challenges above, **the IFC can play a useful role to foster joint and complementary work of the various stakeholders involved in carbon accounting**, support the provision of harmonised and reliable information and thereby contribute to an international solution for addressing the global phenomenon of climate change and its regional impacts. To this end, the Committee has been focusing on sharing experience and best practices among its members, keeping central banks informed about ongoing initiatives by relevant shareholders, and taking stock on existing data sources and future plans. Looking forward, specific action points are being envisaged, including:

- The conduct of a survey among central banks to take stock on existing data sources and plans for the future.
- The mapping of the macro data sets relevant for emission intensities, mostly from AEAs and international IOTs, to make them readily accessible (including for enterprises).
- The review of existing and promising future micro data sources on emission intensities and their interlinkages.
- The development of solutions for providing international access to company-level direct emissions data, as a key prerequisite to properly enable carbon accounting, including product-level information.

This IFC work is a testimony to the fact that **central banks, with their mandates on monetary policy and financial stability, as well as in other areas such as reserve management, are important stakeholders on climate change issues** (IFC (2022)). They are also significant players in the international statistical agenda, benefiting from their unique position as both users and producers of data. As users, they can draw on their holistic view of the financial system to monitor and mitigate environmental risks affecting the global economy. As producers, they are uniquely positioned to integrate environmental data with a wealth of information sources across multiple economic domains and financial sectors – not least banks and insurance companies, which play a key role in the transition towards a greener economy. Central banks have also been paving the way for greater global statistical coordination, by collaborating with each other and international organisations and by operating a robust interconnected system for financial data collection, processing and dissemination. These achievements show that central banks can be instrumental in spurring the global statistical infrastructure to better measure the impact of climate change, building on a comprehensive and consistent carbon accounting framework. The issues at stake suggest that they must act boldly, yet with a long-term perspective. Balancing these two requirements has always been a unique strength of central banks.

[24] These elements have been in fact instrumental in ensuring the success of the DGI, as argued by Tissot (2022); see also van Maanen (2023) on these general issues.

References

Advisory Expert Group on National Accounts (2022): *WS.7 guidance note on the treatment of emission trading schemes*.

Béguin, J-Mc, C Cazes, J Cazes, J-L Leban, F Meunier, A Minczeles, A Paille and V Vanwormhoudt (2024): "Piloter les émissions de gaz à effet de serre – Le potentiel immense de compter en 3D", *Variances.eu*, 9 September.

Chung, H C, L Wanxin and C Loh (2024): "Professionalism: bridging the missing link between environmental MRV and carbon neutrality", *Data & Policy*, vol 6, no e40, October.

Desnos, B, T Le Guenedal, P Morais and T Roncalli (2023): "From climate stress testing to climate value-at-risk: a stochastic approach", available at SSRN, 01.07.2023.

European Commission (EC), International Monetary Fund (IMF), Organisation for Economic Cooperation and Development (OECD), United Nations and World Bank (2009): *System of national accounts 2008*.

European Union (2023): "Regulation (EU) 2023/956 of the European Parliament and of the Council establishing a carbon border adjustment mechanism", *Official Journal of the European Union*, 16 May.

Folk, F and B Hannon (1974): "An energy, pollution and employment policy model", in M Macrakis (ed), *Energy: demand conservation and institutional problems*, MIT Press, pp 159–73.

IMF, Inter-Agency Group on Economic and Financial Statistics and Financial Stability Board Secretariat (2023): *G20 DGI-3 Workplan – people planet economy*, March.

Irving Fisher Committee on Central Bank Statistics (IFC) (2021): "Sustainable finance data for central banks", *IFC Report*, no 14, December.

——— (2022): "Statistics for sustainable finance", *IFC Bulletin*, no 56, May.

Just, J (1974): "Impacts of new energy technology using generalized input-output analysis", in M Macrakis (ed), *Energy: demand conservation and institutional problems*, MIT Press, pp 113–28.

von Kalckreuth, U (2022a): "Pulling ourselves up by our bootstraps: the greenhouse gas value of products, enterprises and industries", *Deutsche Bundesbank Discussion Paper*, no 23, July.

——— (2022b): "Product level greenhouse gas contents – how to get there?", *SUERF Policy Note*, no 288, September.

——— (2024): "Harnessing the power of input-output analysis for sustainability: a simulation study based on US data", *IFC Working Papers*, forthcoming.

Kaplan, R and K Ramanna (2021a): "How to fix ESG reporting", *Harvard Business School Working Paper*, no 22-005, July.

——— (2021b): "Accounting for climate change", *Harvard Business Review*, vol 99, no 6, pp 120–31.

——— (2024): "Principles and content for downstream emissions disclosures", *Harvard Business School Working Paper*, no 50, January.

Kaplan, R, K Ramanna and M Roston (2023): "Accounting for carbon offsets – establishing the foundation for carbon-trading markets", *Harvard Business School Working Paper*, no 50.

Leontief, W (1970): "Environmental repercussions and the economic structure: an input-output approach", *Review of Economics and Statistics*, vol 52, no 32, pp 262–71.

——— (1986): *Input-output economics*, second edition, Oxford University Press.

van Maanen, G (2023): "Studying open government data: Acknowledging practices and politics", *Data & Policy*, vol 5, no e3, January.

MacFeely, S, P van de Ven and A Peltola (2024): "To GDP and beyond: The past and future history of the world's most powerful statistical indicator", *Statistical Journal of the IAOS*, vol 40, no 3, pp 685-711, September.

Miller, R and P Blair (2022): *Input-output analysis: foundations and extensions*, third edition, Cambridge University Press.

Munksgaard, J, J Minx, L Christofferson and L Pade (2010): "Models for national CO_2 accounting", in: Suh, S (ed), *Handbook of input-output economics in industrial ecology*, Springer, pp 533-58.

Network for Greening the Financial System (NGFS) (2024): "Improving greenhouse gas emissions data", NGFS Information Note, July.

Qayum, A (1994): "Inclusion of environmental goods in national income accounting", *Economic Systems Research*, vol 6, no 2, pp 159–69.

Ramanna, K (2024): "Levelling up on carbon accounting and reporting", presentation at a workshop on "Carbon content measurement for products, organisations and aggregates: creating a sound basis for decision-making", Hamburg, 21–23 February.

Rancourt, E (2019): "The scientific approach as a transparency enabler throughout the data life-cycle", *Statistical Journal of the IAOS*, vol 35, no 4, pp 549-58, December.

Richter, K (2024): "Busting the myths of carbon accounting: a new era of radical simplicity", *Encompass*, September.

Suh, S (ed) (2010): *Handbook of input-output economics in industrial ecology*, Springer.

Sun, Y, X Yang, R Wu, G Gong and T Lei (2024): "How to address enterprise collusion in falsifying carbon emission data: A game theory analysis", *Managerial and Decision Economics, Wiley,* September.

Tissot, B (2016): "Globalisation and financial stability risks: is the residency-based approach of the national accounts old-fashioned?", *BIS Working Papers*, no 587.

——— (2022): "The central banking contribution to international statistics: a Basel perspective", *Statistical Journal of the IAOS*, vol 38, no 3, pp. 733-40.

United Nations Committee of Experts on Global Geospatial Information Management (UN GGIM) (2019): *The Global Statistical Geospatial Framework*.

United Nations (2017): *System of Environmental Accounting 2012, Applications and Extensions*, New York.

United Nations Economic Commission for Europe (UNECE) (2024a): *Guidelines for the application of environmental indicators*, 2023 edition, ECE/CEP/200, August.

——— (2024b): *Integration of geospatial and statistical data*, Conference of European Statisticians, Seventy-second plenary session, ECE/CES/2024/8, June

——— (2024c): "A path towards the use of common standards to support the Integration of Geospatial and Statistical information by the INGEST Task Force on Standards Issues", *Working Paper Series on Statistics*, no 11, August.

World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) (2004): *The greenhouse gas protocol: a corporate accounting and reporting standard*, revised edition.

——— (2011a): *Corporate value chain (scope 3) reporting standard; supplement to the GHG protocol corporate accounting and reporting standard.*

——— (2011b): *Product life cycle accounting and reporting standard*.

——— (2013): *Technical guidance for calculating scope 3 emissions; supplement to the corporate value chain (scope 3) accounting and reporting standard.*

Yamano, N and J Guilhoto (2020): "Emissions embodied in international trade and domestic final demand", OEC*D Science, Technology and Industry Working Papers*, no 2020/11, Paris.

Yamano, N, J Guilhoto, X Han, C Webb, N Girouard, J-A Monteiro (2023): "Measuring CO2 emissions embodied in international trade and domestic final demand", in S Arslanalp, K Kostial and G Quirós-Romero (eds), *Data for a Greener World: A Guide for Practitioners and Policymakers*, IMF, Chapter 2, April, pp 23–42.