NOTE

Towards a generalized carbon accounting system

Tracing carbon at product level

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Summary

Introduction

We are now all aware. If we want to reduce greenhouse gases (GHGs) in the face of climate chaos, we need an accurate and reliable system for measuring emissions. There is no public policy initiative in favor of the climate that does not require, at one level or another, proper counting of GHGs, expressed in carbon equivalents. To be effective, specific regulations, such as the emission quotas imposed on car manufacturers, require impact measurements at a detailed economic level to guide the regulator. Targeted subsidies, which help to steer companies towards green innovations, require monitoring at micro level. The same applies if we want to put a price on carbon, whether through a tax mechanism, the trading of emission permits or the application of shadow carbon pricing in company accounts.

To these three main classes of instruments, well described by Blanchard, Gollier and Tirole (2022)[1], we need to add a fourth, which is gradually emerging and which, notably, does not depend directly on governments. It involves the propagation of a culture of sobriety in which *some things are just not done*. It is fortunate that economists are beginning to consider the importance of this social/driver (Pisani-Ferry and Mahfouz, 2023)[2]. It works at many levels in the ESG efforts of companies, particularly when it comes to GHGs[3]. Here, economic players are not simply reacting to a tax, an external financial incentive or the threat of a penalty for non-compliance. They get involved in the fight against climate change out of their own will. With the tally before their eyes, they save the carbon through their day-to-day decisions and make the best of the commercial and reputational advantage they derive from it.

Here again, the company needs to have good data on the carbon emitted. This makes it possible to put a figure on targets for internal purchasing and investment

1. Blanchard, Olivier, Christian Gollier, et Jean Tirole, 2022, *The Portfolio of Economic Policies Needed to Fight Climate Change*, Peterson Institute for International Economics, 2022.
2. Pisani-Ferry, Jean et Selma Mahfouz, 2023, *The economic implications of climate action*, Report commissioned by French Prime Minister, *France Stratégies*, May.
3. This Report does not intend to mean that climate action can be limited to reducing greenhouse gases alone. Biodiversity, for example, is a huge challenge that is resistant to uniform, quantified measures, as is the case for greenhouse gases, and yet it is one of the environmental concerns of companies, as part of their ESG approach. On this issue, see: Dominique Bureau, Jean-Christophe Bureau and Katheline Schubert, 2020, *Biodiversity in Danger: What Can Economics Do?*, French Council of Economic Analysis, n° 59, September.

policies. The data is made available to third parties by decision of the company itself, by legal obligation or under pressure from investors, employees and customers. Performance in terms of carbon saved is monitored over time (this is the "carbon trajectory") and weighed against other companies in the same sector. Having this information in turn, households can direct their purchases according to their views on sobriety and the regulator can refine interventions in terms of tariffs, quotas, or subsidies.

The movement is well underway. Protocols for measuring emissions have been developed over the last twenty years. Firms of experts have been set up to help companies with this task, and software packages are in circulation to assist them. Legislation has followed suit. In France, a decree issued in July 2022 recommended that companies of a certain size should draw up a greenhouse gas emissions balance or "carbon footprint"[4]. The recent European CSRD directive, adopted in early 2023, goes even further, broadening the range of companies required to publish such reports and, more importantly, making the exercise compulsory (from 2025 for the 2024 financial year in the form of a Sustainability Report).

In this broad debate, this Report has a twofold ambition. Firstly, it argues that, when it comes to measuring emissions, we must not limit ourselves solely to the level of the emitting entities, mainly companies. Carbon accounting should, and can, be done at the level of each good or service. This enables companies to control their emissions in their most detailed purchasing and production decisions. By aggregation, it is easy to obtain emissions at the level of the entity, the region, the industry, etc. *Generalised Carbon Accounting* is above all about using goods and services rather than companies as the relevant level for the accounting of carbon. This is already done in part when a company establishes its carbon footprint, as it is required to measure the individual carbon content of the goods and services it buys. The logic must go one step further by making it possible to track the carbon content of a product along the value chain between suppliers and customers. To do this, companies need to inform their customers about the carbon content of the products they sell.

The second contribution of this Report stems from the first: if the product is indeed the relevant level, it is possible to insert the carbon accounting into the financial accounting of purchases and sales. Indeed, the carbon information system must be based on the invoice, that is the basic legal and accounting document for transactions. It is on the invoice that the carbon content of the good or service being traded

4. Décret n° 2022-982 of July, 1st, 2022 relating to greenhouse gas emissions reporting.

can conveniently appear. In this way, carbon measurement fits naturally into the software tools and systems already in place within the company. It relies on the network of accountants, management controllers and internal and external auditors already in place, capable of producing the figures and ensuring their probity (Cazes *et alii*, 2023)[5]. Smaller companies are helped by their chartered accountant. The carbon initiative, the "E" in ESG, which is now part of every company's sustainability requirements, will be more effective if organized jointly by the finance and ESG departments of the company. Carbon accounting is thus destined to become a simple auxiliary accounting statement in the financial accounts. It is for these two reasons – the focus on the product rather than the company level, and the close link with the financial accounts – that the proposal is called *Generalised Carbon Accounting* or GCA.

Our proposal builds on emerging initiatives, such as those in France from the *Carbone sur Factures* collective (2023)[6] and DFCG (2023)[7], with whom the author has had fruitful discussions in preparing this Report. It examines the opportunity, benefits, and costs of the idea. This proposal is almost fully consistent with the GHG disclosure standards that are being adopted in legislation that is underway. One of the best known of these standards, the GHG Protocol[8], has inspired the normative basis of the EU's CSRD directive and the current work of the SEC, the US Securities and Exchange Commission. We examine its relation to the GCA system below in more detail. However, these standards were historically designed for the "company level" and not the "product level". They do not impose the discipline of traditional accounting rules on individual transactions as they appear on invoices, even though this would make the disclosure exercise, soon to be mandatory, easier and more reliable.

The rationale here is not to add to the somewhat heavy disclosure requirements that companies already have or will soon have to comply with, but on the contrary to propose a less costly and more reliable self-fulfilling system in the interests of all participants.

5. Cazes Jérôme, Alain Grandjean, François Meunier, Emmanuel Millard et Katheline Schubert, 2023, *L'entreprise doit indiquer à ses clients le contenu carbone des produits qu'elle leur vend*, Les Échos, on January 4.
6. Voir Carbones-factures.org, *Principes et bonnes pratiques de la comptabilité des carbones.* Read on Internet on April 23, 2023.
7. DFCG, 2023, *Accounting for Climate & Sustainability: what CFOs & CSOs think*, together with Boston Consulting Group, April.
8. GHG Protocol, Corporate Value Chain (Scope 3) Accounting and Reporting Standard, Supplement to the Corporate Accounting and Reporting Standard, read on Internet on February 23, 2023.

I. Carbon flows in the economy

The emission of CO_2 or assimilated gases[9] into the atmosphere results from the chemical transformation of one or more products in the act of production or consumption. Its main source is the transformation of fossil fuels into energy by combustion or direct leakage. To varying degrees, these emissions concern all entities in the economy: the company whose premises are heated with gas, the producer of electricity from fuel oil, the person who uses his car with an internal combustion engine, etc. But other production activities also generate emissions, as is the case with cement production, livestock farming, rice paddies, some chemical plants, etc. Each good and service produced and sold by the emitting companies therefore also contains its share of emissions. (Emissions can be negative if carbon is captured as part of a production activity.)

These emissions are measured in physical units, kilograms or tonnes of carbon equivalent. In the remainder of this Report, we will refer to these emissions as *direct carbon emissions* or *emissions associated with a product.* And, by simple addition, we will refer to the company's direct emissions as the sum of the emissions directly linked to its total production. We also use the term *scope 1 emissions* in reference to the GHG Protocol nomenclature mentioned above, on which we comment below (see §III).

At company level, direct emissions are associated with the finished product. But the finished product requires other goods and services for its production, each of which has caused direct emissions. The sheet of glass requires the gas that burns in the furnace, but also silica, packaging paper, cleaning services for the premises, the furnace itself, etc., all of which have also generated direct carbon emissions for their production. The company that manufactures glass doors in turn uses sheets of glass that "contain" carbon, the carbon that was "embedded" into the glass when it was melted, even though the carbon has long been released into the atmosphere. By a cascading effect, all the products in the economy incorporate carbon directly, but also indirectly, via the inputs required for their production, i.e., from the corporate value chains. These are known as *indirect emissions.*

9. Following the Tokyo Protocol in 1997, the six gases identified as having a greenhouse effect are carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, nitrogen trifluoride, hydrofluorocarbons and perfluorocarbons.

In total, every product in the economy, whether it is a final product, an intermediate product or a capital good, contains a quantity of carbon equivalent emitted both directly and indirectly. The term used to describe this physical quantity, in general and for this Report, is *product carbon footprint*, or simply *product footprint*. The term *carbon weight* (or *product emission factor*) is also used interchangeably. This is the sum, at product level, of the quantities of carbon emitted, directly and indirectly, to manufacture it. It obviously does not include future emissions resulting from the use of the product.

To sum up, three concepts, and only three, are used in this Report: *direct emissions, indirect emissions* and their sum, i.e., the *footprint*, each of which may have several synonyms. As we shall see, they can be aggregated at different levels, but first and foremost they are defined at product level.

II. The basic principle of carbon accounting

What was developed earlier at the level of a product also applies at the level of any entity that produces or consumes it. We refer to the footprint of a company or household as the sum of the direct and indirect emissions associated with the company's production or the household's consumption. How is it calculated? In the case of direct emissions, the assessment requires technical know-how to audit the industrial process in question. We know from experience the carbon that is emitted by a particular technology or chemical transformation. But things get more complicated when it comes to goods coming from the value chain.

Most of this information is currently not known to the players involved. Companies still rarely receive carbon data from their suppliers. Households do not know the CO_2 content of their petrol usage, nor of the yoghurts or biscuits they consume, although they do know their sugar or fat content.

To find out about their indirect emissions, companies usually turn to consultants who carry out a monographic analysis of the production processes and inputs purchased. They work from the bottom up, looking first at Tier 1 suppliers, such as the glass manufacturer that supplies the glass door company. What does this manufacturer consume in terms of gas for its furnaces and fuel for transport? Then we must estimate the carbon content of its other inputs, which means we have to turn to the Tier 2 suppliers, and so on up the value chain. This is very difficult given the infinite complexity of inter-company flows – and even their circularity: a company that sells reels of wire to a paper clip manufacturer will use the same paper clips for its administrative department. A precise calculation is therefore impossible using the monographic method. The expert compensates for this complexity by using flat-rate *emission factors*, adding together the direct and indirect consumption of CO_2 per unit of product, which they may know from surveys of other customers or from databases such as the one that ADEME, a French non-profit and public organization, usefully provides under the name of *Base Carbone*[10]. But these databases are imprecise, static and far from exhaustive. An emission factor is inherently

10. ADEME's Base Carbone® is public and can be enriched by users if they supply their own data.

unstable precisely because companies, in their search for less carbon-intensive solutions, modify the structure of their purchases to optimize them, and therefore the carbon content of the products they buy.

Added to this imprecision and instability are the lack of harmonisation, the duplication of studies, the non-exhaustiveness and the cost of any process for carbon identification in the value chain.

The question then arises: why would the information a company needs not simply come from its suppliers (apart from its direct emissions) and, to put it simply, through the invoices it receives from them? In turn, why doesn't the company, especially if it has already computed its own footprint, "push" this information to its customers via the invoices it sends them? Once in common use, such a practice leads to a system for assessing carbon content that is exhaustive, consistent and inexpensive in the long run. In practice, the company's accountants and management controllers take over from the engineers and technicians, relying on them, if need be, only for the calculation of direct emissions and, as we shall see, for the ramp up of the system and for goods resulting from innovations or imports.

What we see here is a system of distributed intelligence, similar in its effectiveness to the mechanism used to calculate VAT, the value-added tax. In both cases, the data – and the money in the case of VAT – is collected in a decentralised way by the companies themselves, with no central body intervening. We will come back later (see §IX) to the similarity between the two mechanisms, which may have an important application.

Generalized Carbon Accounting (GCA) therefore consists, in principle, of indicating on the invoices, alongside the data in currency units, the carbon content of each product listed therein. By cascading this information, most companies can largely dispense with technical studies and simply pass on the carbon content of the goods and services they purchase. Basically, the GCA system can be seen as a broad algorithm for generating carbon data.

What is proposed here, it should be noted, already exists in embryonic form. This is the case when some banks provide their customers with the monthly carbon footprint of purchases made using their credit card; when the restaurant indicates the carbon weight of the menu chosen; or, for airlines, that of the plane ticket. Telephone operators are obliged in France to show the direct carbon content of Internet use on the customer's bill. But this is still rare in business-to-business trade and for everyday consumer goods. This is the approach that should become more widespread.

What does the invoice look like?

The invoice usually shows the quantity and unit price in currency units of the goods purchased, excluding and including VAT, and the total in currency per product. Under GCA, the company adds the unit values of the product footprint and the resulting total for each product line. If the invoice is electronic, this data is automatically supplied to the client company's information systems. For consumer goods not covered by an invoice, the information appears, where possible, on the retailer's labelling next to its selling price or on the associated technical leaflet.

The generating accounting event, for both carbon and currency unit flows, is the invoice, carbon "purchased" or carbon "sold". We therefore do not deviate from traditional accounting in monetary units, which will remain a general principle of GCA. We only attach the carbon content to it. In the case of an input incorporated into several goods, the management controller helps to make the split, according to the usual principles of cost accounting.

We therefore have the following basic accounting equation, at the level of the product, of a group of products or at company level. In the box below, it is shown at company level.

Total footprint of products shown on supplier invoices
+ direct (net) emissions

= total footprint of products on customer invoices

Each side of the equation is none other than the company's footprint, which can be calculated on an ongoing basis according to the inflow of invoices and direct emissions. By linking this to the company's usual accounting system, a general ledger with accounts receivable and payable all expressed in carbon units is obtained as a by-product. There may be time lags in the accounting entries: an input purchased in one year is consumed in the following year, or the use of a capital good is spread over a long period. This discussion is reported below, in §VIII.

The all-inclusive nature of this mechanism must be emphasised: it is indeed all the incoming invoices (for the carbon contained in the purchases) and all the outgoing invoices (for the carbon transmitted in the sales) which are accounted for, regardless of the supplier, including, for example, banks and insurance companies since their services also consume carbon – we will see later what happens for their loans.

Ideally, all the companies in the country are subject to this mechanism – we will see what happens with imports. For almost all companies, simply adding up the invoices replaces technical immersion in complex nomenclatures. This frees up their time to concentrate on the only thing that matters, that is, reducing their carbon footprint.

III. The GHG protocol and the three scopes

Before turning to the practical implementation of the method, this section looks at the important standardization underway in the measurement of companies' footprints, particularly as it is used for environmental legislation. Generalised Carbon Accounting must be consistent with this body of legislation.

Originally, for example as early as the Tokyo Protocol in 1998, the aim was to measure GHGs for groups such as countries and sectors of activity. It soon came to be measured at the level of legal entities, mainly companies. Standardization was not originally designed to be extended to the level of goods and services produced[11]. This choice of the "company" level rather than the "product" level largely explains the conceptual construction adopted and why it is relatively cumbersome, in contrast to GCA.

The first set of standards was published in 2001 under the name *GHG Protocol*. It was the result of a joint effort undertaken in 1998 by the *World Resources Institute* and the *World Business Council for Sustainable Development*. It was this "protocol", broken down into requirements and guidelines, that first analyzed an entity's emissions according to three categories or scopes, with scope 1 covering direct emissions as we have seen, scope 2 only indirect emissions linked to the production of electricity purchased by the entity, and scope 3 the remaining indirect emissions coming from, and going to, the value chain.

Other private institutions followed suit. For example, the *Carbon Disclosure Project* (CDP, 2022)[12], born in the UK in 2002, set itself the goal of helping companies to disclose their GHG emissions, largely by adopting the concepts developed by the GHG Protocol. In France, ADEME published its own methodology[13], which differs little from that of the GHG Protocol. Many other organizations have established their own methodology, which calls for clarification.

11. In chapter 8 of its document on Scope 3, GHG Protocol Scope 3 (2021) mentions the issue of allocating a company's footprint between its various products sold, without however fully developing the concept.
12. Carbon Disclosure Project (CDP), 2022, Technical Note: Relevance of Scope 3 Categories by Sector, read on Internet on January 20, 2023.
13. ADEME, 2020, Méthode pour la réalisation des bilans d'émissions de gaz à effet de serre conformément à l'article L. 229-25 du code de l'environnement, Version, 5, 2020.

The GCA system outlined here does not attempt to do so, since it remains primarily a mechanism for collecting carbon data. Since it focuses on the smallest scale, i.e., the product, it is compatible with any properly devised standard.

Following the Paris Agreement of 2015, the *Task Force on Climate Related Financial Disclosures* (TCFD, 2021)[14] was created under the aegis of the *Financial Stability Board*. It proposes a method that companies can use to manage climate-related risks and opportunities and how they should disclose them. There are four aspects to this: governance, namely how the board and management deal with these issues; strategy, namely the impact of these risks on the company's operations; risk monitoring, or the system that the company adopts in this regard; and finally, measurement, that is the "metrics" chosen by the company, in accordance with recommendations based on the GHG Protocol's three-score methodology.

Legislation follows. With its *Corporate Sustainability Reporting Directive* (CSRD), which came into force at the beginning of 2023, the EU is updating a set of legislation on extra-financial reporting. The environmental section of the directive imposes disclosure requirements in accordance with standards currently being published, starting in 2025 for the 2024 financial year. In France, we already mentioned the decree of 1 July 2022 recommending carbon reporting. Legislation will very probably make this mandatory when the European directive, announced for the end of 2023, is transposed into French law. The *US Securities and Exchange Commission* (SEC, 2022)[15] has just published a reference document, still under discussion, based on similar concepts.

All legislation must be based on clear standards and definitions. Hence the need for environmental accounting standards to be set by the various standard-setting bodies that already exist for financial accounting. For example, the IFRS Foundation, which enacts the IFRS accounting standards, has brought together the so-called extra-financial standards, including those relating to carbon, within the *International Sustainability Standards Board* (ISSB, 2022)[16]. In the EU, EFRAG, the body responsible for implementing IFRS accounting standards in the Union[17], has

14. TCFD (Task Force on Climate-related Financial Disclosures), 2021, Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures.
15. SEC (Securities and Exchange Commission), 2022, The Enhancement and Standardization of Climate-Related Disclosures for Investors, on the SEC Internet site.
16. ISSB, 2022, Project Exposure Draft S2 Climate-related Disclosures Topic Scope 3 greenhouse gas emissions, October.
17. EFRAG, 2021, Final Report Proposals for a Relevant and Dynamic EU Sustainability Reporting Standard Setting, February.

seen its role extended to extra-financial issues via the *European Sustainability Reporting Standard* (EFRAG, 2021), and it is this latter set of standards that the EU refers to in its CSRD directive. The same applies in the United States. This is a welcome development in view of the proposal made in this Report, namely, to harmonize the rules on financial and environmental reporting.

The truth is, however, that we get lost in all these initiatives and acronyms. The GHG Protocol is a dense set of texts, detailed to the extreme, with the aim of unifying methodologies. By starting from the product rather than the company, it is argued that Generalised Carbon Accounting makes them much more understandable and, all in all, greatly simplifies accounting.

The logic of the three scopes

While scope 1, namely direct emissions, is unambiguous, scope 2 has a hybrid status. It represents indirect GHG emissions linked to electricity purchases. "Indirect" is therefore of the same nature, in terms of carbon, as any other purchase from the value chain. An electricity producer will count the carbon emissions from its thermal power station in scope 1; its customer will count the electricity consumed in scope 2. But it would be double counting to add up the scope 1 of one and the scope 2 of the other.

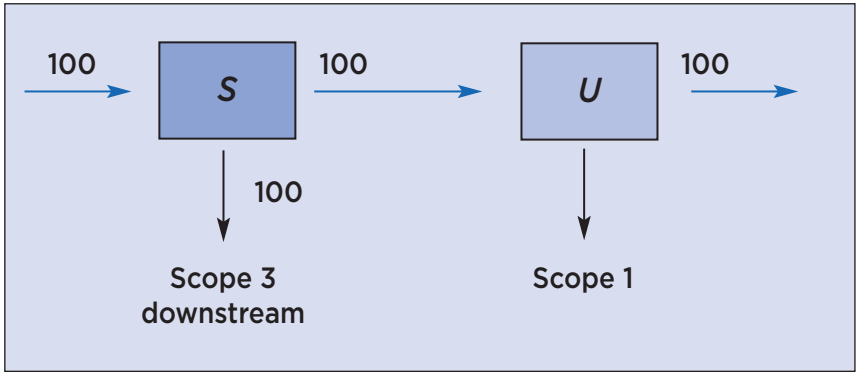
So why are the emissions linked to electricity put in a specific category rather than identified within the rest of the indirect emissions? It was a pragmatic choice. Initially, it was not planned to include all indirect emissions, because the task seemed too challenging. But it made sense to make an exception for purchased electricity, which is one of the largest sources of GHG emissions and a large purchase item for companies, which is also easy to identify. It is also an item that lends itself to cost-saving actions, by using self-generation or by retaining a greener electricity supplier. However, once the measurement of carbon emissions is generalized at product level, electricity becomes a product like any other, albeit a major one, and the concept of scope 2 looses its importance. Accounting at product level, it becomes possible to perform any type of analysis, in the same way as an income statement broken down by type.

Scope 3 deals with other products coming from and going to the value chain, namely the rest of the indirect emissions. This is a complex and detailed standard, as shown by the three years it took the GHG Protocol to develop it. It groups indirect emissions into fifteen categories (excluding electricity consumption, which could in fact form a sixteenth category). Eight of them concern upstream emissions, i.e.,

from supplier deliveries, and seven concern downstream emissions, i.e., those that customers will produce through the use or consumption of the product delivered. Thus, for a washing machine, scope 3 upstream adds up the indirect emissions attached to the goods used to produce the machine, while scope 3 downstream those related to the use of the washing machine, such as electricity, spare parts, the carbon cost of disposal, etc. It seems surprising that two concepts as different as upstream and downstream are placed under the same scope 3 heading and that no scope 4 or 5, dedicated to downstream, has been introduced. This is the result of the history in the development of the standard.

But this choice provides an opportunity to amend the basic rule proposed for GCA, namely that the place where a carbon emission is recorded is the place where it is emitted: the gas burnt by the glass panel company (direct emission, therefore) is measured and declared at that company. Let's explain.

Let's take a company that supplies gas, that is both an importer and distributor of gas (*S* in the graph below). It delivers 100 tons of carbon to another company, the end user of the gas, U on the chart below. If there are no losses of gas in distribution, the 100 tons will be used entirely by U, which must count them as direct emissions, i.e., in scope 1. The GHG Protocol standard recommends that the supplier should also account for them, but this time not as direct emissions but as indirect emissions, in a way "by anticipation", therefore in downstream scope 3, in a particular category (no. 9) of its scope 3 declaration.



The same will apply to GCA, out of pragmatism. *S* will write 100 tons on its invoice, and its customer *U* will only have to carry this amount downstream in its own customer invoices, without worrying about having to do the calculation itself. The place where the direct emission occurs remains centered on *U*, which remains the

emitter. But it is convenient that the calculation be carried out by the supplier. There are two reasons for this: for this type of product, it is the supplier rather than the customer who has the expertise to measure the direct emissions that will occur downstream; moreover, there are few importers and suppliers of fossil fuel products, whereas their customers, particularly households, are very numerous and dispersed. It makes sense that buyers of fossil fuel products should only have to read on their incoming invoices the data produced upstream by their suppliers. But the carbon is still "theirs".

Let's draw the conclusion: in most cases, direct emissions are calculated by a few suppliers who are equipped to do so easily. Consequently, almost all companies, even if they are GHG emitters themselves, do not need to mobilize any specific expertise: they take the carbon footprint declared on all their invoices and pass it on down through each of their customer invoices. If, for disclosure purposes, it is deemed important for the customer company (U on the chart) to report its direct scope 1 emissions separately, its gas or fuel supplier will assist by indicating this as an extra item on its invoice.

IV. Determining carbon content

We have described the accounting principle, but how is information obtained on all companies in the value chain? This a chicken-or-egg question. While a company knows its direct CO_2 emissions after an audit, it cannot know the carbon content of its other inputs if its suppliers do not share the information, which they may indeed not possess. A product at the end of the production chain may be the input for a producer at the very beginning, as we saw above with the example of the metal wire producer buying paperclips. How can this be done, given that the economy is full of such circular flows?

The Appendix shows two results, more for the theoretical comfort of the interested reader than for their practical application:

1. The carbon footprints of all goods and services can in theory be calculated immediately[18].

2. These same footprints can be obtained at the end of an iterative process. Products with a potential for downstream emissions, such as fossil fuels, or directly emitting carbon during their production, such as cement, spread gradually throughout the economy. This spreading alone, after multiple exchanges and multiple periods, progressively accumulates the direct emissions and makes it possible to obtain the indirect carbon content of the products, and therefore their total carbon footprint. Using an image that compares inter-company flows to pipes, these pipes gradually fill up with carbon.

However, there remains the practical reality that companies must first have data on the carbon weight of what they buy. They even need an exhaustive breakdown so that the declaration on outgoing invoices can be used by its customers. If, for example, the supplier indicates on its customer invoice that it has only been able to identify 70% of the carbon emitted during the production of the product, the customer will remain confused, not really knowing what to do with the information. It will not pass it on downstream.

18. The problem of determining the direct and indirect carbon content of products is similar to that of determining the "labour value" of the same goods, i.e., their direct and indirect content in terms of labour hours, a question that fascinated 19th century economists such as Ricardo and Marx.

The chosen approach

We recommend the following approach, taking note of the practice currently underway: many large companies, and even medium-sized and small ones, are already in a position to calculate their footprint, and many even make it public. They do so on an estimated basis, as described above. Although limited in number compared to the total population of companies, they represent a large proportion of economic flows.

For these pioneering companies, whatever their size, the effort consists of breaking down this pre-calculated footprint for their customer invoices. They do this to enhance their reputation, by constraint of their ecosystem, to anticipate a legal obligation or out of simple benevolence. Once the movement has begun, the legislator may wish to speed it up and standardize it.

The three steps are as follows:

1. As soon as the company has its footprint, using the methodologies in place, it breaks down its amount allocating it to each sale, using traditional cost accounting methods, under the responsibility of its financial teams.

2. As a result, customers, in preparing their own carbon footprint, can use these carbon contents for part of their purchases. For the rest of their footprint, they continue to proceed with technical expertise and use of flat-rate emission factors.

As time goes by, carbon footprint calculations become more widespread, so that:

3. The share of the company's footprint calculated by expertise and emission factors decreases and the share from supplier data increases.

A sort of self-generating discipline takes hold: the company will tend to put pressure on its own suppliers to indicate the carbon weight of their deliveries. In this way, data is increasingly circulated via invoices, and companies use the content declared by their suppliers rather than their estimates. In the same way that we know the cost of products in currency units, their "carbon cost" is gradually being disseminated.

Technical experts, both inside and outside the company, have an important role to play in this ramp-up of the system: they continue to fill in the data gaps and can take advantage of the data collected from one customer to help others. This information from outside the invoicing system will remain necessary for imports or for products that emerge as the economy innovates.

The quality control of the figures transmitted is also important. Firstly, the basic accounting equation seen in §II, needs to be balanced for what goes in and what comes out in terms of carbon. This places an initial constraint on the company because falsely greening a product to help its sale, while respecting this balance, means browning another product in its catalogue. This makes the system more reliable, builds trust and, when carbon data really comes under the scrutiny of stakeholders, prevents competition from being distorted by inaccurate disclosures. The monitoring infrastructure is already largely in place for carbon accounting. It is currently provided by external and internal financial auditors for data in currency units. In future, their audits will include data in tons of carbon. In France, as indicated by the Minister of Justice in December 2022, it is planned that when the CSRD directive is put into French law, the *Haut Conseil du Commissariat aux Comptes* (H3C), the supervisory body for financial auditors, will be the proposed supervisory authority for all non-financial auditors. The role of the ANC, the French accounting standards authority, will be asserted in this process. This is again a good thing, as it will ensure that environmental accounting ultimately becomes a simple adjunct to financial accounting, enabling us to capitalize on its robustness and the experience accumulated in this area.

Setting up the system is, of course, costly: updates to accounting and invoicing software, staff training, the cost of a chartered accountant or, for small businesses, the cost of self-help software. Small businesses will be supported in the transition by state grants. The cost incurred initially benefits all businesses by sparing them the repeated costs of a one-off analysis of their carbon footprint. And of course, it benefits the community faced with the climate challenge. There is an important collaborative aspect to the project.

V. How to add up direct emissions and footprints

The central concept for carbon accounting, as we have seen, is that of footprint, rather than direct emissions, because it does not forget indirect emissions. For example, a project that directly emits more CO_2 than another may be accepted as long as its indirect emissions, and therefore its footprint, more than compensate for this disadvantage.

But care must be taken when trying to add the footprints of several companies. To visualize the problem, we note that a company's footprint is strongly related to its sales – and the sales of two companies are not generally added where one supplies products to the other – whereas direct emissions are analogous to operating income – which does add up between companies – or more precisely, analogous to value added, which we know adds up to GDP in national accounts.

Let's look at this in more detail. It is common sense that the CO_2 released by one company is added to that released by another: the atmosphere is bound to absorb both. As a result, it is easy to add up the direct emissions of several products, several companies and any such grouping, whether geographical or sectoral.

Consider product *A*, which is used to manufacture product *B*. If product *A* directly emits 5kg of CO_2 and product *B* directly emits 3kg, then the total production of the two goods results in 8kg of carbon being released into the atmosphere.

Footprints, however, do not generally respect this nice property. In the previous example, suppose that product *A* requires no intermediate consumption other than its fossil fuel purchases. Its footprint will be equal to its direct emissions, i.e., 5kg. But the production of *B* adds to its direct emission of 3kg, the footprint of *A*, namely another 5kg. We could say that the footprint of *B* is 8kg, but it would be double counting to say that their joint production implies a footprint of 5 + 8 = 13kg.

In short, it is not always possible to add up the footprints of products, and therefore of entities. This is frequent when one of them requires another product for its production, i.e., as soon as there is a supplier-customer relationship, which happens by definition in any value chain. It therefore no longer makes sense to talk about

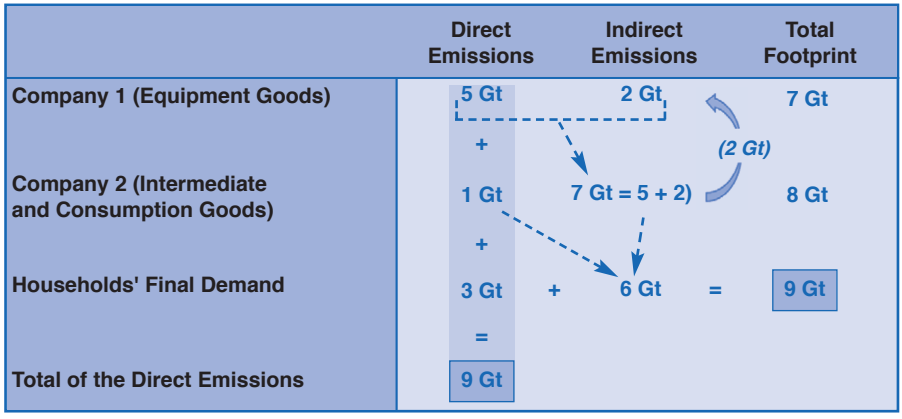
the footprint of a group of companies, a region, a sector of activity or, as we shall see, a financial portfolio. Only the adding up of direct emissions strictly makes sense.

What are the cases where we regain the possibility of adding up footprints? All that is needed is that there is no vertical relationship in the exchange, such as a good *A* being used to produce a good *B*. This is always the case when we refer to a final demand, such as a household's consumption expenditure. Households consume carbon through their purchases of food and clothing. But these are two classes of products that are final goods, not used by the household for further production. We can therefore add up their footprints without fear of double counting, in the same way that we add up the budgets in let's say dollars allocated to these purchases. Nor is there any double counting when we consider a parent company consolidating its subsidiaries. In fact, any internal flows (from product *A* to product *B*) are eliminated by consolidation when adding up the footprints. Consequently, an entity's footprint is the sum of its own emissions and the footprints of the goods and services produced or consumed by that entity. This brings us back to the basic accounting equation, according to which incoming carbon plus direct emissions is equal to outgoing carbon (see §II).

In conclusion, it is the footprint that the company must monitor and communicate downstream. It is on the basis of this indicator and its derivatives that its progress in decarbonisation must be monitored. But when one wants to estimate the CO_2 emissions of a sector of activity, a region or a country, the calculation must be limited to direct emissions. These are the data that the company has when it produces its carbon footprint and that it makes public in its sustainability report, without necessarily having to include the amount on its invoices. In the box below, we show however that it is still possible to link footprints and direct emissions, if viewed from a macroeconomic perspective.

The equivalence at macro-level between footprint and direct emission

Footprints and direct emissions can be reconciled, and regain additivity, at the level of the entire economy. This balancing ensures the coherence of the system, both for a closed economy and an economy open to external trade: *the sum of footprints at the level of final demand is equal to the sum of direct emissions at the level of production.* This is illustrated in the following table, which shows an ultra-simplified economy[19].



It is made up of the household sector, which buys consumer goods, and two companies, company 1, which produces capital goods, and company 2, which produces both consumer and intermediate goods. The first line of the table shows what company 1 produces in terms of direct and indirect emissions. It emits 5 gigatons of CO_2 equivalent directly and uses 2 gigatons of intermediate consumption (i.e., indirect emissions) purchased from company 2. Its footprint is therefore 7 Gt.

The same goes for the second company: it emits 1 Gt directly and receives the 7 Gt purchased from company 1. Its footprint is therefore 8 Gt. Households have direct emissions of 3 Gt and indirect emissions through their purchases of consumer goods from industry 2, i.e., 6 Gt (1 + 5), bearing in mind that some of the emissions of company 2 go to company 1. The footprint of households is therefore the sum of their direct and indirect emissions, namely 9 Gt.

19. The presentation of the economy's economic flows in this form is the one used in the national accounts, known as the Supply and Uses Table, or Input-Output Table.

The basic equivalence mentioned above holds true: the total of 9 Gt of direct emissions (at the bottom of the first column) is equal to the footprint measured at the level of final demand (third row). And we see that adding the footprints of all the sectors carelessly would give a total of 7 + 8 + 9, or 24 Gt, a figure that would include double counting of 15 Gt.

This equivalence is demonstrated in a more general context in the Appendix to this Report. We can, for example, legitimately talk about the footprint of imports (which is a final demand on the part of the importing country) and the footprint of exports (a final demand on the part of the client country). In a elegant study that will be published regularly, INSEE (2022)[20], the French statistical office, uses this methodology to calculate France's direct emissions, making a clear distinction between direct emissions within the country and "national" emissions, which must include the footprint of the goods and services that France imports (i.e., the carbon that it relocates abroad) and deduct what it exports.

Thus, France's annual carbon consumption per capita in 2018 was 6.9 tons of CO_2 equivalent if we base this on domestic production, but 9.2 tons if we add the amount of carbon included in imports net of exports. The first amount is currently the one used in countries' international commitments; the second is akin to the concept of carbon footprint. The difference between the two amounts illustrates that a country can relocate the production of carbon-intensive goods to third countries, just as a company can relocate it to third-party companies. One of the advantages of the footprint concept is that it corrects the bias whereby subcontracting, outsourcing or offshoring appears to reduce the carbon footprint. With GCA, clothing and tools produced in Asia, possibly less expensive than those produced in the EU, could appear much more carbon-heavy, due to high logistical costs, the use of less clean electricity or the use of less efficient technology[21].

20. INSEE, 2022, Un tiers de l'empreinte carbone de l'Union européenne est dû à ses importations, Insee Analyses, n° 74, 20/07/2022.
21. It is estimated that the carbon footprint of a garment made in France is half that of one made in China (20.7 compared with 43.3kg of CO_2). See Cann, Yves-Marie, 2022, *Relocalisons pour réduire notre empreinte carbone*, Les Échos, 19 August.

VI. Practical implementation of the method

This section deals with certain methodological issues that arise in the collection and use of data: the subject of imports, the question of confidentiality, the important role of distribution companies and the role of the company's financial teams.

A – Imports

Carbon accounting is an excellent thing, we are told, but it has the drawback of not applying to foreign companies that export to the country. And imports account for a major part of the value chain in most countries. This would force companies to operate in the dark for a large share of their purchases. There are several answers to this. First, the "problem" of imports is a general one and applies to any climate policy instrument: tradable emission permits, for instance, require border adjustment mechanisms if they cease to be allocated free of charge, and we know how difficult it is to put them in place[22]. Similar difficulties are met for carbon taxation or green regulations.

Secondly, this criticism does not apply to GCA specifically, but to any project that involves calculating a company's footprint, as the legislation requires.

Above all, it would be wrong to overestimate the difficulty. It should be remembered that the GCA approach is initially voluntary. Legislation will follow practices that have become widespread rather than anticipate them. As a result, foreign companies exporting to the EU can just as easily be "early adopters" and comply with this practice for various reasons, including friendly pressure from their European customers. If we move to a legal obligation, we know that most foreign exporters go through trading houses which, as resident entities, are subject to national law. Anyway, it will be easier to require a company wishing to export to the EU to include the carbon content in its sales than to force its country of residence to introduce a domestic carbon tax or to accept a corrective tax at the border.

22. They are currently limited to direct emissions (scope 1) in the recently passed European legislation, which is unfortunate.

The best thing, of course, would be for other countries to gradually sign up to this type of accounting, as has been the case with VAT in the tax field. In the meantime, it will be necessary to keep using emission factors set by experts for imported goods. These will be improved thanks to the information generated by GCA on domestic products.

B – Confidentiality

Some companies indicate that they are reluctant to disclose the carbon weight at product level, for fear of being penalized in competitive tenders or because this data, once in the hands of competitors, may reveal proprietary techniques. The first reaction would be to welcome this, as it would be proof that this customer control over suppliers' carbon footprints is beginning to bite. The footprint has gone from being a piece of information to a driver for change. From a practical point of view, this disclosure is a priori limited to direct customers and the data provided is summary form as the carbon footprint[23]. Finally, it cannot be ruled out that certain companies might recognize the public good nature of this data and agree, by emulation, to disclose it more widely, or even to contribute to public databases such as that of ADEME in France.

C – The importance of retail and wholesale companies

Goods and services generally reach their buyers via the distribution sector. Having legal ownership of the goods distributed, a retailer counts these footprints as part of its own, adding the carbon cost of logistics and distribution, which is often significant for imported goods. The obligation to provide information to the end customer, usually the consumer, therefore falls more on the distributor than on the producer. For example, if carbon data have to appear on a label, this cannot be done by the producer but by the retailer, as it is the case for the display of the selling price, which differs from the producer price. So, the very same item of clothing will not have the same carbon content on the French market depending on whether it is sourced from Northern France, Romania or China.

23. We mentioned above that suppliers could, at their customers' request, make a distinction on the invoice between direct and indirect emissions, i.e. between scope 1 and the total of downstream scopes 2 and 3.

D – A greater role for accountants and management controllers

The step change in Generalised Carbon Accounting, as we have said, is to put the company's carbon footprint on outgoing invoices, triggering a cascading mechanism. In any reasonably large company, this allocation of carbon footprint naturally falls within the remit of management control, since one of its functions is to allocate material costs to the various products for cost accounting purposes.

Some companies are reluctant to take this step even though they already calculate their footprint, claiming that it is difficult. But they fail to see that they already have the means to initiate the exercise. A copper cable manufacturer already allocates the cost of copper according to the physical quantity of it, measured in weight, which is incorporated into the cable. There is little difference in allocating the carbon "raw material".

And when the company does not use such physical measurement, a palliative solution is to start from monetary emission factors rather than physical ones. This is what is done by management controllers for certain expenses that they find difficult to allocate based on physical measurements, such as head office costs and other fixed expenses.

Small companies will find it more difficult. But they generally buy from larger companies, which will be ahead of them in applying this logic and will help them in the exercise. Furthermore, their product range is more limited, which makes the allocation exercise easier. There is already software available to help.

VII. Bringing the carbon logic into the company

In a market economy, a company organizes its internal resources so as to increase, as much as possible, the monetary value of what it sells and to reduce the costs it incurs. The difference is the profit. All the company's teams cooperate. The success of the company depends on the quality of such cooperation. But the exercise is highly constrained, both by technology and the market, and by the presence of "interests" that the company must comply with: those of employees, business partners and the social and natural environment, to name the most important. These "constraints" are alternatively described as "objectives" in their own right, supported by the stakeholders of the company, in parallel with the profit objective supported by the shareholder. This is known as the stakeholder approach to business.

But the fact remains that the company takes its decisions based on the price system. As for the other "constraints" or "objectives", employee well-being for example, the problem is that they are often difficult to quantify, so that other procedures are used: consultation or administrative decisions taken more or less "democratically" within the company.

But now, in response to the major objective or constraint posed by the climate challenge, a rigorous measurement system is emerging, namely the carbon weight of all the company's transactions. The importance of this innovation cannot be underrated. The company had a price system for its financial management decisions, and it now has a carbon unit system for (part of) its environmental management. How to operate on both fronts at the same time?

If the objective is simply to "minimize carbon emissions" in the same way as we say "maximise profit", it becomes meaningless as soon as it is stated. Because to emit as little as possible, just stop producing. So, the two objectives are jointly relevant.

There are two approaches to this:

1 – Put a notional or shadow price on carbon: each ton of carbon would carry a price, to recognize that the carbon emitted carries a cost that no market system can spontaneously express. This solution has the advantage of immediately reconciling

the profit and the carbon objectives, since the carbon cost, expressed in currency units, is implicitly contained in all prices and enters silently into the profit calculation. Done at a collective level, this solution is called a carbon tax and involves administrative intervention, the political cost of which has already been shown. It is well known – and distressing – that the IRA, the gigantic climate plan voted for by the US Congress in 2022, does not include any carbon pricing component.

However, there is nothing against companies adopting a notional price for their internal management. This solution has been the subject of numerous papers (see CDP (2021)[24], The Conference Board (2021)[25], Meunier (2020)[26]). This system provides the company's internal players with a set of price incentives that can be used for internal invoicing between departments or group entities. It may help to prepare the company should the scope of carbon taxation be extended.

Société Générale was one of the first banks in the world to introduce an internal carbon tax (Addicott *et alii* – 2019)[27]. Other companies, such as Danone in France, do this partially, by calculating afterwards what the year's operating profit would have been if the cost of the carbon emitted had been accounted for in monetary terms. This is known as the *"carbon-free margin"*. Getlink, formerly Eurotunnel, calculates the carbon cost of all its inputs and its own emissions and puts a price on them, using the fairly high price of €197 per ton recommended by the US Environmental Protection Agency (see the company's website or Fay, 2023). The economist Christian Gollier, an acknowledged advocate of carbon taxes, helped to draw up this indicator for Getlink. That can only be done if physical measurements of carbon are available at product level.

But no company, as far as the author is aware, is venturing to do this for its commercial and pricing decisions on a product basis until its competitors do the same. Here we have, at company level, an issue similar to the one we encounter at EU level on border adjustments to avoid distorting competition.

2 – Interweave the carbon objective with decisions that have an impact on profit. The carbon "cost" is not expressed in currency units but remains denominated in physical units. This management method is heterogeneous. I might say: for the

24. *Carbon Disclosure Project* (CDP), 2021, *Putting A Price on Carbon: The state of internal carbon pricing by corporates globally,* April.
25. *Conference Board (The), 2021, Internal Carbon Pricing: A Key Element of Climate Strategy, January.*
26. Meunier, François, *Mettre les engagements carbone dans les bilans d'entreprise*, revue Vox-Fi, 29 sept, 2022.
27. Addicott, Ethan *et alii*, 2019, *Internal Carbon Pricing: Policy Framework and Case Studies*, Yale University, May–June.

same price, I buy or sell the product that contains the least carbon, thereby giving carbon a junior position in relation to profit; or say: for the same footprint, I buy or sell the product that has the highest monetary return. This would have an impact on purchasing, by selecting the least carbon-intensive inputs; on production, by selecting the least carbon-intensive production combinations through innovation; and on sales, by promoting the least carbon-intensive products.

This two-pronged approach is more complex, but it does have one advantage, already highlighted in the introduction: the decision-maker in the field does not react implicitly, even unconsciously, to an external incentive provided by the price; he or she is required to justify their decision and is motivated more by intrinsic values. This is a different, almost moral register, which contributes to the effectiveness of the fight against climate change. Note the contrast: the carbon tax has met with a certain amount of collective rejection, essentially because it is a tax. But when implemented, it silently affects microeconomic decisions. Physical carbon accounting meets with broader support at collective level due to its immediate appeal. It is, however, much more demanding in terms of the personal commitment of decision-makers. In both cases, GCA provides the necessary data.

VIII. Accounting standards and extra-financial reporting

This section examines certain carbon accounting principles specific to the product approach when we move out of the entity approach. In doing so, we must take account of a twofold constraint: to remain as close as possible to financial accounting, which Generalised Carbon Accounting seeks to mirror; but not to deviate unduly from the standards already proposed at international level for carbon accounting, because of the quality of the work done and the credit conferred upon these standards by current legislation. This will bring us to the subject of extra-financial communication.

It is understood that some issues are still being debated and will be resolved over time. But things will be made much simpler by the anchoring of carbon accounting in financial accounting.

A – Capital goods, real estate and leasing

The case of capital goods, and more generally durable goods subject to depreciation, can be seen in two ways. Take the example of a company that delivers a machine with five tons of carbon incorporated in its production. What should its customer, who is depreciating the machine over five years, do? Take the whole thing into its footprint at once, or follow the depreciation schedule, one ton a year for the five years?

The main argument in favour of carbon "depreciation" is that it smooths out the footprint profile over time. Otherwise, the regular purchaser of, say, MRI images would see a big bump in his carbon consumption the day the laboratory renews its equipment, and nothing at all in the subsequent years. The same "bump" in the carbon footprint of airline tickets would show if the airline suddenly renewed its fleet[28]. The signal sent by the invoice becomes less intuitive. And the airline that

28. Today, the carbon weight of airline tickets only includes scopes 1 and 2, which is an unfortunate limitation.

leases its aircraft would be spreading its carbon costs more widely than the one that buys them, introducing a distortion when labelling[29].

Having said that, the distortion is much less of an issue for large companies, which generally have a regular flow of investment. Also, while depreciating smooths out the "bump" on the customer's side, it leaves it untouched on the supplier's side, with the curious effect, in terms of consistency in the value chain, of seeing the supplier's footprint higher than that of its customer, when there should be an accumulation of footprints. By not depreciating, we remain consistent both with the accounting treatment of VAT, which is taken "at once", and with the recommendations of the GHG Protocol and those issued provisionally by the ISSB. Finally, we avoid the relatively arbitrary choice of the depreciation period when they are based on tax rules. There is a debate here, the author being inclined to recommend immediate imputation.

B – Time differences between purchases of inputs and finished goods

There are time lags (storage, production in progress) between the moment the input is purchased and when it is incorporated into the finished product. This issue escapes existing standards, which are limited to calculating the company's footprint on purchases rather than passing it on downstream. Here, we can replicate for carbon accounting the rules applied for inventory accounting in financial reports, or, as in the case of capital goods seen above, stick to immediate imputation, as the goods arrive.

C – Downstream emissions

In carbon accounting, it is customary to consider the carbon weight of a product in two stages: from the beginning of its processing to its sale (*from cradle to gate*); then, once sold, in its use until it is discarded, with the possible carbon cost of its

29. IFRS 16 brings operating leases into line with financial leases. It requires the lessee to capitalise in its balance sheet the right to use the asset until the end of the lease term (for example, the right to occupy the premises until the end of the lease term in the case of a property lease). In this way, the balance sheets of the lessee and the purchaser become more similar. There would be an argument here for the lessee to take on the carbon burden of the property he is renting all at once if its use is exclusively reserved to him during the period covered by the contract.

final decommissioning (from *gate to grave*). In other words, there is an "upstream" account in the production phase, and a "downstream" one as it is used. The hydraulic press, for example, will have an upstream carbon content, i.e., the direct and indirect emissions for its production, and a downstream carbon content, mainly for the energy that its use entails.

We need to be clear here: GCA, which focuses on the trading of finished products and their associated invoices, looks at the past, i.e., the carbon content already incorporated. It postpones until later the measurement of the carbon content of its use, when such use will actually incur transactions (an electricity bill, a repair). Under the terms of the GHG Protocol, it therefore covers scope 3 upstream, not scope 3 downstream.

If the company is contractually committed to future services, such as equipment maintenance or waste management, the associated carbon content will be charged when the commitment is fulfilled. In the language of accountants, this is cash-based accounting (the carbon actually emitted) rather than accrual-based accounting (the carbon to be emitted as a result of commitments made today).

Of course, companies cannot ignore the downstream aspects of the products they put on the market. They may be required to do so when responding to tenders. There is an undeniable logic in making this part of their more broadly defined carbon footprint. The need is obvious for a company that makes great efforts to reduce the carbon footprint of its customers, enabling them, for example, to opt for a more energy-efficient solutions, but at the cost of increasing its own footprint. This point is dealt with below, in the section on extra -accounting reporting.

But here we are going beyond the ambitions of GCA, and we would lose data quality by mixing what we know from recorded contractual transactions with what one guesses to be the future use of the asset (putting aside the question of who would make the guess: the customer, the producer?). GCA aims to produce reliable data that can be used to analyze investment projects and refine emission factors linked to the future use of goods. Thanks to GCA, it could be envisaged, within a value chain and with the cooperation of all concerned, for a company to credit to its footprint with documented carbon that has been saved downstream.

In the same way, it would be a mistake to equate a low carbon footprint during production phase with a "green" activity and a high one with a "brown" activity. The engineering company that designs coal-fired power stations and sells the designs all over the world probably emits very little carbon, while the outcome of its activity is considered extremely polluting.

D – Recycling and the circular economy

A convention will have to be adopted for recycling products. If I buy a reconditioned phone, what carbon footprint will my purchase have? What is the carbon footprint for a company buying a second-hand crane?

For consumer goods, the easiest decision rule would be that the first-hand buyer, say of the phone, is the one who bears its full carbon weight; the second-hand buyer is not charged, apart from the carbon weight of the reconditioning process. To do otherwise would penalize an industry where one of its advantages – and its raison d'être – is to use resources sparingly.

For capital goods, the treatment will depend on the depreciation option chosen, as we saw earlier. If the carbon is "depreciated" over the tax life of the asset, then buying it second-hand means that the residual depreciation has to be accounted for.

E – Employee transport

Should employees who use their own cars to get to work count at their level the carbon weight of their transport, or should it be the company? This question may seem secondary, but it is the subject of intense debate, no doubt because the GHG Protocol takes a fairly radical approach to this issue. It provides that such transport costs (petrol and electricity in particular) be included in the company's footprint (in its scope 3, category n° 6)[30]. With the spread of remote working and the resulting costs for the employee (for example, the heating of their homes), we guess this issue will grow in importance.

In practice, the subject is easily dealt with in carbon accounting, based on a single criterion: what does the employment contract say, or what will it say in the future? If the parties agree that these expenses are to be paid by the company, they take on the status of "expense claims", i.e., invoices that the employee sends to his company.

30. And, of course, gas is accounted for at employee level.

Failing this, the employee is regarded as the GHG emitter, and the relevant invoices stay with them. Footprint statements must remain factual. This makes it possible – and this is a general lesson for carbon accounting – to remove any judgment of value or "responsibility" in attributing a carbon charge to one agent or another.

F – Real carbon, financial carbon

Ideally – and this is a recurring theme in public debate – we aim to determine the carbon footprint of a bank's loan portfolio, of an investment fund's holdings or simply the carbon footprint of an individual household's financial savings. Here again, it may help as an incentive. The financial institution would then need to collect the carbon footprints of its investment targets, add them up and make them publicly available. This would move carbon accounting away from measuring what we might call "real carbon", which is traced during the exchange of goods and services, to measuring "financial carbon", i.e., the footprint carried by a financial claim, such as an equity share or a debt security, of a carbon-emitting entity.

This issue falls outside the strict scope of GCA, but it is worth discussing briefly. Concerning financial institutions, such a measurement raises three specific issues: data aggregation, consolidation between entities, and the nature of financial securities.

Regarding aggregation, caution must be exercised, as seen in §VI, and the limitations of the footprint concept must be acknowledged when applying it to a portfolio of investments, since the companies in the portfolio frequently have client-supplier relationships. This applies to both debt and equity investments. However, the institution can still measure the direct emissions of its financial portfolio by reading the extra-financial reports of its investments. At best, the footprint aggregate can be used as a rough guide to monitor changes over time of the portfolio.

Consolidation rules next. A rough distinction is made between strategic holdings, where a company controls a subsidiary, and financial holdings, where an entity, possibly a company, holds a minority stake with no rights of control over another entity. However, this distinction opens the door to numerous hybrid situations that require the establishment of fairly complex consolidation rules. No consensus so far exists on this issue. The rules advocated by the GHG Protocol, for example, differ from those used by IFRS for financial accounting. In summary, the GHG Protocol offers a choice between full consolidation (taking 100% of the carbon emissions of the subsidiary for which control is presumed, such as owning more than 50% of the shares) and proportional or equity-based consolidation (where two shareholders,

one with 60% and the other with 40%, include carbon emissions proportionally). IFRS excludes equity-based consolidation. As a result the carbon emissions retained by an investment fund from its minority stakes may already be counted in the footprint of the majority shareholders of the respective companies. This does not prevent the construction of a tracking indicator based on footprints, but at the risk of being inconsistent.

Finally, the nature of the financing, whether it is provided by debt or by equity finance. It has been mentioned that the institution would consolidate 100% of the carbon from the subsidiary in which it has a majority stake. However, this subsidiary is also financed by debt. Does this mean that the loan or bond issued would not include the carbon it is helping to finance? There are two approaches to this issue: either counting the carbon emission twice, once on the equity side and once on the debt side, which seems to be the nascent practice of some financial institutions in France; or proportionately allocating the footprint of the investee company based on the respective proportions of the financing types. In the latter case, which is the author's preference, it would be necessary to start from the company's "economic balance sheet", clearly differentiating between equity and net financial debt[31]. If the allocation results in 60% for equity and 40% for net financial debt, the shareholders will bear 60% of the footprint, while the creditors will bear the remaining 40%.

It is now clear to the reader that the methods for calculating "financial" carbon footprints are still being explored. Generalized Carbon Accounting helps in any case to provide more reliable basic data for the construction of relevant indicators.

G – Performance measurement and sustainability reporting

Here we return to the primary purpose of carbon accounting: helping companies and individuals to decarbonize. The concepts of footprint and of direct emissions have been emphasized as metrics for tracking the decarbonization effort. These two metrics make it possible to build all sorts of indicators by linking them to financial accounting aggregates, either to track changes over time (the carbon trajectory), or for comparison purposes.

31. The economic balance sheet is the same as the accounting balance sheet, but for two adjustments: cash assets are deducted from financial debt, and trades payables is reclassified as a negative item in working capital requirements.

Here, a distinction needs to be made between internal management and external communication. As far as internal management is concerned, the approach promoted by the GCA system provides accountants and management controllers with detailed product-level figures, allowing for all possible combinations. It becomes easy to construct performance indicators, or KPIs, as from Lego-like building blocks.

This allows each company to adapt its indicators to its business model, so that it can highlight this or that aspect of its low-carbon policy. The case of Getlink cited above is illuminating. The company is gaining market share vis-à-vis the ferries for transporting cars between France and England. It therefore conveys a growing number of vehicles. The carbon cost of this mode of transport, 1 kg of carbon per car according to the company's reporting, is much lower than the car boarding a ferry, because then, says the company, the carbon would amount to 74kg. (Getlink forgets in this calculation the carbon cost of the tunnel drilling, in good financial rigor since the investment is behind it).

But this shift from ferry to train increases the activity of Getlink and therefore its carbon footprint. Using the aggregated footprint as the sole performance indicator would be not only insufficient but misleading. The social gain in decarbonization has certainly not disappeared, but it does not show in the reporting of Getlink. It is therefore necessary to add another indicator to the footprint, for example a footprint per vehicle transported. That would measure the real progress of the company, beyond the trend of customers shifting to the train. Another indicator, that of the carbon-free margin as mentioned above, is also relevant. This example shows the tension that must always exist, to varying degrees, between the sales and profit objective and the carbon objective. The company that helps its customers to save carbon, yet with a negative effect on its footprint, should not avoid the (soon to be legal) requirement to disclose its total footprint, but may add into its disclosure more forward-looking indicators that highlight its contribution to the climate.

Here again, GCA helps in providing the necessary data for the building of KPIs. It also helps with the drafting of the Sustainability Report that European regulations will impose from 2025 on large companies. The content of this report is still under discussion. A draft of the European Sustainability Reporting Standards drawn up by EFRAG[32] was sent to the European Commission in November 2022, which should make it, after approval, binding by the end of 2023. The author does not

32. ESRS (European Sustainability Reporting Standards), 2022, November. See particularly the Explanatory Note.

hide his perplexity – and leaves the reader to form his own judgement – on the mass of information that is required, classified under seventeen, then reduced to twelve, "disclosure requirements," even admitting that it covers more than just carbon impacts. Some requirements involve extensive data collection and major reclassifications. The standard-setter intends to cover all possible configurations, which is often illusory and visually gives a strange looking to the analytic tables presented: a very large number of boxes remain empty only because a given criterion does not apply to the company.

A more parsimonious approach to the data collected is recommended. It must focus mostly on the notions of footprint and direct emissions, as a first step to enable companies to be tracked over time and compared. A balance should be found between the transparency requirements of investors, who are looking for comparability, and the latitude given to companies to put forward indicators that are suited to their business model. A premature drive to standardize is unrealistic[33]. In fact, a progressive approach is essentially what is underway for financial reporting. The only requirement that must not be compromised is that carbon emissions, like the aggregates in financial reporting, be calculated in a manner that is rigorous, uniform and audited.

33. See Demarigny, Fabrice, 2023, *Sustainability information and financial market efficiency*, Association Europe Finance Regulations, Debate Paper Issue n° 1/2023 – January.

IX. Carbon accounting to the rescue of carbon tax?

The similarity between VAT and carbon accounting was mentioned above. It is worth noting that this similarity might provide another base for the carbon tax.

First, a reminder of the VAT mechanism. Companies apply a tax rate, generally 20% in France, to the invoices they send to their customers. It is the customer who pays the tax, not the company, but it is the company that collects it on behalf of the tax authority. It then deducts from this amount the tax it has paid on its incoming invoices, so that in the end the tax does not weigh on its accounts. So, for sales of 100 and purchases of 60 excluding VAT, it invoices its customers for 20 in VAT (20% x 100) but deducts 12 (20% x 60) already paid on its purchases. In the end, the amount collected by the tax authority is 8, which is the application of a 20% rate to the company's "added value", i.e., in accounting terms, the difference between outgoing and incoming invoices. The company's role here is merely to collect a tax that is paid by its customers, who in turn pass it on downstream. The final consumer stands at the end of the process and there is no one to pass it onto. VAT is correctly described as a tax on consumption, even if the consumer does not pay it directly to the tax authority.

Things are pretty much the same in terms of carbon accounting: the company's direct emissions, added to the carbon of incoming invoices, give the total carbon on outgoing invoices, according to the basic accounting equation presented in § II. Direct emissions are therefore the difference, expressed in carbon units, between outgoing and incoming invoices, and analogous to the value added in currency units. They could just as easily be referred to as "carbon added" .

Given this parallel, could we use another base for carbon tax, namely the company's direct emissions? Today, the tax is levied very much upstream on large GHG emitters in the form of a tax on their sales and the effect of this spreads to the rest of the economy. In the future, it could be levied on all invoices, but with the same crediting system on incoming invoices as for VAT. This is what Lequien (2022)[34] suggests,

34. Lequien, Matthieu, 2022, *Taxe sur le carbone ajouté*, Presentation *to* France Stratégie, December 7, 2022.

naming it CAT for Carbon-Added Tax. The accounting rules would be the same for both, notably the exception we have introduced for GCA for fossil fuels distributors, namely that the tax would be levied at their level rather than on end customers.

The idea is worth examining. On the upside, it would give companies an incentive, albeit an unpleasant one, to calculate their direct emissions and put the carbon content on their bills. Direct and indirect carbon emissions would thus be under the eyes of its decision-makers, with the incentive effect already mentioned. On the downside, by aligning carbon tax with VAT, companies might see the tax as largely painless since, as with VAT, they could push it down the road to their customers[35]. The need for change may feel less important at their level. It would be a pity since carbon savings are more easily realized at company than at household level.

This is an idea for the future open to empirical debate. To be enforceable as a tax base, the invoice in carbon units must have the same contractual accuracy as the invoice in currency units. We are very far from it, but CGA is the way forward.

35. To the best of the author's knowledge, there has been no study of the carbon tax to determine the extent to which this tax, like VAT, would be passed on fairly automatically downstream, with a lesser incentive effect on businesses in the value chain.

Conclusion

Generalized Carbon Accounting is the most viable approach to obtaining, long term, dependable and accurate data on the carbon footprint of production and consumption. It is such data, once systematic, that will foster behavioral change and enhance the efficacy of climate public policy instruments.

Moving towards this target will take time and effort. By way of conclusion, these recommendations summarise the message of this Report:

1 – Companies that already measure their carbon footprint should communicate this information to their customers. The challenge for them is therefore to allocate their footprint to the goods and services they sell and put this on their outgoing invoices, following the practices of cost accounting. This will induce suppliers, including overseas suppliers, to follow suit.

2 – For these companies, the process needs to be industrialized as quickly as possible. For that matter, it is important to integrate carbon accounting into the company's financial and purchasing systems, with the support of the purchasing, sales, and marketing departments. The ESG unit can be instrumental in coordinating the process.

3 – Companies that do not measure their own carbon footprint yet, should obviously embark on it as soon as possible, anticipating future regulations. Data on inputs should preferably be handled by accounting teams and possibly be integrated into management systems, as stated in recommendation n°2.

4 – The data produced must promptly be subject to appropriate control and audit procedures. Internal and external auditors will be called upon to do this, replicating as closely as possible the work they already do on the financial accounts.

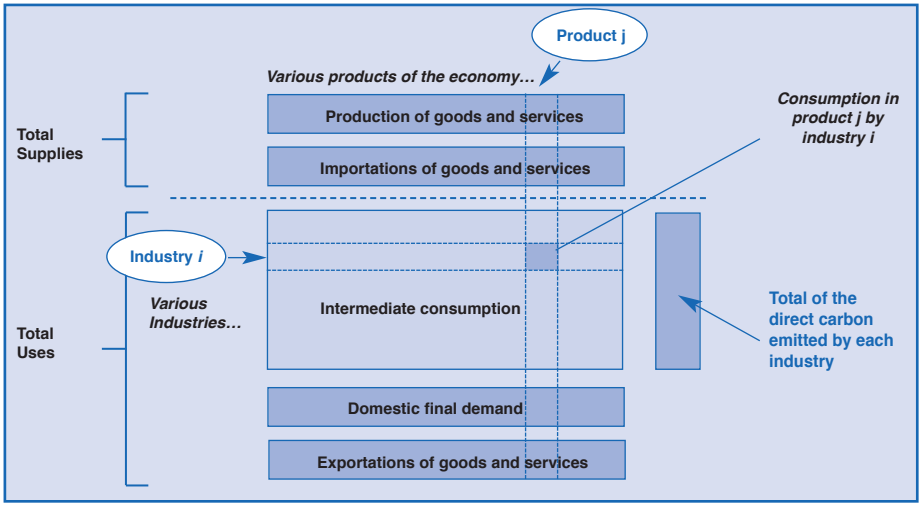
5 – Professional firms will assist in implementing the system and delivering interim data to enhance the accuracy of carbon content until the system is generalized.

6 – Public authorities should enhance implementation initiatives, including providing grants for equipment and technical guidance for SMEs. They should foster accounting standardization and act at an international level to spread these carbon measurement techniques.

Given the scale of the climate challenge, the solution appears simple. The case for swift corporate adoption is compelling.

Appendix: the carbon economy. A theoretical framework

1 – We give here an overall view of the carbon trade flows in parallel with monetary trade flows at the level of the economy. We therefore move away from corporate accounting and towards national accounting. National accounts produce what is called the Supply and Use Table (SUT), or, more restrictively, the Input-Output Table. It is presented as follows:

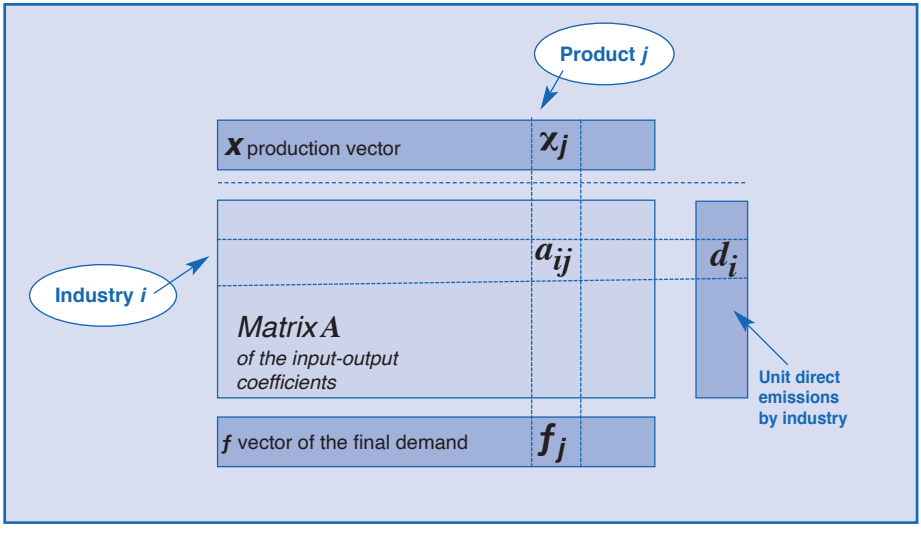


The data are measured in constant prices relative to a reference period. The columns show the supplies for each of the *n* products of the economy over a period, such as a year. These supplies are domestic production and imports (the first two rows in dark color of the table). The uses are broken down into intermediate consumption (in the light-colored rectangle), domestic and foreign final demand (in dark)[36]. Domestic demand represents the addition of consumption and investment.

36. This table deviates slightly from the usual national accounts presentation, with industries in rows and products in columns. The matrix is therefore "transposed".

The rows in the light-colored rectangle show the different industries of the economy and their consumption of each of the intermediate products. For convenience, an industry can be assimilated to a company. The difference with the SUT, building on our previous discussion on VAT, is that we replace the value added, i.e., the compensation in currency units of labor and capital, by the emissions of carbon in physical units, for example in tons of carbon (see the light-colored rectangle on the right-hand side). There are n industries, as many as there are products, bearing in mind, for simplicity's sake, that we do not consider joint-production, i.e., products that are combined within an industry. In total, each industry uses intermediate consumption, which has its own footprint, and produces direct emissions.

2 – For the analysis, it is customary to present the intermediate consumption table (light-colored in the diagram above) in the form of technical coefficients, defined as the quantity of good j required to produce one unit in industry i. They are denoted by a_{ij}, and all together give the matrix A, also known as the Leontief matrix. Similarly, d_i is the direct unit emission of industry i, i.e., the physical quantity of carbon directly required to produce one unit (in prices of a reference period) of the industry. Taken together for all industries, this gives the vector d. For simplicity's sake, imports and exports are omitted, without loss of generality at this stage. The SUT is thus simplified to:



3 – The footprint of one unit produced by industry i, noted e_i, is therefore written as the sum of the unit intermediate consumption footprints and the unit direct emission. It gives:

(1) $e_i = a_{i1} \times e_1 + \cdots + a_{in} \times e_n + d_i$, for the *n* industries of the economy.

We therefore have *n* equations of this kind, which can be written more conveniently in matrix form:

(1 a) $e = Ae + d$ or alternatively: $d = (I - A)e$, I being the unit matrix.

This establishes a relationship between footprints and direct emissions for all products in the economy.

The matrix A naturally has positive or zero coefficients. Furthermore, the economy is "productive", which intuitively means that it can produce more than its own intermediate consumption. This allows for a positive final demand (Gale, 1960)[37]. If the matrix A is productive, then, whatever the value of the direct emissions vector d, the existence of a non-zero footprint vector can be shown. We assume here that if an industry captures some carbon (negative direct emissions through carbon removal), then this does not compensate for its positive emissions. Based on these premises, the matrix $(I - A)$ is invertible and has positive or zero coefficients. In this way, we establish the passage in the opposite direction between footprints and direct emissions:

(2) $e = (I - A)^{-1}d$.

If we know the direct emissions of each industry (or, more broadly, each entity), we can theoretically assume that, in a productive economy that emits carbon, footprints exist and can be calculated.

4 – A second approach to footprints is to use the backward regression mentioned in §II above, where we move up the value chain: to produce a good, there is a direct emission plus the footprint of the intermediate products, which in turn requires direct emissions and intermediate consumption, and so on. Initially, the footprint of each industry is equal to d. In the first round of exchanges, indirect emissions from Tier 1 suppliers are added together, which gives an amount of emissions of $d + Ad$. In the second round, for Tier 2 suppliers, the same cumulative total is: $d + Ad + A^2d$.

The final footprint of the industries is therefore:

(2a) $e = d + Ad + A^2d + \cdots + A^n d + \cdots$, which converges to: $(I - A)^{-1}d$.

37. Gale, David, 1960, The Theory of Linear Economic Models, McGraw Hill, ch. 9.

This second equation is important. It shows that footprints can be calculated on the basis of the natural interplay of economic exchanges, as it is for VAT, each industry declaring only its direct emissions and downstream industries adding them to their own emissions.

5 – A final characterization of footprints involves introducing the levels of production and final demand in the economy.

Equation (1) represented the carbon decomposition of production for each industry (the rows of the matrix). But we can look at the dual relationship, that is, the allocation of each product to intermediate consumption and final demand, i.e., the columns of the matrix. We call x_i the production of good i and f_i its final demand.

We therefore have the supply and balance for product j:

(3) $x_j = a_{1j}x_1 + a_{2j}x_2 + \cdots + a_{nj}x_n + f_j$.

This gives a set of equations that are more conveniently written as follows (the ‘sign indicates that the vector, or matrix, is transposed):

(3a) $x' = x'A + f'$.

To calculate the footprint of a product, we then need to reason in marginal terms: what would be the additional direct emissions in the economy if only one final unit of product 1 had to be produced? We would then rewrite equation (3.a) on the assumption that the final production of product 1 is equal to 1, all the other products being equal to zero. In total:

(4) $$x^{1\prime} = \begin{bmatrix} x_1^1 \\ x_2^1 \\ \vdots \\ x_n^1 \end{bmatrix}' = \begin{bmatrix} x_1^1 \\ x_2^1 \\ \vdots \\ x_n^1 \end{bmatrix}' \times A + \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}'$$

We thus obtain the footprint of product 1 by associating the direct emissions of each product with the marginal production required to produce one unit of product 1. The footprint of product 1, in this third sense, is written as:

(4a) $$\varepsilon_1 = x^{1\prime}d = \sum_{k=1}^{n} (x_k^1 \times d_k).$$

We do the same for the product 2, then 3, then *n*. We therefore have *n – 1* other equations similar to (4) for products 2 to *n*, which we can put *en masse* into a single matrix *X* associating the n vectors x^1, x^2, ..., x^n, so that we write:

(5) $X' = X'A + I$.

The footprints of the *n* products are then written, by post-multiplying this equation by the vector d of direct emissions. It gives:

(6) $\varepsilon' = X'd$.

It is easy to show that the two definitions are equal, i.e., $\varepsilon = e$. Premultiplying (1.a) by the matrix *X* gives: $X'e = X'Ae + X'd$, that is: $(X' - X'A)e = X'd$. The term in brackets is equal to I, the unit matrix, according to equation (5), so that: $e = X'd = \varepsilon$.

This last approach to the footprint, despite the cumbersome formalism, gives a simple intuition: we add up, step by step by backward regression, the new direct and indirect emissions that it takes to produce a single unit of each product. Once again, we obtain the dual relationship between carbon footprint and direct emissions. Or, going from upstream to downstream, each unit of direct emissions in the production of a good is scattered *ad infinitum* in all the other goods of the economy. All goods are measured and aggregated according to their direct and indirect carbon content, in the same way as 19th century economists, including Ricardo and Marx with their labor theory of value, looked for the direct and indirect labor content of goods as an aggregator[38].

6 – We now turn to the relationship at macro level to demonstrate the basic equation stated intuitively in section §VI above: *the sum of the footprints of final demand is equal to the sum of the direct emissions of each industry*. In other words, despite their complex dispersion throughout the economy, the carbon generated at industry level are all to be found in final demand.

Using the above notation, the total direct emissions of the industries can be written as:

(7) $$x'd = \sum_{i=1}^{n} x_i d_i.$$

The total of the final demand footprints, which are additive, is written as:

(8) $$f'e = \sum_{j=1}^{n} f_j e d_j.$$

By equation (1.a), we have: $d = (I - A)e$, hence:

$x'd = x'(I - A)e = f'(I - A)^{-1}(I - A)e = f'e$. Equality is proven.

38. This latter approach uses Mishio Morishima's formalisation of the labour-value theory. See Morishima, Michio, *Marx's Economics. A Dual Theory of Value and Growth*, Cambridge Un. Press, 1973.

7 – Introducing foreign trade does not change in any way the equilibrium relationship between footprints and direct emissions as shown above for the domestic economy. Imports are added to domestic production to give the domestic supply (assimilated to the x vector used above). Exports are part of final demand and, as such, their footprints are additive. We can easily calculate the footprint of foreign trade and thus distinguish between a "domestic" footprint (the carbon footprint of domestic agents) and a "national" footprint (by adding the footprint of imports and subtracting the footprint of exports).

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