Transaction to Carbon (TtC)

An open standard framework for consumer carbon calculations based on payment transactions.

organisation for conscious consumerism

Version 3.0

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About OfCC (Organization for Conscious Consumerism)

As a non-profit organization, we envision enabling the development of an impact economy driven by conscious consumerism. Our mission is to accelerate the adoption of conscious consumerism through behavioural change incentives and sustainability data transparency, leading to positive social, economic, and environmental impacts. Our data- and technology-driven concepts aim to bring new insights into the process, from shifts in individual consumption behaviours to systemic change. The open standards, methodologies, and data concepts we establish, in collaboration with our scientific and industry partners, serve the common good of our society. We are an independent non-profit organisation owned by the ecolytiq GmbH, Berlin.

Disclaimer

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1. Introduction

The increasing inclination of people towards sustainable consumption to mitigate their impact on global climate change has led to the emergence of financial technology (fintech) solutions designed to help users make informed and meaningful actions. The proper design of such consumer carbon tools requires careful consideration of data and collection methods, means of calculation, eventual usage, and an understanding of how the tool influences its users. These should be encoded in corresponding standards that ensure they contribute to the broader purpose - environmental sustainability. This Open Standard for consumer carbon calculations based on payment transactions closes the gap.

1.1 Purpose of this Standard

The goal is to promote sustainable consumption by linking climate currency to fiat currencies. People's spending behaviour reflects their lifestyle. The Open Standard for consumer carbon calculations based on payment transactions provides a standardized approach for estimating carbon intensity factors (CO_2e/monetary unit) for specific household consumption expenditure categories.

This standard aims to help users achieve the following:

- Estimate carbon intensity factors for different consumption categories that can be replicated, tested, and improved upon.
- Ensure consumption information enables climate action.
- Publicly reporting carbon intensity factors, methods, and meeting stakeholder demands for transparency.

The objectives of the Standard are:

- To put the end-user and transparency at the centre of the processes.
- Define a standardized method for calculating carbon intensity factors for different consumption categories.
- Ensure data is collected and structured in a standardized manner that facilitates its use in drawing valid conclusions (i.e., in creating information) and enables its integration into related products and services.
- Ensure that actions enable desired climate outcomes.
- Discover and elaborate upon the major dimensions required to implement a fintech carbon-to-purchase system to design flexible solutions for all interested parties, enabling broad adoption.
- To help users to provide accurate, consistent, transparent, complete, and relevant information.
- To support consistent and transparent reporting for comparison purposes and continued improvement.
- To create international consistency and transparency in how information is provided to the end-user.
- To establish a quality management system for the community that provides carbon intensity factors based on payment transactions.

1.2 Primary users

This Standard is primarily for companies, entities, and organizations that want to estimate carbon footprint based on transaction data. National and subnational government entities might also find this standard useful to track changes in carbon intensities for different consumption categories at the household level in their respective countries.

The term “user” refers to the company, entity, or organization implementing the Standard; “end-user” refers to the individual using the application or bank interface, using the information generated when implementing this Standard.

1.3 Application of the Standard

This Standard applies to companies in all countries and regions.

1.4 Scope of the Standard

This Standard includes steps related to implementing the transaction to carbon system, including contextual analysis, estimation of carbon intensity factors, alignment with transaction data, verification, and reporting. Use of the Standard is voluntary. Users may initially choose to implement the Standard in part with a view toward full implementation. However, when users want to verify conformance with the Standard, the user shall follow all requirements.

1.5 Capacity for implementing the Standard.

Information processing plays a key role in fulfilling the carbon footprint based on transaction data. Users should guarantee information security, covering services and supporting processes involved in processing sensitive data. This includes the Information Technology (IT) department and any areas in which tests are carried out on products developed by the development department. The user is responsible for all activities to maintain and improve information security, ensuring the basic values of Confidentiality, Integrity, and Availability (CIA-Triad of Information Security)1 of information and customer data. The technical requirements of the system and the security standards that shall be in place for the implementation of the footprint calculation based on transaction data are beyond the scope of this Standard. The user shall comply with national and international standards in this regard.

1.6 Terminology: shall, should, and may

For purposes of this Standard, unless indicated to the contrary, the following terms have the meanings attributed below:

- "shall" is used throughout this Standard to indicate what is required to conform to the Standard.
- "should" indicates a recommendation but not a requirement.
- "may" indicates an option that is permissible or allowable.

[1] The CIA triad is a common model that forms the basis for the development of security systems. They are used for finding vulnerabilities and methods for creating solutions.

1.7 Limitations

Users should exercise caution in comparing the results of the estimations based on this Standard. Comparable results can be achieved if carbon intensity factors are undertaken using comparable data, assumptions, and methodologies, enhancing consistency between analyses. Differences in reported carbon intensities may result from data sources or methods (for example, when utilizing lifecycle assessment cradle to grave vs. cradle to gate). Efforts to ensure additional consistency may be necessary to enable valid comparisons. All data sources, methodologies, and assumptions must be transparently reported to understand whether comparisons are valid.

1.8 Main changes to the second edition

The second edition, published by the Organisation for Conscious Consumerism in 2022 provided guidance on the underlying principles for the calculation, the framework for the implementation of the carbon estimation based on transaction data, key concepts, analysis of the context guidelines, explained two approaches: 1) ecolytiq 1.4 and 2) EEIO hybrid for carbon intensity estimations, provided general recommendations regarding alignment between consumption categories and transaction data, implementation, verification, and reporting.

This third edition follows the structure from edition 2 but expands on the estimation of emissions factors for household consumption categories derived from Global Multiregional Input Output Tables, incorporates limitations of the approach and areas for further collaborative work. The third version do not consider the ecolytiq 1.4 approach.

The Open Standard framework seeks to continue the discussion on the agenda regarding methodologies and collaborations across the financial sector and sustainability-minded businesses. Only together we can develop good practices through the Open Standard in the interest of clients, customers, and climate.

2. Guiding principles

To estimate carbon intensity factors, we apply generally accepted principles to ensure that the reported information represents a faithful, true, and fair account of GHG emissions. These principles are transparency, data integrity, relevance, and localization and are aligned with GHG Protocol (Figure 1).

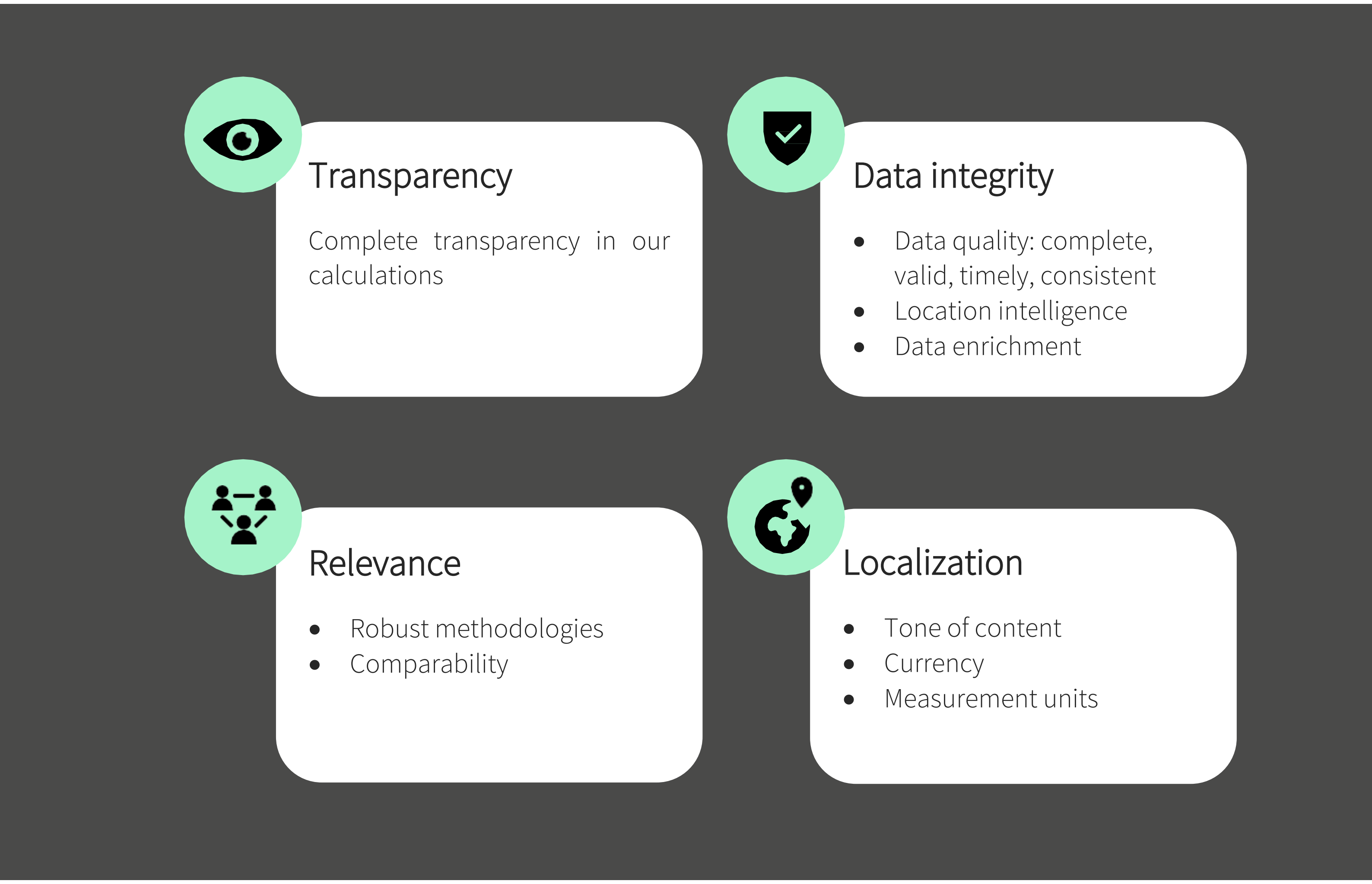

Figure 1. Guiding principles.

2.1 Transparency

Calculating the carbon intensity factors associated with personal consumption categories is a new approach to assessing an individual's climate impact. The number of such approaches are increasing. Yet none of these approaches are correct in an absolute sense. Transparency relates to the degree to which information on the processes, procedures, assumptions, and limitations are disclosed in a clear, factual, neutral, and understandable manner based on clear documentation.

Information needs to be recorded, compiled, and analysed to enable internal reviewers and external verifiers to attest to its credibility. Information regarding methodologies, assumptions, references, and data sources should be disclosed. The information should be sufficient to enable a third party to derive the same results if provided with the same source data.

2.2 Data integrity

The data is the element with the most aspects and decisions involved, being, as the popular contemporary metaphor goes, the *oil of the modern economy*. For the estimations, the user relies on secondary data; thus, deciding which sources to use shall align with the company policy regarding data integrity, quality assurance, and quality control systems. Sources must include data that is complete, accurate, consistent, and in context. The data integrity policy of the user shall cover the following key elements:

- Data quality: through an in-depth literature review, different sources of information are identified and scrutinized before they can be used. All sources of information must be
    - Complete: The data represents a large percentage of the total data needed.
    - Valid: Data conforms to the syntax and structure defined by the business requirements.
    - Timely: Data is sufficiently up to date for its intended use.
    - Consistent: Data is consistently represented in a standard way throughout the dataset. End-users of GHG information will want to track and compare GHG emissions information over time. The consistent application of calculation methodologies is essential to producing comparable GHG emissions data over time.

- Location intelligence: data is more actionable when a layer of richness and complexity with location insight and analytics is added. The user shall provide benchmark values that are country specific.

- Data enrichment: calculations are refined based on data enrichment, which shall be tailored to the country. This refines the estimations and provides a more complete, contextualized, and powerful analysis. The user shall encourage the end-user to provide feedback regarding its transactions.

2.3 Relevance

We use studies that apply appropriate methodologies to provide a credible quantification of GHGs emissions; this applies the same criteria and assumptions to evaluate significance and relevance. Any data collected and reported allow for meaningful comparisons over time.

2.4 Localization

“Localisation involves taking the product and making it linguistically and culturally appropriate to the target locale (country/region and language) where it will be used” (Esselink, 2000). This is an integral part of our carbon intensity estimation process as emissions highly vary based on the country's technology, infrastructure, and culture consumption, among other aspects, and therefore cannot be generalised. Additionally, to trigger positive change, we want to appeal to the day-to-day consumption patterns and activities familiar to their country's customers.

Despite most categories being defined as local categories, meaning local country-specific data is employed to calculate the carbon footprints, a few categories are deemed global, meaning global data is used instead. This country-specific approach reflects and considers the prevalent significant variance regarding expenditures and emissions, which particularly apply to certain consumption categories, e.g., 'groceries,' where the locality of consumption considerably affects the carbon footprint. For the global categories, such as 'Air Travel,' 'Video Streaming Services ', and 'Audio Streaming Services', it is assumed that the locality of consumption does not significantly affect the carbon footprint due to the cross-border scope of the product.

3. Key concepts and analytical framework

This section defines some specific terms intended to be interpreted in the context of this Standard. It captures concepts from the Intergovernmental Panel on Climate Change (IPCC) and scientific publications regarding the household consumption model.

3.1 Carbon footprint

It is the measure of the exclusive total amount of carbon dioxide emissions (CO2) that is directly and indirectly caused by an activity or accumulated over the life stages of a product (Allwood et al., 2014). Carbon footprint calculation is one of the most effective, quantifiable methods a) to understand a country's, an organization's, or an individual's carbon footprint impact on the environment, and b) to involve everyone, from heads of state down to individual citizens, in actions to fight climate change.

3.2 Carbon intensity

Carbon intensity is the number of emissions of carbon dioxide (CO2) released per unit of another variable, such as gross domestic product (GDP), output energy use, or transport (Allwood et al., 2014). In this Standard, the emission intensity is measured in grams of CO_2e emitted per monetary unit spent in a specific activity and country, which is the emission rate of a given pollutant relative to the intensity of a specific activity or an industrial production process (Du et al., 2018). The concept is mostly used for energy analysis, for example, grams of carbon dioxide equivalent released per megajoule of energy produced (Ali et al., 2022; Cheng et al., 2018; Hocaoglu & Karanfil, 2011; Zhu et al., 2014), or the ratio of greenhouse gas emissions produced to gross domestic product (Davis & Caldeira, 2010; Garrone & Grilli, 2010; Hocaoglu & Karanfil, 2011). In this Standard, carbon intensity estimations are derived from a carbon footprint and expenditures per household consumption categories.

3.3 Consumption categories

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Consumption categories refer to the Classification of individual consumption expenditures. It is based on the Classification of individual consumption by purpose, abbreviated as COICOP, which the United Nations Statistics Division developed to classify and analyze individual consumption expenditures incurred by households, non-profit institutions serving households, and general government according to their purpose. It includes categories such as clothing and footwear, housing, water, electricity, gas, and other fuels (UN, 2018a).

3.4 Consumption-based accounting

The consumption-based approach to carbon accounting differs from the traditional, production-based inventories because imports and exports of goods and services, directly or indirectly, involve CO_2 emissions (Davis & Caldeira, 2010). In today's global economy, emissions embedded in trade makes a significant share of the country's emission, and therefore the traditional approach largely underestimates the emissions. Consumption-based accounting considers the CO_2 emitted in producing goods elsewhere, which are later imported, or emissions from exported goods. This approach links local consumption and global environmental consequences (Ivanova et al., 2017).

3.5 Household consumption model based on functional units.

The household consumption model proposed by Hertwich (2005) and applied by Girod & De Haan (2010) shall be the basis for the estimation of emissions based on functional units, following the model formulation and monetization as proposed by Girod & De Haan (2010):

Equation 1 $$i = CS(I - A)^{-1} * Y$$

where i is the life cycle impact, expressed as a vector of GHG emissions for different impact categories; Y is the vector representing the functional units; $I - A$ represents the matrix of production, use, and disposal processes that contribute to the product life cycle; S represents the matrix of emission factors per unit process; and C is the matrix of characterization factors per impact category (Girod & De Haan, 2010). Adjusting the model to GHG emissions then Equation 1 can be simplified as follows:

Equation 2 $$ghg_{h,i} = ghgy_i * y_{h,i} \; (1 \leq i \leq n)$$

Where $ghg_{h,i}$ are the GHG emissions of household h from consumption category i; y is the consumption in functional units for the n consumption categories and $ghgy_i$ are GHG emissions per functional unit. The price per functional unit can be derived as follows:

Equation 3 $$\pi_{h,i} = s_{h,i} / y_{h,i} \; (1 \leq i \leq n)$$

Where $\pi_{h,i}$ describes average product price per functional unit in consumption category i paid by the household h and s describes the monetary expenditure of the household. The carbon intensity factors for specific consumption categories are estimated based on this model specification, particularly when analysing substitution effects.

3.6 Household consumption model based on expenditure.

The household consumption model proposed by Vringer & Blok (1995) and applied by Girod & De Haan (2010) shall be the basis for the estimation of emissions based on expenditure, following the model formulation and monetization as proposed by Girod & De Haan (2010):

Equation 4 $$ghg_{h,i} = ghgs_i * S_{h,i} \; (1 \leq i \leq n)$$

where $ghg_{h,i}$ is the total emissions and $ghgs_i$ is the carbon intensity for the consumption category *i* measured in CO_2e/monetary unit.

3.7 Merchant Category Codes (MCCs)

According to the ISO 18245 for Retail financial services (2003), "Mer*chant category codes (MCCs) shall be allocated to enable the classification of merchants into specific categories based on the type of business, trade or services* supplied." The MCCs are four-digit numbers that a credit card issuer uses to categorize the transactions consumers complete using a particular card. Section 4.3 elaborates more on how the merchant category codes estimate CO_2e based on transaction data.

3.8 Lifecycle assessment (LCA)

When applying the household consumption model based on functional units, CO_2e emission data generated from the Lifecycle Assessment (LCA) is used. The LCA is a widely used technique defined by ISO 14040 as a "compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle" (Allwood et al., 2014). The results of LCA studies strongly depend on the system boundaries within which they are conducted (Dincer & Rosen, 2021). LCA has different scopes (Cao, 2017):

- Cradle-to-grave is the full life cycle assessment from resource extraction ('cradle') to the use and disposal phases ('grave').
- Cradle-to-gate is an assessment of a partial product life cycle from resource extraction (cradle) to the factory gate (i.e., before it is transported to the consumer).
- Cradle-to-cradle is a specific kind of cradle-to-grave assessment, where the end-of-life disposal step for the product is a recycling process.
- Gate-to-gate is a partial LCA method, looking at only one value-added process in the entire production chain.

For the carbon intensity factor estimation, the user should use a cradle-to-grave assessment which represents a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the product or service throughout its life cycle (Means & Guggemos, 2015; Rebitzer et al., 2004). However, when cradle-to-grave analyses are not available for the product, the user shall provide information to the end-user about the limitations of the estimations.

3.9 Environmentally extended input-output approach

The environmentally extended input-output (EEIO) expands the traditional Input-Output (IO) analysis. The IO analysis examines the interdependencies between different sectors of an economy by tracking the flow of goods and services between them. Incorporating the environmental impacts associated with economic activities provides a detailed picture of an economy's production and consumption activities. Therefore, EEIO is an excellent tool for consumption-based accounting of CO_2 emissions. The EEIO analysis varies in scope and level of detail based on the IO tables used. Some of the most common types of IO tables are the Single Region Input-Output (SRIO), Multi-Regional Input-Output (MRIO) and Hybrid Input-Output tables. The SRIO focuses on the economic interdependencies within a single geographic region or economy where the interactions between different sectors or industries within an economy are captured. The MRIO captures the transactions between sectors within each region and the trade flows between regions or countries, each represented by its own set of sectors and IO tables. Hybrid input-output tables are similar to SRIO tables but combine monetary and physical units and incorporate elements of life cycle assessment and process analysis.

3.10 Integrating top-down and bottom-up emissions accounting

The Environmentally Extended, Input-Output tables provide a consistent framework for allocating environmental burdens from the overall emissions and resource consumption generated by economic systems at a macro scale to the expenditures of final consumers. However, this top-down approach lacks details at the product level. The level of aggregation of products and services in EEIO tables is generally much larger than the product level considered in standard process-based Life Cycle Assessment (LCA) approaches. LCA is a bottom-up technique to assess the potential environmental impacts of a product, activity or process throughout its life cycle from raw material acquisition to production, use and waste management stages. From a detail-oriented perspective, LCA methods can offer higher accuracy in estimations at their best. However, estimating the emissions of a whole consumption category or industry by exclusively applying the LCA method would force one to assume a limited number of products/processes to represent a consumption category and, hence, lose accuracy on the general category estimation.

On the other hand, the IO analysis provides a better general category estimation, accounting for a wider range of category characteristics and, eventually, a more desirable overview. Therefore, integrating both ways of emissions accountancy and using each to fit the consumption category best leads to a clearer understanding of the household consumption impact. LCA and EEIO tables cover various impact categories, such as land use, water use, acidification, eutrophication and greenhouse gas emissions. Putting the two methods together provides a clearer understanding of household consumption (Berners-Lee, 2020).

4. Steps to implement TtC

This Standard is organized according to the steps required when the user provides end-user "carbon calculations based on payment transactions" (TtC) (Figure 2). Depending on individual objectives, users may not need to follow all the steps in Figure 2. If users have already analysed the context, the guidance in step 1 may be skipped, but all users shall follow all other steps if aiming for verification based on this Standard.

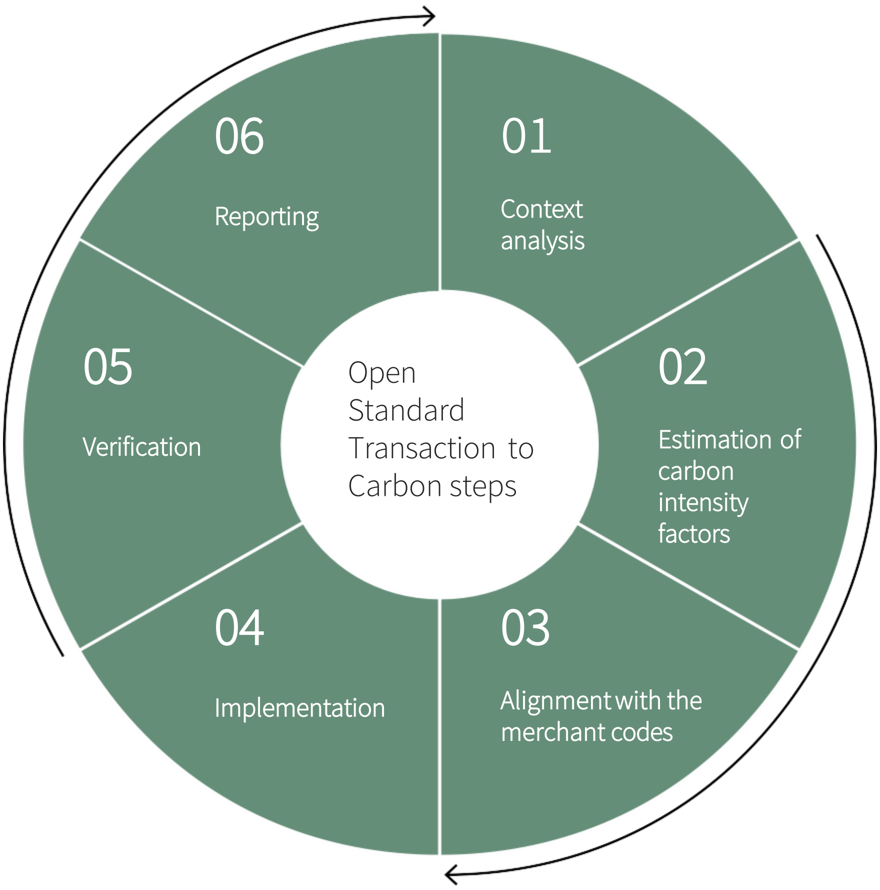

Figure 2. Steps to implement the Open standard framework for consumer carbon calculations based on payment transactions (TtC)

4.1 Step 1. Analysis of the context

As governments worldwide make more ambitious net-zero commitments, they are increasing attention to household greenhouse gas emissions (Reeve & Aisbett, 2022). Carbon emissions are very specific to the country in which people live. Thus, the first step is to gather contextual information about the country. The national data sources provide a reference to set the base values. Public emissions accounting frameworks - developed for National Accounts - possess attributes of relative simplicity and modularity, which make them worthy of consideration as a starting point for the development of consumption-based accounting. Particularly for developed countries, the regulation requires reporting on air emissions in thousand tons and kilograms per capita.

Environmental accounts are a statistical system bringing together economic and environmental information in a common framework to measure the contribution of the environment to the economy and the impact of the economy on the environment (S. E. Eurostat, 2021). Environmental accounts are a reliable source as they organize environmental data from many domains using the same concepts and terminology as national accounts. Thus, they show the interaction between economic, household, and environmental factors and are more informative than national accounts alone. They are designed to answer questions: Which industry emits the most greenhouse gases? How do patterns of consumption and production affect the environment? What is the effect of economic policy measures, such as an environmental tax, on the generation of waste or air emissions? How fast is the environmental economy growing, and how does it compare with the rest?

During the context analysis process, information regarding official data related to population, energy matrix, and trade balance, among other elements, is also documented to provide an understandable overview of each country's scenario. To assure consistency through the analysis, the latest population and household size values are employed to make comparisons. The national benchmark value is identified from each country's National Greenhouse Gas Emissions Inventories. This value is used to reference the end-user regarding their overall carbon footprint. Nonetheless, the value is not appropriate for gleaning insights into personal, individual spending for consumption; thus, we need to provide a higher level of granularity regarding carbon footprint per consumption category. Once the user understands the country's priorities and what information is available, it is recommended to proceed to the selection of the GMRIO table.

4.2 Step 2. Estimating the carbon intensity factors

The following figure outlines the five-step approach for calculating a person's transaction-to-carbon footprint.

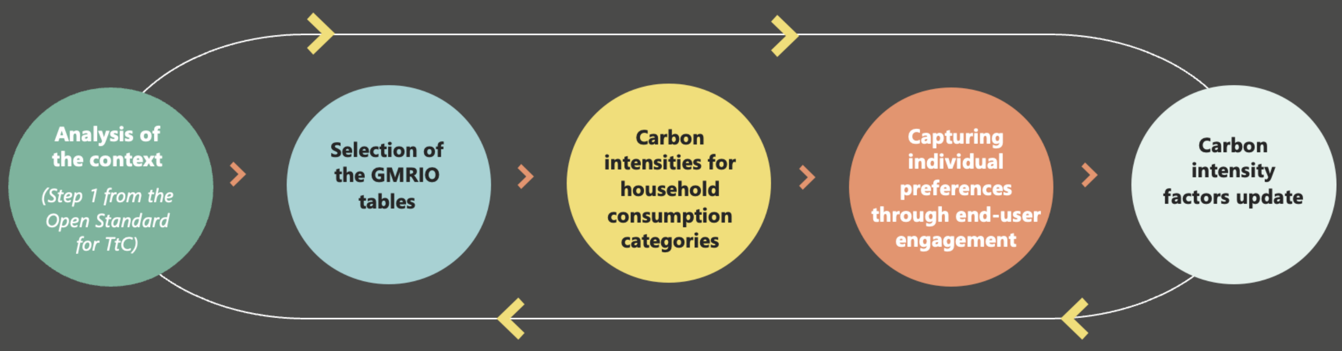

Figure 3. A five-step process for estimating carbon intensity factors.

4.2.1 Selection of the GMRIO table

Global Multi-Regional Input-Output (GMRIO) provides a detailed understanding of the global economic system. As mentioned in Section 3.9, global GMRIO models are widely used to analyze the economic interdependencies between regions in the context of global trade and environmental research. GMRIO has proved useful for describing and understanding supply chains and relationships between consuming and producing sectors (Huo et al., 2022). Thus, it is the preferred approach for estimating transactions to carbon. MRIO tables connect the sectors in different regions along the supply chain and track both direct and indirect impacts of global production (Huo et al., 2022; Tukker et al., 2020). Several GMRIO tables are available with different scopes and reach; each GMRIO varies in the country coverage, sectors, and products under analysis (Figure 4).

The selection of the GMRIO from which the emission factors will be derived, depends on the country of analysis, industry and sector coverage, assumptions, and latest year available.

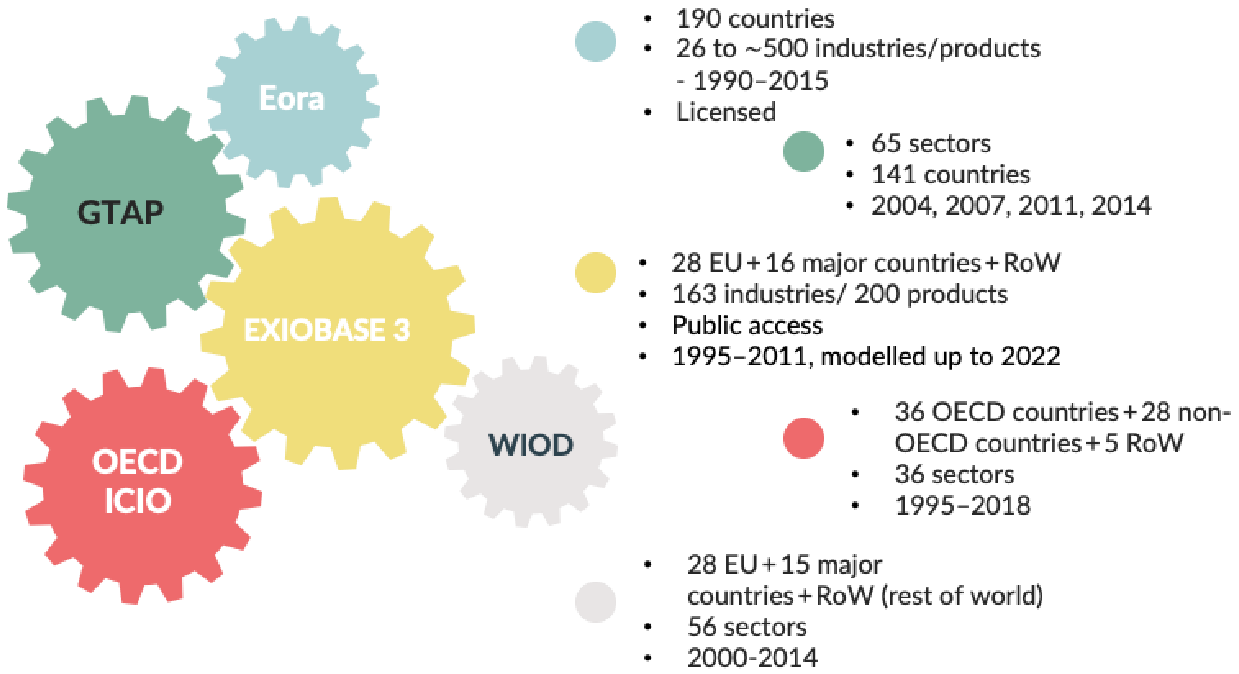

Figure 4. Characteristics of existing GMRIOs

Source: (Huo et al., 2022; Mangır & Şahin, 2022; Tukker et al., 2020). For further information on OECD ICIO, see OECD.Stat (2022), GTAP see (Purdue University (2019), EXIOBASE see Stadler et al. (2018), WIOD see Dietzenbacher et al. (2013) and EORA see KGM & Associates Pty. Ltd. (2023).

Several authors have performed an in-depth analysis of the limitations and advantages when applying the different GMRIOs (Dawkins et al., 2019; European Commission. Statistical Office of the European Union., 2021; Huo et al., 2022; Steubing et al., 2022; Tukker et al., 2020), the main findings are presented in Box 1.

Box 1. Available GMRIO databases used for consumption-based accounting.

- EXIOBASE focuses on environmental accounts, but mainly for EU countries. It has the highest level of sectoral detail in all countries covered in its database, including 163 sectors in EXIOBASE 3. In EXIOBASE V3.8, the trade and macroeconomic data run up to 2022 based on forecasts. However, EXIOBASE 3 (V3.8) only covers 28 EU member countries plus 16 major economies and five other regions. EXIOBASE 3rx disaggregates to 214 countries, based on EXIOBASE 3.

- Eora is a global, high-resolution GMRIO database covering 187 individual countries with a total sectoral detail of 15,909 sectors, spanning a time series of 21 years. The Eora energy accounts are built on national energy data wherever available. Nevertheless, these cases only represent a small fraction of the countries in the model. Despite its large and detailed database, Eora does have some notable limitations. For instance, its detail on sectors is highly variable (ranging from 26 to over 400 sectors), which limits cross-country comparisons for specific sectors and only provides consistent data for 26 sectors across all countries.

- The OECD inter-country input-output (ICIO) table was first constructed during the joint OECD WTO project on Trade in Value Added (TiVA). Production-based CO_2 emissions by ICIO industries are directly estimated from the IEA CO_2 fuel combustion data. For most CO_2 flows, a straightforward allocation to the ICIO industries is possible. The OECD ICIO has limited sectoral detail, including just 45 aggregated sectors.

- The Global Trade Analysis Project (GTAP) provides a harmonized database with IOTs and trade data that can be used to construct MRIO tables. GTAP covers 121 countries and 20 aggregated regions. The GTAP 10 MRIO consists of /65 sectors (76 sectors in the GTAP-Power database), which makes adequate assessments of specific sectors difficult, especially highly diverse service sectors. Moreover, GTAP provides MRIO tables only at three- or four-year intervals.

- WIOD. The World Input-Output Database (WIOD) is based on raw data from national statistical institutes (NSIs) and UN COMTRADE and covers 1995–2011. The main source for the energy reported in the WIOD database is the energy balances provided by the IEA, except in cases in which equivalent data from NSIs were available. Emissions datasets for EU countries were retrieved from Eurostat.

- IDE-JETRO, Asian Development Bank (ADB) and the Institute of Developing Economies, Japan External Trade Organisation, Tokyo (IDE-JETRO) mainly cover the Asia Pacific region. ADB expands the WIOD database to cover Asian economies. To address any specific informational and analytical needs associated with this region, the ADB MRIO tables cover 25 Asian emerging economies. The IDE-JETRO database also mainly focuses on Asian economies, which limits its usefulness for emerging economies in other world regions.

- FIGARO is a compilation of intercountry SUTs and IOTs at the EU level (European Commission. Statistical Office of the European Union., 2021; Mangır & Şahin, 2022; Steubing et al., 2022; Tukker et al., 2020).

4.2.2 Carbon intensities for household consumption categories

To provide a carbon intensity factor for different consumption categories, we use a combination of process-based and input-output approaches as applied by Berners-Lee (2020). Referencing the data available for the European Union, where the EXIOBASE is available, we provide 51 categories (Figure 5) to cover the whole household consumption spectrum. The total number of consumption categories is not fixed as it depends on the quality and data availability specific to the country under study.

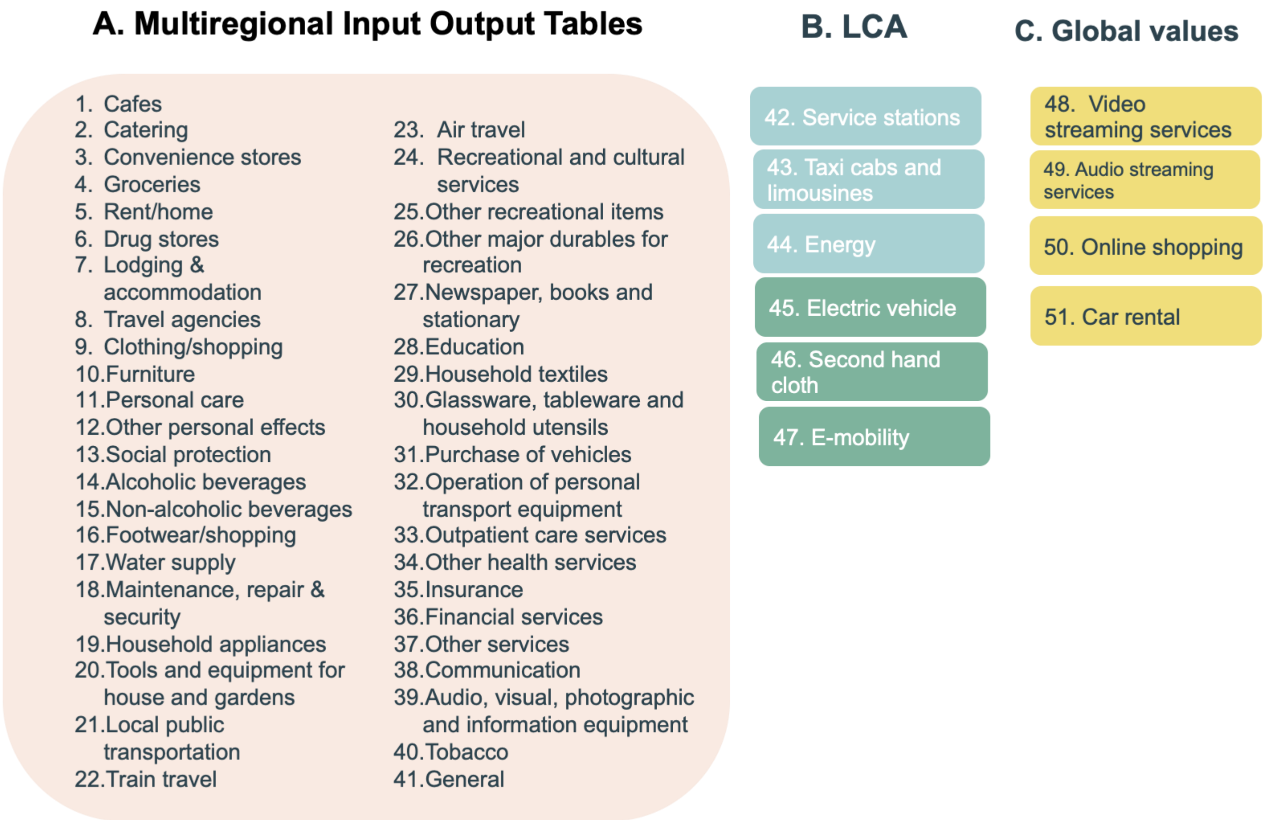

Figure 5. Household consumption categories indicate the source of information for the carbon intensity factors.

4.2.2.1 Categories derived from the GMRIO

The GMRIO estimates emissions for goods and services by collecting data on the economic value of goods and services purchased and multiplying it by relevant secondary (e.g., industry average) emission factors (e.g., average emissions per monetary value of goods) (Barrow et al., 2013). The EXIOBASE 3 GMRIO environmental accounting provides a high and consistent level of sector detail for the economic activities that create high but diverging environmental pressures, such as agriculture, mining, and energy extraction (Stadler et al., 2018), particularly for Europe, 16 major countries and five regions.

Emission factors are taken from GMRIO Tables (Stadler et al., 2021b), representing cradle-to-gate GHG emissions for a given industry or product category (Barrow et al., 2013). The output of EEIO models is typically the number of GHGs emitted per unit of revenue in a particular industry sector. For instance, EXIOBASE reports specific industry emission factors using the Third Revision of the International Standard Industrial Classification of all Economic Activities(Department of International Economic and Social Affairs, 1990).

Emission factors from EXIOBASE are further allocated to the nomenclature of consumption following the Classification of Individual Consumption According to Purpose (COICOP). COICOP is the international reference classification of household expenditure and an integral part of the System of National Accounts (UN, 2018b), which provides a framework for homogeneous categories of goods and services.

For the allocation from EXIOBASE emissions to COICOP, the allocation proposed by Castellani et al. (2019) is used. For allocation at the subcategory level within the COICOP, the allocation tables for European countries from Cai & Vandyck (2020) are used as references.

Based on the GMRIO, we also derived the General category. This value is used when there is no specific information regarding the type of consumption transaction made by the consumer and is classified as general. It gives an average emission intensity for the total emissions and total household consumption expenditures in the country under analysis. It represents the average grams of CO_2e per each monetary unit spent.

4.2.2.2 Categories derived from LCA ~ functional units.

The process-oriented approach allows a fine estimation of GHG value per functional unit (i.e., passenger-km, kWh, etc.); emissions are then monetized using the market price value of that functional unit. In some cases, the market price is influenced by public subsidies that distort the perception of the real monetary value; there, a readjustment according to the governmental support is needed.

Energy

Energy bills are classified under this category. To estimate the emissions factor for energy, we use the CO_2e emission per unit of electricity produced/consumed specified for the country under analysis. When analyzing the different methodologies for estimating the CO_2e emission factor per unit, we recommend using the consumption data estimated using the integral method. The integral method is based on the total (renewable plus non-renewable) electricity production in proportion to the use of natural gas, coal, and nuclear energy allocated to electricity. Electricity from waste incineration plants and residual gases is not included. Regarding expenditures, we follow market price values, measured by how much the customer pays on the monthly bill; we use the official price per kilowatt-hour (kWh) as specified by the energy companies. To obtain the grams of CO_2e per currency unit for energy, we monetized the carbon intensity factor by dividing the CO_2e by the price per kWh.

Further details regarding the calculation and refinements can be found in the OfCC.

E-Mobility

This category includes electrically driven vehicles, such as e-bikes or pedelecs, electric motorbikes, and electric scooters. For simplicity, emissions associated with this category represent the emissions associated with the carbon intensity for electricity.

Taxi cabs and Limousines

This category covers the transport of individuals and groups of persons and accompanied luggage by share taxis and hire vehicles with driver. These hire vehicles are smaller than buses and usually take passengers on a fixed or semi-fixed route without timetables. They may stop anywhere to pick up or drop off their passengers. The vehicles used as share taxis range from four-seat cars to minibuses. They are often owner operated. Taxi cabs and limousines' estimate of CO_2e per currency unit depends on the average CO_2e from a standard passenger car and the market price per kilometre.

Secondhand clothing

This category includes merchandise or secondhand goods such as accessories, shoes, and clothing. The carbon intensity factor is estimated by reducing 42% of the clothing carbon intensity factor to reflect the reduction in emissions associated with the consumption of secondhand cloth[2].

Service Stations

This category includes transactions in service stations and automated fuel dispensers that supply petrol, diesel, and other related products to road vehicles. Emissions are generated from the entire aspect of a fuel's life, i.e. feedstock extraction, refining, transport, and combustion. Expenditure data is based on the market price per litre for a fuel type and is averaged for the last 12 months to account for the dynamic changes in fuel prices. Sales volume of the different fuel types or the share of passenger cars by fuel type is taken as a weighting factor to calculate the average emission intensity in grams of CO_2e per currency unit for the category.

Further details regarding the calculation and refinements can be found in the OfCC.

4.2.2.3 Categories derived from global data.

Although most categories are defined as local categories, meaning local country-specific data is employed to calculate the carbon footprints, a few categories are treated as global, meaning global data is applied for the category. This country-specific approach reflects and considers the prevalent significant variance regarding expenditures and emissions, which particularly apply to certain consumption categories, e.g., 'groceries,' where the locality of consumption considerably affects the carbon footprint. For the global categories, it is assumed that the locality of consumption does not significantly

[2] The use of second hand clothing has been studied by Farrant et al (2010) and Navodit et al. (2019) considering the Life cycle stages of collecting second-hand apparel, retail & distribution, and use & end-of-life stages. According to the Comparative Life Cycle Assessment (LCA) of SHC vs new clothing conducted by Navodit et al., 2019 using second-hand clothes generates only 16.6 kg CO2e, equal to 58% of the CO2 impact the new clothes create.

affect the carbon footprint due to cross-border. Global categories are:

- Video streaming services
- Audio Streaming Services
- Online shopping
- Car Rental

Further details regarding the explanation

4.2.3 Capturing individual preferences through end-user engagement

Refinements aim to increase the precision of carbon footprint and increase customer satisfaction. Refinements capture individual preferences; thus, successful implementation requires end-user engagement. In the context of the transaction to carbon estimations, refinements require end-user engagement to provide information that will allow to:

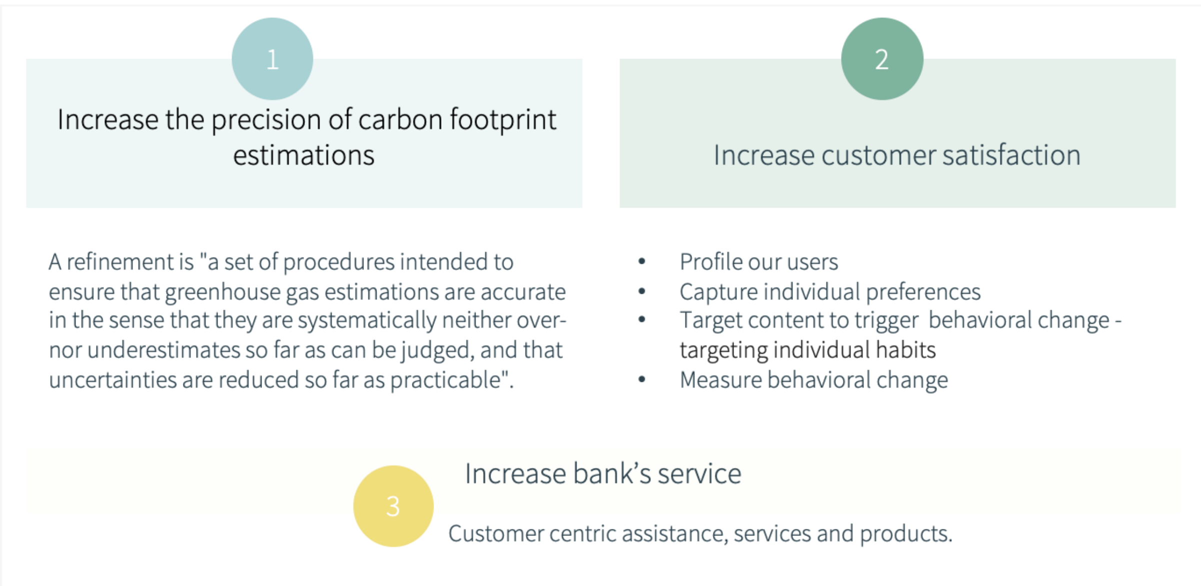

Figure 6. Objectives of capturing individual preferences ((IPCC, 2019)

The user can refine the estimation by capturing individual preferences regarding diet, energy at home at type of car owned. The calculation approach is the following:

$$\frac{Value\ of\ CO_2e}{transaction} = \frac{base\ value\ CO_2e\ per\ category}{monetary\ unit} * adjustment\ factor$$

The adjustment factor is then understood as a numerical factor to obtain the carbon intensity values of the refinement options from the base value. It adjusts the baseline emission intensity to reflect better users' consumption preferences.

The carbon footprint associated with groceries is refined by considering individual diet preferences; the refinement is done by applying adjustment factors derived from the research led by Kim et al. (2020), which modelled the greenhouse gas and water footprints of nine diets aligned with criteria for a healthy diet specific to 140 countries. This scientific publication estimates footprint reduction when shifting between diets and carbon and water footprints of different food categories per serving, kilocalories, protein content, and edible kilograms. The model considers trade flows when addressing the environmental impact of national consumption patterns. Furthermore, the GHG and water footprints of international food items are attributed to countries where the food is consumed, focusing accountability on the population responsible for changing demand. The diets identified by the study are then provided as options with adjustment factors developed for each country's scenario. The complete scope of refinements refinements can be found in the OfCC.

4.2.4 Update of the estimations

Estimations should be reviewed and updated yearly. Depending on the data source, some estimations will require revision in six months. The developing team decides this, and a date for the following revision is agreed upon.

4.2.5 Limitations

- Due to data collection difficulties and data compilation constraints, many existing MRIO databases (Tukker & Dietzenbacher, 2013) do not release annual MRIO tables. This impedes the ability to analyze historical supply chain data and international trade patterns to forecast future trends.(Huo et al., 2022; Huysman et al., 2016).

- The resolution of MRIO assessments is limited to a number of sectors. Anything more detailed requires additional data and deeper analysis. The National Footprint and Biocapacity Accounts have continuous time series from 1961 onwards, while GTAP data are limited to four years (2004, 2007, 2011, 2014).

- MRIOs have different scopes in industries and products; thus, values are not always comparable. For instance, EXIOBASE 3 provides:

  - A product-by-product table based on the industry technology assumption.
  - An industry-by-industry table based on the fixed product sales assumption.

  The industry technology assumption assumes that each industry has its specific technology (in terms of inputs), irrespective of the product mix of that industry. Fixed product sales structure assumption that each product has its own specific sales structure, irrespective of the industry where it is produced (E. : S. A. der E. G. Eurostat, 2008)

- Constant prices for categories are estimated using the functional units when monetized. Average prices for the last 12 months are used; thus, price differences over time are not considered.

- Data inconsistencies across time and countries, ranging from changes in classifications to modifications of the underlying accounting concepts over time. Understandably, the statistical agencies improve their approaches over time. Still, if the statistical agencies do not revise the older time series according to the new concepts, the time series are not directly usable for analysing structural changes over time (Stadler et al., 2021a).

- Language barriers when dealing with non-European national statistical agencies ‘data. Data available in the original language and English differ, so local knowledge becomes essential for appropriate data usage.

- Lack of transparency regarding the source of information used for the calculation when applying the Transaction to Carbon Approach, the user shall indicate which GMRIO is using as a reference, to enhance trust from the end-user.

4.3 Step 3. Alignment to the merchant codes

Carbon intensity factors are measured in CO2e per monetary unit, as explained in section 5. To provide individual carbon footprint based on one unit of currency purchased in each category, the user shall correctly align the end-user transaction per consumption category. To do this, the user should revise the bank transaction code information.

The transaction code information aims to deliver a harmonized set of codes applied in bank-to-customer cash account reporting information. The bank transaction code information allows the account servicer to correctly report a transaction, which will help account owners perform their cash management and reconciliation operations (ISO, 2020).

Transactions are recorded based on the following:

- The financial institution provides Merchant Category Codes (MCCs) for credit card payments.

Financial companies have no general mandate to use a common Merchant Category System. Thus, it differs from bank to bank. However, the International Organization for Standardization developed the ISO 18245 *Retail financial services — Merchant category codes* as a reference for the financial system. As stated in the scope, "ISO 18245 defines *code values used to classify merchants into specific categories based on the type of business, trade, or services supplied. Values are specified only for those merchant categories generally expected to originate retail financial transactions"*.

It is not within the scope of this International Standard to mandate the use of merchant category codes in any given situation. Thus, all institutions have a different catalog. Depending on the financial institutions with whom the user is working, the user may use the following catalogs:

- Visa Merchant Data Standards Manual, Visa Supplemental Requirements - November 2021
- Mastercard Quick Reference Booklet—Merchant Edition
- Citibank Merchant Category Codes

The alignment tables between MCC from the Visa Merchant Data Standards and the carbon intensity factors derived from the EEIO Hybrid method, are available at https://conscious-consumerism.com/.

Illustrative household consumption categories

Groceries/Retail	Air Travel	Clothing/Shopping	Service Stations	Catering	Lodging & Accommodation
MCC: 5411, 5422, 5441, 5451, 5462, 5499, 5999	MCC: 3000-3299, 4511	MCC: 5137, 5139, 5611, 5621, 5631, 5641, 5451, 5655, 5661, 5681, 5691, 5697, 5698, 5948, 5949	MCC: 5542, 5542, 5983	MCC: 5811, 5812, 5813, 5814, 7011	MCC: 3501-3790, 3816, 3831, 7011, 7012, 7032, 7033
Streaming Services	**Train Travel (Long Distance)**	**Taxi Cabs & Limousines**	**Bakeries & Cafes**	**Drug Stores**	**Local Public Transport**
MCC: 5734, 5815, 5816, 5817, 5816, 5817, 5818, 5999	MCC: 4112, 4789	MCC: 4121, 7999	MCC: 5462	MCC: 5122, 5912	MCC: 4011, 4111, 4112, 4789
Travel Agencies	**Online Shopping**	**Car Rental**	**Furniture**	**Energy**	**Convenience Store**
MCC: 4722	MCC: 4816, 5964, 5969, 5999	MCC: 3351-3441	MCC: 5021, 5712, 5932, 5933, 5937, 9753	MCC: 4900	MCC: 5499

Figure 7. Illustrative alignment between the Visa Merchant Data Standards Manual for some consumption categories

- Payment Service Providers (PSP) to categorize Single Euro Payment Area (SEPA) / Direct Debit Payments

For countries in the European Union, transactions are regulated by the SEPA Direct Debit Core Scheme Rulebook. The Scheme provides a set of inter-PSP rules, practices, and standards to be complied with by Participants who adhere to the Scheme. It allows payment service providers in SEPA to offer a SEPA-wide core and basic euro direct debit product to customers. The rulebook lays out the attributes for the identifier of the Creditor, which is unique in the Scheme. The Identifier of the Creditor allows the identification of one Creditor without ambiguity in SEPA (EPC, 2022). the user shall review the identifiers used by the PSP for the direct debit transactions and align/map those with the categories.

- Merchant name via the standard algorithm for debit payments / SEPA transactions if not categorized

4.4 Step 4. Implementation

The algorithm defining the procedure for linking the carbon intensity factors with the transaction data, listing the instructions to conduct the alignment, and selecting the carbon intensity may be proprietary information. Therefore, it is beyond the scope of this Standard. It is noted in this document because it is a core element in measuring performance. The user should write an algorithm that could become available to be public at any time. An illustrative example of the general setting of the system is shown in Simple general setting of the system for linking the carbon intensity factors with the transaction dataFigure 8.

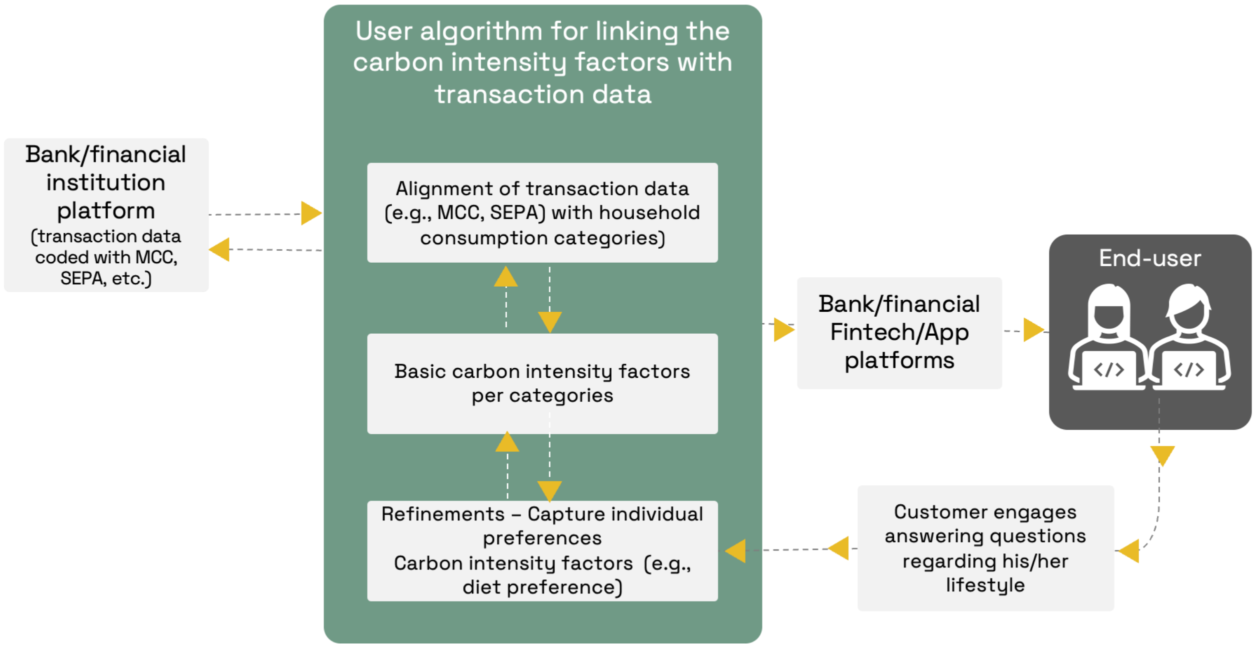

Figure 8. Simple general setting of the system for linking the carbon intensity factors with the transaction data

The algorithm(s) underlying a TtC system can analyze and extrapolate. The user's algorithm may be used to learn from the end user's data to improve the information provided to the end user and the information and foresight gleaned from the aggregate user data. The user should disclose these algorithms to clarify how conclusions were reached. The best way to deal with extrapolation is to make it user driven. This has the added advantage of giving the user a task to increase efficacy, even if that is just hitting a button. As a result, they can translate money spent into some intermediate measurement variable (distance, location, volume) and then translate that into their carbon footprint. This allows consumers to see how their money transforms into carbon via consumption. It adds explainability to the algorithms and tangibility to the carbon emissions.

4.5 Step 5. Verification

Carrying out verification gives the stakeholders and end-user confidence in the report's results. Verification assesses whether the reported information is relevant, complete, accurate, consistent, transparent, and without material misstatements, thereby providing assurance or confidence in the findings. Verification is related to quality assurance and quality control. Depending on stated objectives and circumstances, users should use any combination of verification and QA/QC[3].

4.5.1 Verification in the context of the Open Standard

Verification in the context of this Standard applies at two levels: 1) verification of the carbon intensity factors per category and 2) verification of the algorithm.

- Verification of the carbon intensity factors.

For this guidance, verification activities include comparisons with independent assessment and/or empirical testing.

Comparisons with carbon intensity factors prepared by other bodies and comparisons with estimates derived from fully independent assessments. Correspondence between the estimate factors and independent estimates increases the confidence and reliability of the carbon footprint by confirming the results (Winiwarter et al., 2016).

Empirical testing. Mathematical models assemble (many) variables and relations to simulate system functioning and performance for variations in parameters and inputs. The model mimics the appearance or functioning of systems, for example, the factors influencing individual consumption decisions and their relationship with emission (Allwood et al., 2014). Through a model

[3] As reference, the user should the guidance on verification and QA/QC from the Winiwarter et al. (2016).

specification, the user could predict the carbon intensity factors. This approach is only applicable when the user has access to specific characteristics of the end-user, characteristics proven in the scientific literature to influence consumption decisions.

- Verifying the algorithm

An important aspect of any algorithm is that it is correct: it always produces the expected output for the range of inputs and eventually terminates. The user shall have a Quality Assurance Platform that guarantees that the algorithm produces the expected estimations. For example, reported emissions to the end-user regarding the groceries category should be traced to the base carbon intensity factors and their associated refinements. Empirical analysis discovers inputs where the output is unexpected.

The specifications of the QA/QC platform are beyond the scope of this Standard, and it is the responsibility of the user to ensure a proper design according to international standards (e.g., ISO 27001, Chapter 6. Quality Assurance/Quality Control and Verification of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories) (Levin et al., 2014)

4.5.2 Verification process and benefits

Verification can provide a variety of benefits, including:

- Increased confidence that the information provided to the end-user with carbon footprint is robust and may trigger a change in the consumption patterns of individuals.

- Increased confidence in the results reported among the entities using the Open standard framework for consumer carbon calculations based on payment transactions (TtC), promoting a credible representation of the efforts undertaken by different users participating in a collective goal.

- Greater stakeholder trust in the reported results

The Verification process should be a cooperative, iterative process that provides feedback and enables users to improve their estimation procedures (Levin et al., 2014). The verification process involves evaluating whether the principles of the Open standard framework for TtC have been met and a review of users' justifications for chosen methods and assumptions. Verifiers assess reported information against agreed criteria, following a rigorous and systematic process. The verifier assesses whether all the standard requirements are met through the published country profile reports and internal QA/QC and algorithm. The verifier needs to check that the information reported meets the requirements and that the methods and assumptions used are reasonable.

Verification activities provide information as part of a continuous improvement process and is part of the overall QA/QC and verification system of the user (Winiwarter et al., 2016).

4.6 Step 6. Report

This chapter provides reporting requirements that outline which information shall be publicly reported to be in conformance with the Open Standard framework for TtC. When carbon intensity factors are estimated, the user shall prepare a country profile and make it publicly available. The country profile shall provide the following information:

- General information regarding the country under analysis – for instance, the total population used to estimate the national benchmarks and potential standardization of the emissions in the categories.
- For each category, an explanation of the factors considered for the estimations, a narrative of the GMRIO table use, if exchange rate was applied and any other consideration relevant that affects the cdelivered carbon intensity.
- A table with the carbon intensity factors. The user may use visualization tools to show the carbon intensity factors.
- All sources of data used to estimate carbon intensity factors, as well as for expenditure data. As explained in section 5, if LCA data for cradle-to-grave was unavailable for specific categories, it should be clearly stated in the report.
- The approach used for the quantification of the carbon intensity factors.
- A complete list of references so the end-user and stakeholders can review the information. This fosters transparency and allows replicability of the estimations.
- The user shall provide information regarding when the factors need to be updated.
- Whether the estimations were verified, and if so, the type of verification performed, and the opinion issued by the verifier. If possible, a link to the opinion by the verifier is publicly available.
- Contact information is relevant in case of questions through a contact email or a contact form. In case of questions, the end-user and

stakeholders can provide feedback as part of the constant improvement process.
- Any other information that the user like to provide.

Figure 9 provides a basic template for reporting; the user can expand the information provided in the template but, at minimum, provide all the information listed in the template.

Country Profile

1. Country

2. General description of the country — Specifying nationwide data used for the estimations (e.g., population).

3. National benchmark

4. Carbon intensity factors per category

Category	Carbon intensity factor (CO2e/monetary unit)
Food	

5. Explanations

Category	Explanation (A narrative providing information regarding where emissions are coming from)	Source (Reference) of expenditure data
Food	–	

6. List of references
7. Date of publication
8. Recommended date to update the estimations.
9. In conformance with the Open standard framework for consumer carbon calculations based on payment transactions (TtC) - Yes ☐ No ☐
10. External verification Yes ☐ No ☐
    Provide details about the entity that performed the validation.

11. Contact email

Figure 9. Template for the country profile

5. Further resources

The purpose of this Open standard framework for consumer carbon calculations based on payment transactions has been to start a conversation.

Information complementing this Standard and illustrative examples are the following:

- An open standard framework for consumer carbon calculations based on payment transactions. Methodology 2. EEIO Hybrid.
- Country profiles specifying reference values for emission and consumption, benchmark values, and sources of information are available at https://conscious-consumerism.com/.
- The methodology has been applied to estimate carbon intensity factors for the following countries: Germany, Sweden, The Netherlands, Norway, France, and Ireland.

We invite you to be part of the community of practice (CoP). Participation by the whole community in innovating and improving this Open Standard framework leads naturally to one of the big outstanding questions: what other aspects of TtC systems should be 'open,' that is, freely accessible to the community. Your data, algorithms, and program code have value. However, the proprietary value may be exceeded by the value created if some of these are open source. Open-source projects can be much more secure, accurate, and comprehensive while sending messages to certain actors - 'hackers' and consumers - about your intentions and ethics. Open source does not necessarily mean your end-product is free, which would be 'Free and Open-Source software (FOSS)”, though some innovators may wish to move in this direction and earn their profits through services.

6. Glossary

Carbon footprint	A measure of the exclusive total amount of carbon dioxide emissions (CO_2) that is directly and indirectly caused by an activity or accumulated over a product's life stages.
Carbon intensity	The amount of emissions of carbon dioxide (CO2) and/or equivalent carbon dioxide (CO2e) released per unit of another variable such as gross domestic product (GDP), output energy use, or transport.
Categories	The consumption categories are specified in the Category Catalogue.
Category Catalogue	The consumption category catalog is specified in the Open Sustainability Registry.
COICOP	The Classification of Individual Consumption According to Purpose (COICOP) is the international reference classification of household expenditure. COICOP aims to provide a framework of homogeneous categories of goods and services, which are considered a function or purpose of household consumption expenditure.
Country profiles	Is the document recommended by the Open standard framework to report carbon calculations based on payment transactions (TtC).
Emissions	The release of Greenhouse gases (GHGs) into the atmosphere.
EEIO-hybrid	Environmentally extended input-output (EEIO) hybrid methodology is the estimation using carbon intensity factors using the EEIO table with lifecycle assessment data for specific categories.
EXIOBASE	EXIOBASE is a global, detailed, Multi-Regional Environmentally Extended Supply-Use Table (MR-SUT) and Input-Output Table (MR-IOT). It was developed by harmonizing and detailing supply-use tables for many countries, estimating emissions and resource extractions by industry. Subsequently, the country supply-use tables were linked via trade, creating an MR-SUT and producing MR-IOTs. The MR-IOT can be used to analyze the environmental impacts associated with the final consumption of product groups.
EXIOBASE3	EXIOBASE3 is one of the most extensive Environmentally Extended Multi-Regional Input-Output (EE-MRIO) systems available worldwide. EXIOBASE 3 builds upon the previous versions of

	EXIOBASE by using rectangular supply-use tables (SUT) in 163 industries, with 200 products classified as the main building blocks. The data comes in two versions: a monetary version consistent with macroeconomic accounts and a hybrid mixed-unit version.
Emission factor	A factor allowing GHG emissions to be estimated from a unit of available activity data.
Gross domestic product (GDP)	The sum of gross value added, at purchasers' prices, by all resident and non-resident producers in the economy, plus any taxes and minus any subsidies not included in the value of the products in a country or a geographic region for a given period, normally one year. GDP is calculated without deducting for depreciation of fabricated assets or depletion and degradation of natural resources.
Greenhouse gases (GHGs)	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapor (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4), and ozone (O3) are the primary GHGs in the earth's atmosphere.
Global warming potential (GWP)	It is a factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GHG relative to one unit of CO_2 over a given period.
NACE	NACE is a four-digit classification providing the framework for collecting and presenting a large range of statistical data according to economic activity in economic statistics (e.g., production, employment, and national accounts) and in other statistical domains developed within the European statistical system (ESS).
Standards	Set of rules or codes mandating or defining product performance (e. g., grades, dimensions, characteristics, test methods, and rules for use). Product, technology, or performance standards establish minimum requirements for affected products or technologies. Standards impose reductions in greenhouse gas (GHG) emissions associated with the manufacture or use of the products and/ or application of the technology.
Transaction Data	Data in relation to a payment transaction of a User on the Customer's digital platform.

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Transaction to carbon:

An open standard for consumer carbon calculations based on payment transactions

Technology is a tool for changing the world, but only by putting people at the center of that tool can its use be truly transformative, changing the person so the changes in making the world more livable are themselves sustainable.