Title of the Paper: Impact Estimation and Product Classification under IMACS

Author Names: Vincent Dert

Affiliations: Founder of Sustain One World – LLC

Abstract

The Impact Measurement and Conservation System (IMACS) was developed to calculate environmental and human condition impacts and to apply conservation required to neutralize such impacts for products and services purchased by end-user consumers *(1- 6).* With its implementation, the IMACS system would allow the fastest return to the best approximation of pre-industrial sustainable conditions. All environmental impacts take place on a location. Location Based Impacts (LBIs) are environmental impacts assigned to parcels (land) or designated areas (marine). Under IMACS, LBIs can be calculated for parcels and areas with a relatively high level of accuracy using remote sensing instruments *(7).* LBIs are distributed in a dynamic fashion over the products made and services rendered using these areas. However, as of today such accurate methods are not yet or insufficiently available. This article focuses on the use of methods to estimate impacts of the underlying variables needed for parcel delineation and the environmental impacts taking place on them (LBIs). These impacts include landscape change and the subsequent use as cultivated area, changes in biodiversity, greenhouse gas emissions, fresh water consumption, soil and surface water acidification, soil & sediment loss, coastal area at risk of flooding, atmospheric ozone layer damage and includes all applicable types of conserving impacts, including wildlife area conservation, carbon storage and protection of coastal areas from flooding due to sea level rise. The IMACS system depends on personal and organizational participation. The system can be jumpstarted and participation can be ramped up faster by using impact classification and estimation systems for products and services, labor outputs and location-based impacts (LBI)s. The use of such classification methods would allow a gradual transition from static and more crudely estimated impacts for products, services and personal labor to more accurately calculated dynamic impacts at higher levels of participation and is expected to significantly shorten the transition period to sustainable conditions.

Keywords: Sustainability, Sustainable economy, biodiversity, protection, restoration, carbon neutrality, carbon negativity, Carbon capture engineering, Sustainability sciences, international protection of human rights

Statement of Preprint: This is a non-peer reviewed preprint submitted to EarthArXiv.

Journal and DOI (if applicable): 10.5281/zenodo.11225058

Journal and DOI for all versions: 10.5281/zenodo.11225057

Author Confirmation: This submission has been uploaded by the author listed on the manuscript. The corresponding author's email address is provided below.

Corresponding Author:

Name: Vincent Dert

Email: leedert@gmail.com

Twitter account: @vincentdert1

Impact Estimation and Product Classification under IMACS

1. Abstract

The Impact Measurement and Conservation System (IMACS) was developed to calculate environmental and human condition impacts and to apply conservation required to neutralize such impacts for products and services purchased by end-user consumers *(1- 6).* With its implementation, the IMACS system would allow the fastest return to the best approximation of pre-industrial sustainable conditions. All environmental impacts take place on a location. Location Based Impacts (LBIs) are environmental impacts assigned to parcels (land) or designated areas (marine). Under IMACS, LBIs can be calculated for parcels and areas with a relatively high level of accuracy using remote sensing instruments *(7).* LBIs are distributed in a dynamic fashion over the products made and services rendered using these areas. However, as of today such accurate methods are not yet or insufficiently available. This article focuses on the use of methods to estimate impacts of the underlying variables needed for parcel delineation and the environmental impacts taking place on them (LBIs). These impacts include landscape change and the subsequent use as cultivated area, changes in biodiversity, greenhouse gas emissions, fresh water consumption, soil and surface water acidification, soil & sediment loss, coastal area at risk of flooding, atmospheric ozone layer damage and includes all applicable types of conserving impacts, including wildlife area conservation, carbon storage and protection of coastal areas from flooding due to sea level rise. The IMACS system depends on personal and organizational participation. The system can be jumpstarted and participation can be ramped up faster by using impact classification and estimation systems for products and services, labor outputs and location-based impacts (LBI)s. The use of such classification methods would allow a gradual transition from static and more crudely estimated impacts for products, services and personal labor to more accurately calculated dynamic impacts at higher levels of participation and is expected to significantly shorten the transition period to sustainable conditions.

2. Introduction

An Impact Measurement and Conservation System (IMACS) is developed to calculate environmental (E) and human (H) condition impacts and to apply conservation required to neutralize such impacts *(1,2).* With its implementation, the IMACS system would allow the fastest return to the best approximation of pre-industrial sustainable conditions. The system assigns costs to resources used and damage done, creating strong incentives to minimize resource use and prevent environmental (E) damage while maintaining and improving human (H) conditions. The system uses Environmental Supply Chain Step (ESCS) calculations, with Individual Supply Chain Steps (ISCS) for individuals, Product Supply Chain Steps (PSCS) for products & services and Rating Supply Chain Steps (RSCS) to estimate impacts not resulting from ISCS or PSCS calculations. Each ISCS represents one individual, while each PSCS represents one or a series of identical product or services. All E-impacts enter the system as Location-Based Impacts (LBI), while all H-condition impacts enter the system through ISCSs. Although ultimately highly automated, LBIs and H-impacts are always estimated using a RSCS calculated (or audited) by an Impact Rating Organization (IRO). Employees can live sustainable; in which case the employee labor output is free of impacts. All impacts from non-sustainable employee labor are transferred to products and services made. For services provided, all impacts are transferred to the new organization during the sale transaction. For products made, all impacts are temporarily stored in the product, until sold. All impacts that enter the supply chain, exit as Individual Sustainable Absorption (ISA) *(3)* and as Excess Impact Deduction (XID) *(4).* See figure 1. The system allows transformation of products and services with damaging impacts, to products and services free of damaging impacts through the application of neutralizing conservation. IMACS allows the acceleration of the transition to global sustainability and to humane conditions, on a global scale, for all impact variables carried. A few dozen impact variables are divided over eleven impacts groups. Conservation in the form of protection and restoration can be made available to end-user consumers, while paid for by sellers. Under IMACS, conservation of all types needed can be made available in small and fractional amounts, such that conservation of the exact amounts required can be

applied during the purchase, in name of the buyer. Such “title-to-conservation” (TTC) is purchased at market prices by the end-user consumer under condition or permanency *(5).* This means that existing and new types of conservation need to meet stringent IMACS requirements in order to allow their sale as TTC. Many types of conservation needed, are not yet available or only in very small quantities, while none of the above requirements are met. The amounts of conservation available as TTC will start at zero and only gradually increase. This in turn means that initially only a very small fraction of all products and services can be consumed impact-free. On the positive side, this means that all types of conservation made available as TTC each week, will be fully sold that week, maximizing the growth of conservation organizations and their capacity. The IMACS organization sets the daily product participation percentage for participating organizations, such that demand for conservation is kept equal to the supply, by increasing the percentage of products and services that is required to “participate”. Impact variables are shown in capitalized supply chain step notation as [L, U_m, P_n] | [C] when expressed in their customary units, or are shown in regular font notation as [l, u_m, p_n] | [c] when expressed under normalized (unitless) conditions *(2).* In figure 1, impact variables [l, u_m, p_n] | [c] are shown under normalized conditions for resource use and historic impact variables. Except for the inputs for “Supplies” and “Locations-Based Impacts” (for which the values can vary), figure 1 also represents reference conditions (100% sustainable conditions).

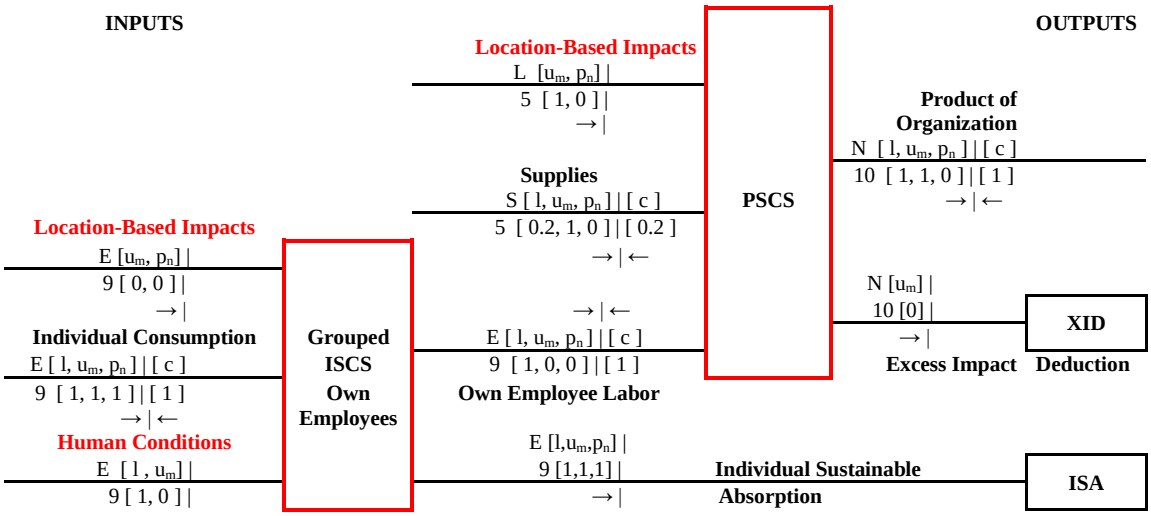

Figure 1: Combined ISCS-PSCS under normalized (unitless) and reference conditions (100% sustainable) for resource use and historic damage variables *(2).* The PSCS represents one product of an organization. One ISCS represents one employee and their labor. The ISCSs of multiple own employees are combined in a grouped-ISCS to use as an input to a PSCS. Except for financial compensations paid, all impacts flow from left (resources) to right (end-users) through the figure as indicated by the arrows above or below the values. Impacts for each variable balance over each supply chain step. All original variables with their specific units, L = labor hours worked, U_m = resource *m* used, P_n = conservation *n* applied and C = salary or price paid, can be expressed as normalized (unitless) values by division by their corresponding reference value: $l = L/L_{ref}$, $u = U/U_{ref}$, $p = P/P_{ref}$, $c = C/C_{ref}$. Each reference value reflects 100% sustainable conditions for the specific variable. All impacts first enter the supply chain as Location-Based Impacts (LBIs). All impact (except for salary paid) enter the supply ISCS or RSCS as human-condition impacts. Of all H-impacts, labor hours and salary paid are always carried and shown in supply chain step notation in all figures. Other human condition variables can be added to the ISCS input labeled “Human Conditions”. Under reference conditions, all current damage is zero, the resource use is equal to the individual allowance, conservation applied is equal to requirements, while resource use and conservation applied leave the supply chain as ISA *(3),* rendering the labor output free of impacts. For numerical simplicity of the example values in figure 1, the Location-Based Impacts of employees (mostly low in developed countries) are set to zero, while the impacts for products are evenly distributed over Location-Based Impacts and Supplies used. Under non-sustainable conditions, impacts are recycled with products made and consumed by employees. A fraction of al impacts enters the PSCS twice, requiring an Excess Impact Deduction (XID) to prevent supply chain accumulation of impacts. The XID *(4)* is zero under sustainable conditions. For current damage variables under normalized reference conditions, the same figure can be used, with the difference that all values for u_m and p_n are zero. For grouped-ISCSs, the multiplier E represents the number of own employees and is used for all ISCS inputs and outputs. N represents the number of products made, while L and S represent respectively the number of “batches” of Location-Based Impacts and Supplies used.

For each ISCS or PSCS figure and calculation made, LBIs only include E-impacts that pertain to or originate from the land or sea area assigned to the specific ISCS or PSCS. While all E-impacts originate at a specific location, and enter there as an LBI, some LBIs are easier to follow and calculate through purchases made. For example, an individual renting an apartment uses the projected surface area of the apartment floors and a fraction of the apartment grounds (parking lot, garden, etc.). This surface area used could be calculated for the individual, independent of the amount of rent paid. However, it is much easier to include this surface area used as part of the payment data for the service of “providing the apartment”. While theoretically qualifying as an LBI for the renting

individual, once included as part of the rent data, the apartment surface area is no longer a separate LBI input, since that would lead to erroneous double counting. LBI inputs thus only include the theoretical LBIs that are not already included with purchases made. For products and services purchased, impacts will include those collected before and anticipated after the purchase. For example; fuels purchased will reflect all impacts up to the point of sale, plus all impacts for the future burning of the fuel. Under *reference conditions*, no damage is done, the resource use is exactly equal to the individual sustainable available amounts (individual allowances), while all conservation is applied as required to render all resource use sustainable and to neutralize the required amounts of current and historic damage done. Under sustainable conditions, the resource use amounts and the required amounts of conservation applied are deducted in the ISCS calculation as individual sustainable absorption (ISA), rendering the labor output free of impacts *(3).* Under non-sustainable conditions, the resource use, current damage done and historic damage assigned are larger than can be deducted as ISA, and the labor output carries impact values for resource use, current and/or historic damage larger than zero (non-sustainable), while the excess impact deduction (XID) becomes larger than zero *(4).* The impacts for employee labor, products and services can be calculated accurately, when all LBIs and human condition impacts of all employees are accurately determined, and when all other impacts that are inputs to the ISCS and PSCS, themselves result from ISCS and PSCS calculations. Using the calculated impacts, sustainability values can be calculated for products, services and individuals *(6).* All LBIs that enter the supply chain for organizations and persons, need to be measured in order to calculate impact and sustainability values for products, services and persons and need to be measured at the lowest possible cost. Almost all environmental impacts needed as LBIs can be measured using remote sensing instruments *(7).* However, early after first implementation of the IMACS system, no accurate determinations of LBIs and human condition impacts are available, while very few ISCS and PSCS based impacts are calculated for employee labor, products and services.

3. Classification of Products, Services and Salaries

Once LBI are measured using remote access system and impacts for individual labor, products, services are calculated (“rated”) using ISCSs and PSCSs, these can be stored in the IMACS database. The IMACS database impact values can then be used for the calculation of impacts for new products and services and to update impacts of labor outputs. All products and services for which impacts are calculated as the outputs of a PSCS or ISCS, are given a unique IMACS Sustainability QR code (”SQR-code”). All selections are adequately named and all critical data (impacts and supply chain linkages) are stored in a product data sheet (public). Participating individuals are assigned a unique IMACS ID code and all critical data are stored in an individual data sheet (private). However, at first implementation no remote access based LBI data are available, while no or few rated products, services and labor outputs are available; no product, service or individual data sheets are available. In addition, product and services are not labeled with IMACS SQR codes and no systematic naming system is used to recognize products and services for what they really are. The question is: how do we jumpstart the IMACS system and allow it to grow rapidly? Starting from zero, we need an increasing fraction of producers to enroll in participation in order to make participating products and services available to participating customers. However, it is even more important that the product labeling is modified early on to best identify what the products and services sold really are. This is called *product, service and salary classification* and represents a form of “pre-participation”. For example, before we spend time on PSCS calculations for a product sold by a retailer (say a 450-gram net weight jar of chunky peanut butter made from more than 99.9% peanuts), we need the original product manufacturer (OPM) to identify the product on the label, such that it can be more easily and globally identified as the product it is. This could be done using a unique Classification QR code (“CQR-code”) and would only apply to products, services and salaries that are unrated. The CQR-code would indicate whether it would refer to a product, service or salary. For products it would further indicate whether it is a food or non-food. For foods, it would indicate the type (meat, milk product, cereal, fruit, veggie, etc.). In addition, the most relevant information should be “selectable”, like country of manufacturing, net product weight (for foods), gross weight and sizes (for shipping purposes), etc. This could be expanded to 10 or more selection rows, with each multiple section options. Visually (when printed on paper) the selectable options would resemble a “pyramid” with the actual product, service or salary selection to be made somewhere at the bottom row (figure 3).

Anything sold
Product, Service, Salary
Food products, Non-food Products
Meat, Fish, Cereal, Vegetable, Milk Product, …..
Beef, Mutton, Lamb, Pork, Poultry, Rabbit, Goat, Bison, Hare, Deer, Elk, Boar
Steak, Chuck, Brisket, Rib, Flank, Round, Belly, Shank, Ground, Mechanically Recovered
Ribeye, Fillet Mignon, Delmonica, Tomahawk, Flank, Cube, Hanger, Denver, Loin, Mock, Strip, Newport, NY

Figure 2: Showing the pyramidal structure of selectable choices (products, services, salaries) of the CQR-code software, with a few choices on top and many choices on the bottom line. In the example shown, each time the left most item is selected, after which additional selections are shown on the lines below. Using selectable fields, the correct CQR-code can quickly be found.

A similar "pyramid" could be made for services and salaries. The IMACS organization should define the different selection options at each level and provide the software to go through the classification process (OPM-CQR classification software). At the end of the classification process, the software would produce the globally unique CQR code that should be printed on the product label or services document. The presence of the SQR code would thus indicate that the product was sustainability rated, while a CQR code would indicate that the product was classified to its closest product or service category. Likely, the CQR system will start with a less detailed classification and will become more detailed over time and all CQR codes will include software revision numbers. For services (no labels are used), the service provider could provide the CQR code on the service classification sheet. This service classification sheet should be made available prior to providing the service and (in modified form if so needed) after providing the service. The CQR code needs to be assigned by the Impact Rating Organization (IRO) hired by the seller. Note that the overall CQR code provided is a combination of three codes; the SQR-code for the product, the software revision used and the code for the original manufacturer (OPM) for whom the classification was carried out. These three codes are needed to allow classification changes as needed after a SQR code revision change or to correct classification errors. After the OPM code is read, the computer checks whether the OPM has products in circulation with an erroneous SQR code or whether the code read represents an older code. In the latter cases, the erroneous or older codes are instantly replaced with the corrected or new code.

However, on the first day of IMACS implementation, it is likely that no or few products exist with an CQR code. In absence of the CQR code, an alternative option is to manually "scan" the product packaging and extract as much information as possible from the product. For packaged products with labels, a semi-automated process could be used where all products are put on a moving belt and one by one moved on and off a rotating platform where the entire product is scanned for information. Such a system would need to be operated by an IRO and would present higher costs and a higher errors rate than CQR labeling by the OPM. For products and services without packaging (e.g., 10 gal of gasoline tanked at the gas station or car wash service provided) this would not be possible, but CQR labels could be displayed by the LCD screen used to select the product or service type and be transferred to the payment system.

Method No.	Impact Determination Method Used	Impact Values	Sustainability Value	Costs of Impact Determination	IRO Role
1 (A, B)	PSCS based SQR code (for participants only)	Lowest	Highest	Low	Software setup and data auditing
2 (C)	OPM Classification based CQR code	Medium	Medium	Very Low	Initially CQR assignment, later review
3 (C)	Scanned CQR packaging classification at retailer	High	Low	Medium - High	Hard & software setup and product scanning
4 (C)	Manual CQR classification at retailer	Higher	Lower	High	Software setup and product scanning
5 (C)	E-impacts / dollar value at retailer	Highest	Lowest	Almost None	None

Table 1: Effect on E-impact and sustainability values calculated and costs of the various impact determination methods. Letters A, B and C refer to the impact calculation methods discussed in paragraph 5.1., where different standard deviations and values for X are used for method C. Methods A and B represent PSCS impact balance calculations (no standard deviation term is used).

Once products, services or salaries are classified to their closest product, service or salary class, their impacts can be estimated based of rated products within each class. The CQR code would link to a Classification Data Sheet, listing the product class, product description, OPM range of impacts within the class (with averages and standard deviation for each impact variable measured) and the impacts assigned to the product or service.

For products without CQR codes, the highest impacts found over all product classes for each impact variable would be assigned to the product. The same applies to services and salaries.
An overview of E-impact determination methods is given is table 1. Initially the CQR-code could be determined by OPMs on an "honor system" basis. However, as in any other field, fraud is likely to occur and increasing misrepresentation of CQR codes will later require IRO review of each CQR-code label prior to their acceptance and uploading to the IMACS database. For methods 3 and 4, the activities require a more nuanced and conservative approach; hardware and software setup and product scanning need to be carried out by and IRO.
In order to minimize time and costs, a product retailer may decide to forgo any manual or scanned packaging classification and apply the E-impacts per dollar value for all product sold without an OPM-CQR-code. This would lead to the highest E-impact estimates for products sold, but (besides the low costs) has the advantage of putting pressure on suppliers to either provide PSCS rated products & services or to at least provide OPM-CQR-codes in order to lower the estimated impacts of their products.

4. Impact Estimation in Absence of "Rated" Inputs

4.1. The Core Principle of Impact Estimation for IMACS

Impacts of products, services and individuals can only be calculated accurately using accurate inputs for the corresponding PSCS and ISCS calculations *(2, 3, 4)*. To get truly accurate values, this means that the inputs for these PSCS and ISCS should themselves be results of accurate LBI impact calculations and outputs of PSCS or ISCS calculations. All impacts of products and services calculated using PSCS are stored in (public) databases, while impacts of individuals are stored in databases that are kept private (under the control of the individual representing the ISCS). Using these database values, the impact balance calculations over PSCS and ISCS are fully automated, while IRO organization only have an auditing role (figure1). However, at initial implementation, LBIs cannot yet be determined accurately, while no products, services or labor impacts are calculated using PSCS or ISCSs. Only once the above-described hybrid environmental and civic databases (HECD) and the associated software are available to extract all required impacts, the LBI inputs can be calculated accurately. The database and extraction software could first be developed in full, after which the LBIs for participating organizations and impacts for products, services and individuals could be extracted. However, such development would be time consuming and costly relative to the small size of the market of initially participating organizations and individuals. Even in case all retail products would be rated (for the retailer by an IRO), most (upstream) products, services or labor impacts would not yet be calculated using PSCS and ISCS calculations, preventing the initial accurate calculation of (downstream) products, services or labor impacts.
In absence of inputs originating from PSCS and ISCS outputs (database values), all inputs to PSCSs and ISCSs need to be estimated using Life Cycle Analysis (LCA) for products and services and "impacts-per-dollar-income" for salary impacts, processed using Rating Supply Chain Step (RSCS) calculations (figures 2a and 2b).
Impacts of individual labor, products and services can be calculated or estimated in three ways (methods):

A. From ISCS and PSCS calculations using inputs that are outputs of other ISCS and PSCS and accurate HECD determined LBIs (most accurate).
B. From ISCS and PSCS calculations using inputs that are outputs of RSCSs, based on LCA estimated product and service impacts and impacts-per-dollar-income estimated labor impacts that are inputs to RSCSs (less accurate).
C. From statistical methods using geographic location, the product class, averages and standard deviation of impacts (only used for inputs to RSCSs, least accurate).

In figures 3a and 3b method B is used as the overall method, but inputs to the RSCS can be determined using methods A, B or C. Initially only method C would be used. However, with increasing availability of impact data calculated using methods B and A, impacts would increasingly be calculated using method B and transition to essentially only method A at full implementation.

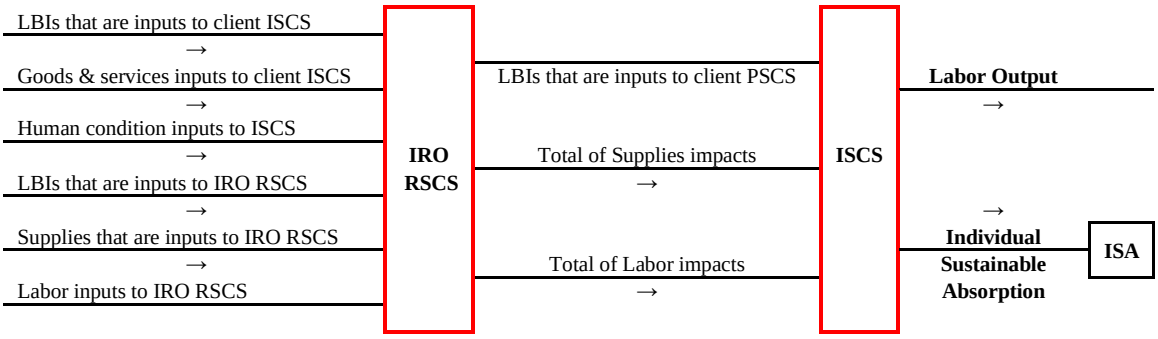

Figure 3a: A Rating Supply Chain Step (RSCS) is used by an Impact Rating Organization (IRO) to estimate the impacts of ISCS inputs, while adding its own impacts for doing the work. The detailed ISCS calculations provide more accurate values for the labor output of the individual, compared to more crudely estimated values not using ISCS calculated outputs. LBIs that are inputs to the IRO-RSCS, turn into services entering the ISCS. LCA based estimates are used for all non-rated inputs to the IRO-RSCS.

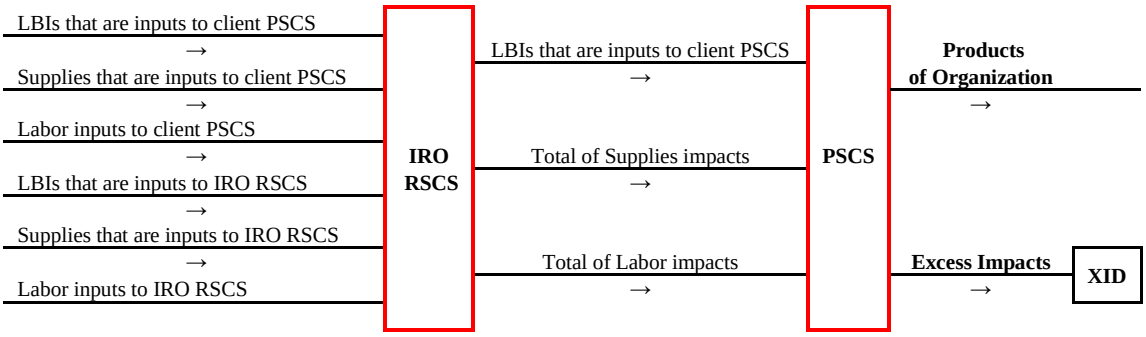

Figure 3b: A Rating Supply Chain Step (RSCS) is used by an Impact Rating Organization (IRO), to estimate the impacts of PSCS inputs, while adding its own impacts for doing the work. The resulting PSCS calculations provides more accurate impact values for products and services produced by the organization, compared to more crudely estimated values not using PSCS calculated outputs. LBIs that are inputs to the IRO-RSCS, turn into services entering the PSCS. LCA based estimates are used for all non-rated inputs to the IRO-RSCS [D:\Sustainability\Calculations\SupplyChainStepCalcs_12m.xlsx, sheet Draw_4]

Initially each product service of labor output requires the use of a RSCS for the calculation of PSCS or ISCS impact outputs (a 1 to 1 ratio). Once all products, services and individuals participate and their impacts are available in databases as outputs from PSCSs and ISCSs, one PSCS calculated set of impacts for a product series can be used directly as inputs for many other PSCSs, for as many products as were made in the series. See figure 4.

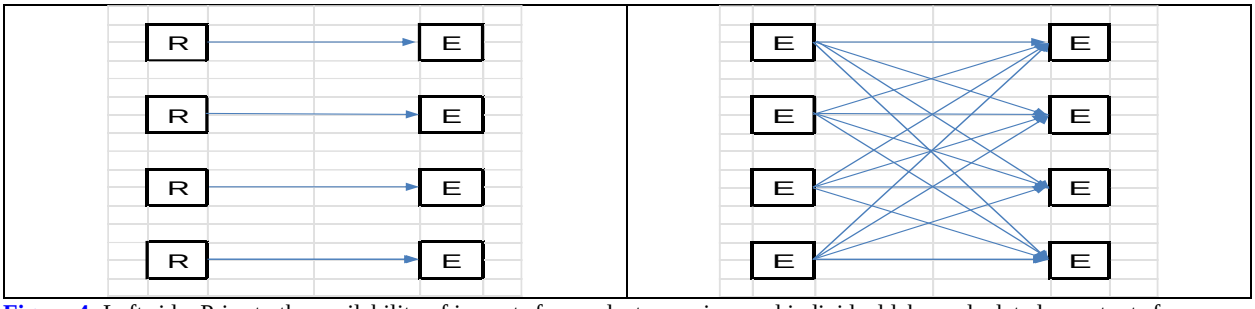

Figure 4: Left side: Prior to the availability of impacts for products, services and individual labor calculated as outputs from ESCSs (Environmental Supply Chain Steps as PSCS and ISCS), indicated in the figure as "E", all impacts that are inputs to PSCS and ISCS need to be estimated using Rating Supply Chain Steps (RSCS) indicated in the figure as "R". Right side: Once impacts for products, services and individual labor are calculated as outputs from ESCSs, all inputs needed are available as outputs of ESCSs and can be copied directly from their product, service or individual data sheets, minimizing/preventing IRO costs. The above does not apply to location-based impacts (LBI), which will always need to be determined by an IRO using a RSCS (although the process can be highly automated). The figure is limited to four different products (or series) or to four individuals, but should be imagined as expandable to billions of products and people *(17).*

For any estimate made, resources are spent on IRO labor hours, software, travel, etc., with less resources spent for crude estimates and more resources for more detailed estimates. A RSCS represents the impacts that are inputs to a PSCS or ISCS, based on estimated values to which the impacts of the impact rating organization (IRO) doing the work are added. The core principle of this estimation is, that the resources used and the damaging impacts for an unknown product or service, or for impacts resulting from a cruder estimation should be significantly higher, than they would be for impacts resulting from a more accurate estimation or calculation. While the estimated impact values need to be as accurate as possible, the calculated values used need to be artificially increased to significantly higher values. This is needed to prevent underestimation ("greenwashing") of impacts. For example: if the CO_2 emissions for a small sample of 1 kg bakery products in a given city vary from 0.2 to 2.0 kg CO_2 per kg bakery product, the actual CO_2 emissions for an unknown bakery product (say a pastry) can be larger than 2.0 kg CO_2 per kg bakery product, due to the small sample size. Participating retailers pay for the cost to neutralize the impacts of participating products and services sold and would like to reduce the estimated impacts to save money.
Under those conditions, higher estimated impacts resulting from crude estimates using methods C, would be a driving force to spend more time and money on more detailed PSCS calculations using LCA. To make sure that the estimated value used is sufficiently high, the calculated sample average impact value is increased with X times the standard deviation of the sample impacts (where $X \geq 3$).

$$U_{EstimateUsed} = U_{Average} + X * U_{StandardDeviation} \quad (1)$$

where $U_{EstimateUsed}$	= estimated impact value used as inputs to RSCS for use and damage variable U	[IU]
where $U_{Average}$	= average impact value of sample data for use and damage variable U	[IU]
where $U_{StandardDeviation}$	= standard deviation of impacts of sample data for use and damage variable U	[IU]
where X	= number of standard deviations used	[ ]

For a non-participating baker producing the "average bread", impacts would be estimated using method C and formula 1 prior to product rating. This means that participating customers buying his bread will see high impacts from this baker's breads purchased. After the baker starts IMACS participation, product rating method B using LCA is used and the "average" impacts for the product type "average bread" would be found, but no standard deviation term would be used for the "average bread", significantly reducing the impacts of his breads sold. For non-participating bakeries in the same town, method C would be used and the SD term would be included. For each product or service calculated using a PSCS (method B), the resulting impact data (plus location and time) are added to the database. This allows narrowing of product and service classes resulting in more accurate averages and smaller standard deviations (bakery products can be split into categories like bread, croissants and pastries, each with their own averages and smaller standard deviations). The same applies to labor impacts. With increasingly more inputs to ISCS and PSCS available as outputs of ISCS and PSCS, the calculated impact values will (on average) drop over time and become increasingly more accurate. As part of the IMACS objectives, we need to reduce the use of natural resources, eliminate damage to natural resources and grow the environmental conservation capacity needed to restore environmental damage done, in order to return to be best approximation of pre-industrial environmental conditions. Under IMACS, growth of the environmental conservation capacity can only take place through participating individuals buying "title-to-conservation" (TTC) and the retail sellers paying for it. To start and ramp this up as quickly and early as possible, IMACS implementation needs to start at the retail and individual consumer end of the supply chain. At this end, the relative contributions of LBIs to the PSCS are (on average) small while the impact contributions from supplies and employee labor are large.

4.2. Process and Labor Impact Estimation

Using the IMAC system, all impacts enter the PSCS as one of three input types; LBIs, Supplies and Own Employee Labor (see figure 1). In absence of "rated" (= PSCS and ISCS calculated) inputs to PSCS and ISCS, these inputs must be estimated. Supplies represent all products and services that are inputs to the PSCS. The Excess Impact Deduction (XID) output of the PSCS is zero, when employees are non-participating or when products and services are "unrated". When the latter is the case, the Supplies can be split in their original LBIs and their original labor impact components without the need for an XID correction *(4)*. In figure 5, the RSCS and PSCS as shown in figure 3 are combined in a "Combined RSCS and PSCS". Looking along the entire supply chain, the Supplies impacts are first split in their "LBI part of Supplies" and into the "Labor Impacts of Supplies". The LBI streams are then combined in "All Process Impacts" and the employee labor streams are combined in "All Labor Impacts" (figure 5).

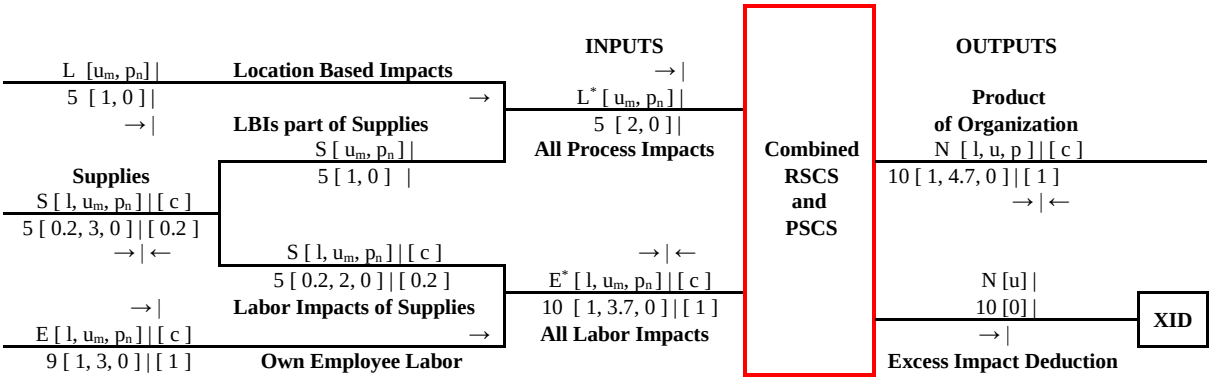

Figure 5: Example scheme for PSCS calculation of resource use or damage impacts under non-sustainable conditions in absence of "rated" (= PSCS and ISCS calculated) inputs. Inputs of Supplies to PSCS are split in LBI contributions and Labor impact contributions. To simplify the figure, the RSCS and PSCS of figure 3 are combined in a single RSCS-PSCS block. The "All Process Impacts" represent all impacts needed to make the product, but have no labor contribution. Labor impacts represent all damage done and all resource use above the individual allowance and/or in excess of available conservation. The "All Labor Impacts" have no "process" contribution. The example reflects conditions where the fraction of "rated" and participating products, purchased by participating individuals, is still essentially zero, leading to an essentially zero XID impact deduction *(4)*.

The resulting sum of labor impacts represent all damage done and all resources used in excess of the individual allowances and individually conservation applied along the supply chain. The sum of all labor impacts applied along the supply chain also represents the impacts of hours worked by own and supplier employees and investors who received the fraction of revenues from all products sold as income. The impacts for the products made and services provided can thus be calculated using the sum of the *process* and the *labor* impacts that are inputs to the PSCS. For figure 5, the assumption made is that LBI inputs to the ISCS can be ignored. For developed societies, LBI inputs to the ISCS are very small compared to the impacts from products and services consumed. For the impact estimations made, the effects of the standard deviation term used in equation (1) are likely to outweigh the excluded LBI that are inputs to the ISCS.

4.3. Estimated Labor Impacts Using Price and Impacts-Per-Dollar Income

PSCS calculations needs to be carried out for all participating products and services *(2, 3, 4)*. Using figure 1, this requires LBI inputs as well as impact inputs for Supplies and Own Employee Labor. Using figure 5, this can be modified to using "All Process" and "All Labor" impacts (equation 2). How do we estimate these? Starting with All Labor Impacts, the total of labor impacts is the sum of "Own Employee Labor Impacts" and "Labor Impacts of Supplies".

$$\text{All Labor Impacts} = \text{Own Employee Labor Impacts} + \text{Labor Impacts of Supplies} \quad (2)$$

Impacts associated with individual spending are typically distributed unevenly over individual income deciles. In addition to housing, the lowest income earners typically spend mostly on food and energy products with a relatively low labor content, resulting in high impacts per dollar spending. High income earners spend more on expensive products and services, having a high labor content, resulting in lower impacts per dollar spending. Lower income earners save relatively little if anything and spending is about equal to income earned. Higher incomes can afford to save more, further reducing the impacts per dollar income earned. As an example, the CO_2 emissions per dollar income are shown in figure 5 for the 2021 US income deciles *(8, 9, 10)*. Similar charts need to be made for all impact variables used.

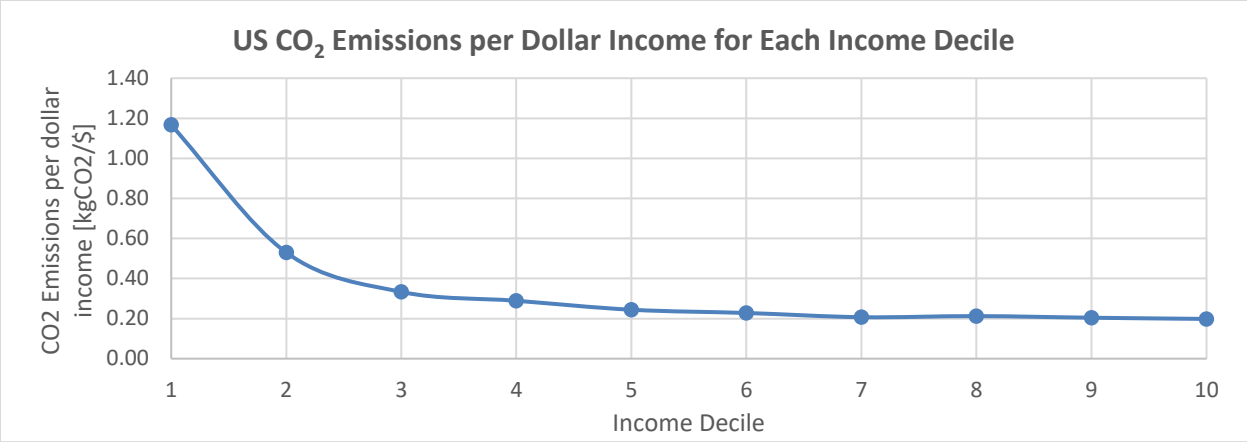

Figure 6: The CO_2 emissions per dollar spending are shown for the 2021 US income deciles. Lower income groups have higher CO_2 emissions per dollar spending *(9,10).* See *(16)* sheet "Income".

At the start of the IMACS implementation process, few or none of the employees making products are IMACS participants and the impacts of their labor are unknown. However, in case the following are known:

- the sales revenues for product or service p
- the salary amount paid to own employees (including all benefits) for making and/or selling product p
- the impacts-per-salary-decile for the geographic area (for each impact variable carried)
- the standard deviation of the impacts-per-dollar-salary for each income decile for the geographic area.

Using these inputs, the annual labor impacts for employee i for variable j in geographic area g for product p can be calculated using the impacts-per-dollar-income (IP$) method. Initially, the personal emissions for each of the ten income deciles can be treated as a sample of emissions-per-dollar-income for which the standard deviation can be calculated. Individual CO_2 emissions representing the individual's labor are calculated using equation 3. The effects of the number of standard deviations X used, is shown in figure 7 using zero to three times the standard deviation ($0 < X < 3$).

$$U_{i,j,g,p,Labor,IP\$,Own} = C_{i,g,p,Own} * (U_{Aver.j,PerDollar,Geo.g} + X_{L,j.g} * U_{SD,j,Labor,PerDollar,Geo.g}) \quad (3)$$

where $U_{i,j,g,p,Labor,IP\$,Own}$ = own employee i labor impact for variable j in geographic area g for product p using the IP$ [IU/y]
where $C_{i,g.p.Own}$ = salary amount paid to own employee i in geographic area g for hours worked on product p [$/y]
where $U_{Aver.j,PerDollar,Geo.g}$ = average impacts for variable j per dollar salary paid in geographic area g [IU/$]
where $U_{SD,j,Labor,PerDollar,Geo.g}$ = standard deviation of impacts for variable j per dollar for all salaries in geographic area g [IU/$]
where $X_{L,j,g}$ = number of standard deviations used for labor impacts for variable j in geographic area g [ ]
where "IP$" stands for "impact-per-dollar method" and "IU" stands for "Impact Units".

Using $C_{i,g.p.Own}$; the salary amount paid to own employee i in geographic area g for hours worked on product p, the labor impacts of each employee need to be distributed equitably over the products the employee made based on the hours worked on each product (or service) p. For the same product p made by multiple employees E, the sum of impacts over all employees i must be calculated:

$$U_{j,g,p,Labor,IP\$,Own} = \sum_{i=1}^{E} U_{i,j,g,p,Labor,IP\$,Own} \quad (4)$$

where $U_{j,g,p,Labor,IP\$,Own}$ = total employee labor impacts for variable j in geographic area g for product p using IP$ [IU/h]
where $U_{i,j,g,p,Labor,IP\$,Own}$ = labor impacts for employee i, for variable j in geographic area g for product p using IP$ [IU/h]
where "IP$" stands for "impact-per-dollar-income method" and "IU" stands for "Impact Units".

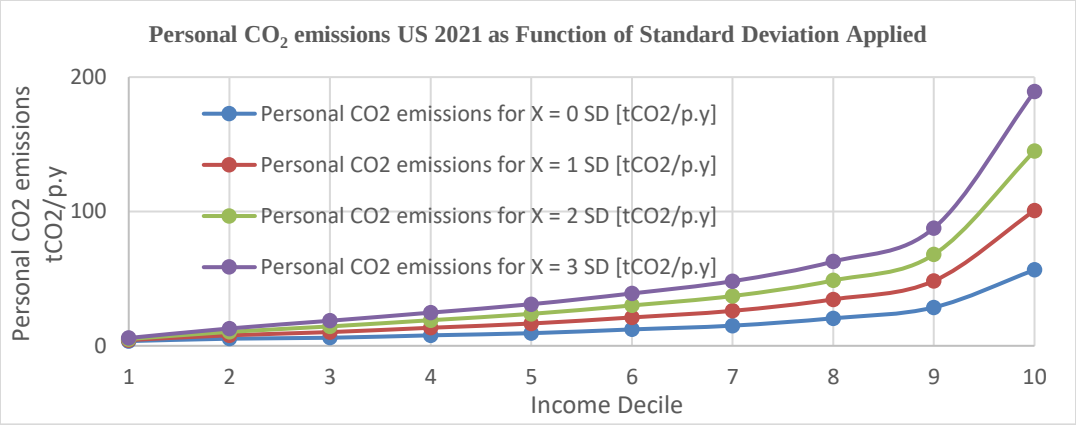

Figure 7: Personal CO_2 emissions as function of income decile and the number of standard deviations applied. See *(16)* sheet "Income".

The standard deviation term in equation 3, increases the estimated impacts by a factor 1.7 (for the 1st decile income) to a factor 3.1 - 3.3 (for the 3rd to 10th decile incomes) for X = 3 compared to X = 0 (figure 7). In most cases the use of X = 3 may be enough, but X may need to be increased, once impact data from participating employees become available, in order to prevent greenwashing. The use of the standard deviation term creates an incentive for individual participation. Participation and the resulting more accurately calculated/estimated impacts will (on average) reduce the individual labor impacts due to the reduction of impact uncertainty. This effect will be stronger for participating individuals with below average environmental impacts.

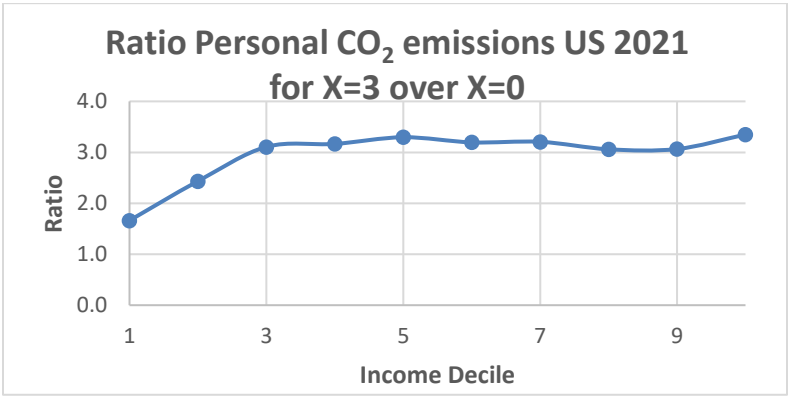

Figure 7: Effects of number of standard deviations (X) used to calculate own employee i labor impact for 0 < X< 3. The standard deviation term in equation 3, increases the estimated impacts by a factor 1.7 to a factor 3.1 - 3.3 for X = 3 compared to X = 0. See *(16)* sheet "Income".

At a later stage, with sufficient CO_2 emission data for each income decile, standard deviations per decile (instead of using all deciles) should be used instead, resulting in a more accurate estimate of the upper range of personal CO_2 emissions for each income.
All payments C_{Prod} for product p sold, are paid to people, either Own Employees or Supplier Employees and investors, with payments C_{Own} and C_{Sup}; hence $C_{Prod} = C_{Own} + C_{Sup}$. For unrated supplies, the individual incomes made by supplier employees and investors are unknown. To prevent greenwashing, these incomes must be assumed to be in the income decile with the highest impacts per dollar income (the 1st decile for CO_2 emissions impacts).

$$U_{j,g,p,Labor,IP\$,Sup} = C_{i,g,p,Sup} * (U_{Aver.j,PerDollar,Geo.g,Max} + X_{L,j,g} * U_{SD,j,Labor,PerDollar,Geo.g}) \quad (5)$$

where $U_{j,g,p,Labor,IP\$,Sup}$ = annual supplier labor impact for variable j in geographic area g for product p using the IP$ [IU/y]
where $C_{i,g.p.Sup}$ = salary amount paid to supplier employees in geographic area g for hours worked on product p [$/y]
where $U_{Aver.j,PerDollar,Geo.g,Max}$ = average impacts per dollar for highest impact decile for variable j in geographic area g [IU/$]
where $U_{SD,j,Labor,PerDollar,Geo.g}$ = standard deviation of impacts for variable j per dollar for salaries for geographic area g [IU/$]

where $X_{L,j,g}$ = number of standard deviations used for labor impacts for variable j in geographic area g [ ]

Using the above defined terms, equation 2 can be expressed as equation 2a:

$$U_{j,g,p,Labor,IP\$} = U_{i,j,g,p,Labor,IP\$,Own} + U_{i,j,g,p,Labor,IP\$,Sup} \quad (2a)$$

Impacts per dollar salary would need to be estimated for each impact variable that is used. In order to prevent "greenwashing", the factor $X_{L,g}$ must be set sufficiently high to meet the highest impact that is likely to be found within each income decile. The average, standard deviation and factor $X_{L,g}$ would be different for each impact variable j in each geographic area g.

Example Part 1: "All Labor Impact calculation":

A bakery owner requests a determination of the carbon dioxide emissions of their breads. This includes the "All Labor" impacts and the "All Process" impacts" components as shown in figure 5.
Part 1: In the 1st part of the example, we only address the "All Labor" impacts *(15).*
Neither the bakery owner nor the employees are IMACS participants. None of the products and services supplied ("Supplies") are IMACS rated. Although his employees are not yet participating, the bakery owner/manager knows the salaries paid to employees C_1 and C_2 and to himself (C_3), and also knows the daily revenues from all breads sold (C_p). The Impact Rating Organization (IRO) selected needs to estimate "All Labor" impacts to be assigned to the bread products for a week with typical bread production and sales. To simplify the impact assignment to the various types and sizes of bread, the Labor impacts are assigned per dollar-bread-price paid. Upon sales, the "All Labor" impacts per bread are calculated based on the bread price. The bakery also makes pastries, for which the impacts are determined separately. Data used:

- Employee 1: total hours worked = 50, hours worked on breads 30, hourly pay 2 $/h.
- Employee 2: total hours worked = 40, hours worked on breads 20, hourly pay 4 $/h.
- Owner/manager: total hours worked = 50, hours worked on breads 10, hourly pay 40 $/h.
- The US CO_2 emissions per decile data are used (figures 6 and 7).
- The "Own Labor" cost fraction is set to 27% of total operating costs.
- Total weekly bread revenues: $ 2000.

"All Labor Impact calculation": *(15)*

- Using hourly wages and weekly hours worked, weekly employee salaries are calculated: $C_{Own,Bread,Weekly}$
- Labor impacts from Supplies are calculated as: $C_{Suplies,Bread,Weekly} = C_{Bread} - C_{Own,Bread,Weekly}$
- Assuming 52 paid weeks per year, the annual employee i incomes are calculated as $C_{Ei,Total,Annually}$
- Data for CO_2 emissions per income decile are collected and expressed as a "CO_2 emission function".
- The Standard Deviation (SD) of CO_2 emissions is calculated over all income deciles.
- The weekly "Own Employee Labor" CO_2 emissions per employee are calculated by adding "average" (using the "CO_2 emission function" and X * SD of CO_2 emissions for each income (equation 3).
- For "Supplies Labor", the underlying individual incomes are unknown. To prevent greenwashing, the income decile with the highest emissions per decile must be used (the 1st decile).
- "Supplies Labor" CO_2 emission impacts per $ income are calculated by adding the 1st decile CO_2 emissions per dollar income and X * SD for CO_2 emissions per $ income. The weekly "Supplies Labor" CO_2 emissions are calculated by multiplying the "Supplies Labor" CO_2 emission impacts per $ income, with the weekly "Supplies Labor" income [$kgCO_2/w$].
- The weekly "All Labor" CO_2 emission is the sum of weekly "Own Employee Labor" CO_2 emissions and "Supplies Labor" CO_2 emissions [$kgCO_2/w$].
- The "All Labor" CO_2 emission" per $ bread is calculated by dividing the "All Labor" CO_2 emission per week by the bread revenues per week. Using example input values, the "All Labor" emissions are calculated as 1.243 $kgCO_2/\$$. See *(16)* sheets "All Labor (1)" and "All Labor (2)" using respectively weekly and annual inputs.

4.4.Estimated Process Impacts Using Life Cycle Assessment *(18)*

In absence of inputs to the PSCS and ISCS that are themselves calculated using PSCS and ISCS (figure 1), these inputs need to be estimated (figures 2a, 2b and 4) as Process and Labor impacts. The *"process"* E-impacts can be estimated using Product Lifecycle Assessment (P-LCA) or Environmentally Extended Input-Output Life Cycle Assessment (EEIO-LCA) *(11, 12, 13)*. Life Cycle Assessment (LCA) estimates represent *process* impacts free of *labor* impacts. Note that current LCA methods are based on averages of impacts of process inputs and produce a single-impact value for each impact variable used. For example; LCA methods can estimate the E-impacts for a batch of 10,000 jars of (500-gram) peanut butter made by a specific manufacturer at a certain location and date. The LCA method should include all "upstream" impacts and may include "downstream" impacts like the average shipping and storage impacts to the retailer and should include the average retail impacts. However, all impacts included are "static" and do not automatically change for different retail conditions of for different dates. Using IMACS in its fully implemented form, all impacts are "dynamic" and change with changes in process, suppliers, transportation or retail operation, including changes in daily pricing. These changes are automatically captured using IMACS without any additional work done. For the above-mentioned batch of peanut butter jars, sold by hundreds of retailers at different prices, many hundreds of potentially widely varying impact values will be calculated automatically (for the same variable) using a fully functional IMACS system. The same static approach applies to assigning environmental impacts to products. Therefore, even the most "accurate" LCA method thus only produces "crude" process impact estimates, especially in a world where impacts of products and services continuously change. Less accurate but simpler and faster and low cost LCA methods are therefore preferred. Even so, LCA methods can be used as initial estimates for the process impacts of products and services, until replaced by more accurate IMACS methods.

4.5. Combining Life Cycle Analysis and Impacts-Per-Dollar-Income

Using the modified PSCS calculation as shown in figure 4, the overall impacts for a product or service can be estimated as the sum of the process impacts, using the LCA method, and labor impacts, using the impact-per-dollar-income method.

$$U_{j,p,g,EM1} = (U_{j,p,g,Process,LCA} + U_{j,p,g,Labor,IP\$} - U_{j,p,g,XID}) /N \quad (6)$$

where $U_{j,p,g,EM1}$ = estimated impact j of product/service p in area g using the combined LCA and impact-per-dollar-income method [IU]
where $U_{j,p,g,Process,LCA}$ = estimated process impact j of product or service p in geographic area g using the LCA method [IU]
where $U_{j,p,g,Labor,IP\$}$ = estimated labor impact j of employee income spent in area g using the impact-per-dollar-income method [IU]
where $U_{j,p,g,XID}$ = excess impact deduction for product or service p [IU]
where N = the number of products or services in the series produced

This method is referred to as Estimation Method 1 (EM1). Note that using EM1, information about participating own employees and their use of participating products is unknown and the XID is accordingly equal to zero, leading to higher impacts. The impact data calculated for each product using equation 6 are stored in a database. These PSCS calculated impacts apply to a unique product or service. Unfortunately, the number of different products sold worldwide is staggering; over 75 million on Amazon alone and the time and costs involved to make all these LCA estimates would be too long and prohibitive. As a start, it would be better to distribute all products and services over circa 20 broad groups using the above-described classification system (CQR codes) and to estimate the highest and the lowest impacts within each group for the first geographic area (country, state) where the system will be implemented. Doing so would create a database with PSCS estimated upper and lower impact values for products and services per group. In order to limit the initial costs, this could be limited to the first impact variables used and for about 100 to 200 products and services. Impacts can thus be calculated and stored in the LCA database, for the following product and service groups:

- Fuels like natural gas, gasoline and diesel fuels, propane
- Utilities like electric power, fresh water, sewage water treatment, and internet access
- Food staples like wheat, corn, rice, soybeans, potatoes, sugar, etc.,
- Meats like beef, pork, mutton, poultry, and derived products like milk, butter and cheese,
- Types of fish and shellfish,
- Bakery products,

- Fruits and vegetables
- Building products like wood products, steel, cement, drywall, roofing, windows and doors,
- Vehicles like bicycles and cars

For products the impacts need to be expressed per item and per unit net weight. A similar list can be made for services, including insurances, hospitality, transportation, real estate, financial services (loans and investments) and government services (taxes paid). This approach allows estimation of impacts of products and services within each product or service group, using the same defined method for the first few implementation regions. For services, the impacts need to be expressed per separate service and per dollar transaction value.

Example Part 2: Combined Impact Calculation

Part 2: In the 2nd part of the example, we combine the "All Labor" impacts calculated in Part 1 with the "All Process" impacts and calculate the CO_2 impact balance over the PSCS for the bread made and sold. The selected IRO uses LCA software to estimate the "All process Impacts" that are inputs to the bakery and distributes these over all products sold and assigns the corresponding fractions to the bread and calculates the CO_2 impacts per kg bread. Results, using realistic example input data, are shown in table 2. Note that the labor impacts for the bread made are about four times larger than the process impacts, illustrating the limitations of "LCA only" impact estimates.

Input	Value	Units		Outputs	Value	Units
LCA Impacts 1 kg whole wheat bread / kg	0.9	$kgCO_2/kg$		Price of bread purchased	1.5	$
Price whole wheat bread per kg	3	$/kg		All Labor impacts of bread purchased	1.86	$kgCO_2$
Weight of whole wheat bread purchased	0.5	kg		All Process Impacts of bread purchased	0.45	$kgCO_2$
"All Labor" CO_2 emissions per $ bread	1.243	$kgCO_2/$$		XID	0	$kgCO_2$
				CO_2 Impacts for bread purchased	**2.31**	**$kgCO_2$**

Table 2: Estimation of CO_2 impacts for bread, using LCA based *(14)* Estimation Method 1 to calculate "All Process" impacts and the impacts-per-dollar-income method to estimate the "All Labor" impacts as inputs to the PSCS. The impact balance over the PSCS is calculated, resulting in the estimated CO_2 impacts for the bread purchased *(15)*. See *(16)* sheet "PSCS-Out".

5. Estimation Methods and Standard Calculation Used

When accurate LBI data are available for extraction from databases and impacts for all supplies and labor are available as ESCS outputs, the fully automated Standard Method (SM) is used for impact calculations for products, services and individuals. This standard method uses figure 1, with standard PSCS inputs LBI, Supplies and Own Labor. The impact balances over ISCS and PSCS, including ISA, XID and the resulting impacts of the product or service produced, are calculated using this standard method *(2, 3, 4)*. However, initially the availability of LBI data is limited, while no ESCS impact data are available; most or all impacts need to be estimated. Two estimation methods will be used to estimate impacts of products and services; Estimation Method 1 (EM1), already used in the above example, and Estimation Method 2 (EM2), where EM2 uses data calculated using EM1 on previous occasions. As preparations for the use of the Standard Method (SM) and impact Estimation Method 1 (EM1), the IMACS organization will calculate the impacts per income decile for the first few impact variables for the first geographic area where implementation starts.

5.1.SM, Standard Method

The standard Method is the default method used in case **ALL** inputs to PSCS and ISCS originate from PSCS and ISCS calculations **and/or** when these inputs are estimated using EM2 and the "impact per dollar income" method (mixing of inputs types is allowed).

- **SM calculation steps (default):**
    a. Figure 1 is used, with standard PSCS inputs LBI, Supplies and Own Employee Labor
    b. The (individual) LBI, impacts of Individual Consumptions and the Human Condition Impacts for the employee are used as inputs to the ISCS.
    c. The (own operation) LBI, and impacts for "Supplies" and "Own Employees" are used as inputs to the PSCS.

d. The standard impact balance calculations are carried out over the ISCS (including the ISA calculations for participating employees) and over the PSCS (including XID calculations) resulting in the SM product or service impacts $U_{j,p,g,SM}$.
e. In case $U_{j,p,g,SM} < U_{j,p,g,EM1}$ all product description info, geographic location and all relevant impact data are added to the Product Data Sheet, labeled as "Standard Method" and are added to the global IMACS database. No database entries are made for Standard Method if $U_{j,p,g,SM} > U_{j,p,g,EM1}$.

As long as most PSCS inputs are estimated using EM2 and impacts-per-dollar-income, the Standard Method is essentially an estimate. For every product or service for which impacts are calculated using both the Standard Method and EM1, the lower impact outcome is used and the higher impact outcome is discarded.
With few "rated" (PSCS calculated) products and services available, method EM2 will always estimate higher impacts for non-rated items than EM1, due to the standard deviation term added to the averages calculated using EM2. However, when all products and services are CQR coded by the OPM, EM2 can be fully automated, requires little time and represents low costs.
Initially many producers of products and services will prefer method EM1 to use their lower than default impacts. However, this will change with increasing fractions of "rated" products and services. This will lead to an increasing fraction of participating employees and an increasing selection of rated and participating products and services bought by participating sellers and employees. The impacts of participating products and services will reduce and the estimated impacts using method EM2 will become smaller than using method EM1. Due to higher cost, method EM1 will be abandoned and the Standard Method will dominate, using decreasing fraction of EM2 and "impact-per-dollar-income" estimated values. To calculate the impacts of individual participating employees, only the standard method (SM) is available. The impacts for the inputs to the ISCS can be rated products or can be estimated using EM2.

5.2. Estimation Method 1 (EM1)

EM1 calculates the overall impacts of the product or service, by splitting the three standard inputs LBI, Supplies and Own Labor as shown in figure 1, into the two "All Process" and "All Labor" inputs to the PSCS as shown in figure 5. The "All Process" impacts can be estimated using Life Cycle Analysis methods, while the "All Labor" impacts are estimated using the "impacts per dollar income" method.

- **EM1 calculation steps** (requested by seller):
  a. Figure 5, with PSCS inputs modified to "All Process" and "All Labor" impacts is used.
  b. A LCA method is carried out to estimate "All Process" impacts.
  c. The "All Labor" impacts are estimated using the "impacts per dollar income" method.
     i. For supplier employees the "impacts per dollar income" method is used based on the supplier payments $C_{Supplier} = C_{Sales} - C_{Own.Employees}$ and using equation 5.
     ii. If none of the own employees are participating, the own employee impacts are calculated using equation 3 and 4.
     iii. For participating own employees, the impacts are known and used as inputs.
     iv. For the remaining non-participating own employees the "impacts per dollar income" method is used for the balance of incomes paid ($C_{Non\text{-}part,Own\ Emplees.} = C_{Own.Employees} - C_{Part.Employees}$) and otherwise calculated using equations 3 and 4.
     v. The "All Labor" impacts are equal to the sum of impacts calculated for c_i, c_{ii}, c_{iii} and c_{iv}.
  d. Impact balance calculations are carried out over the PSCS using the results of EM1-b and EM1-c as PSCS inputs resulting in the EM1 product or service impacts $U_{j,p,g,EM1}$.
  e. In case $U_{j,p,g,EM1} < U_{j,p,g,SM}$ (see below) all product description info, geographic location and all relevant impact data are added to the Product Data Sheet, labeled as "EM1 Estimate" and are added to the global IMACS database. No database entries are made for Standard Method if $U_{j,p,g,EM1} > U_{j,p,g,SM}$.

To prevent greenwashing, the selection leading to the highest impact for each impact variable must be selected during LCA impact estimations, for each numerical or categorical selection of parameter conditions, unless the documented supply chain data allows otherwise. Note that EM1 does not allow a separate estimation of impacts for the various products or services used as "Supplies", that are input to the PSCS, since these are already covered as part of the "All Process" and "All Labor" impacts.

5.3. Estimation Method 2 (EM2)

Once impacts are estimated using EM1, the growing number of EM1 based impacts available, allows a narrowing of the classes (i.e., narrowing "bakery products" to "breads" and "pasties"). This in turn allows more accurate impact estimation method for products and services for which sellers did not request an LCA-PSCS based rating. Estimation Method 2 (EM2) is used in combination with the Standard Method (SM) to estimate impacts of products or services that are part of the "Supplies" inputs to the PSCS or part of the "Individual Consumption" inputs to the ISCS. As preparation for EM 2, the IMACS organization will calculate impacts for a limited number (say 100 to 200) of different products and services (p), distributed over 50 to 100 broad classes (q), using EM1. Using EM2, impacts are estimated as the sum of the class average and X times the class standard deviation (SD):

$$U_{j,p,g,EM2} = U_{j,p,g,EM1,Average,Class\text{-}q} + X_{EM2,j.g} * U_{j,p,g,EM1,SD,Class\text{-}q} \quad (7)$$

where $U_{j,p,g,EM2}$ = Impact for product p, for variable j, in geographic area g using Estimation Method 1 (EM1) [IU]
where $U_{j,p,g,EM1,Average,Class\text{-}q}$ = Average impacts for products in class q, for variable j, in geographic area g using EM1 [IU]
where $X_{EM2,j.g}$ = number of standard deviations used for EM2 for variable j in geographic area g [IU]
where $U_{j,p,g,EM1,SD,Class\text{-}q}$ = Stand.Dev. of impacts for products in class q, for variable j, in geographic area g using EM1 [IU]

Available LCA databases may be used to expand the number of products and services for which impacts are already estimated.

- **EM2 calculation steps**:
    a. Determine the CQR code for the product or service. The CQR code is either scanned from the product packaging or service order, or must be assigned by the IRO.
    b. Using the CQR code, the average class impact, class SD and the value for X assigned to the products in the class, are looked up for each variable used. The impacts are estimated using equation 7.

  Due to the standard deviation term, impact estimates using EM2 are on average higher than using EM1.

5.4. Estimation Method 3 (EM3) – Default

For product sold to participating customers without CQR or SQR codes, default impacts must be estimated reflecting the highest impacts per dollar value used for all products found in the geographic area. The same applies to services purchased. However, due to the high contribution of labor in services, the highest impacts for services are typically lower than the highest impacts of products in a geographic area. This applies to participating end-user consumers buying non-CQR coded products, since the sum of all products and services purchased needs to be calculated, irrespective of any QR coding used, in order to calculate the impacts of the ISCS labor output. This does not apply to organizations, for which no representing supply chain step exists. Note that the PSCS represent a single product or service (or a series of identical products or services), not an organization. This may sound harsh, but a non-CQR or non-SQR coded product or service could be the highest impact product or service in the geographic area. Using any value lower than the highest would in most cases lead to greenwashing. This high default impact creates a strong incentive for participating end-user consumers to buy CQR and SQR coded products and services and in turn creates a strong incentive for retailers to ask OPM producers to provide CQR and SQR codes for their products and services.

5.5. LBI Estimation

As long as impact estimates are based on LCA methods, all impacts corresponding to LBIs should be included in the LCA values. However, the frequency of updating environmental databases for LCA methods will vary per environmental variable and per geographic region, while the resolution of mapping systems varies globally *(16)*. While moving away from non-dynamic LCA impact estimation to the dynamic and more accurate impact calculation using PSCSs, environmental impacts need to originate from dynamic frequently updated databases. For example; cleared forest sections need to be identified ASAP after a satellite such as Landsat satellite passes over. As indicated by figure 1 (and extended to all upstream supply chain steps), all E-impacts first enter the supply chain as location-based impacts (LBI). At first implementation, hybrid environmental and civic databases (HECD) designed

to calculate LBIs at a high level of accuracy, are not available. Prior to accurate per parcel determination of LBIs using such HECDs, the LBIs can be estimated based on landscape type per country or region for each parcel (residential, commercial, industrial, agricultural, commercial forestry, fisheries, aquaculture, wildlife, biodiversity protected wildlife areas, etc.). To allow a faster start, a default automated LBI determination system needs to be created. Default LBI values can be based on literature values (likely already in part available in existing databases) for satellite image recognizable landscape types. Conservative values should be used by default (damaging impacts set to larger values than on average expected) and could be lowered after parcel evaluation by IRO staff. This system would not be dynamic, since changes in satellite data and civic databases would not be automatically updated, but it could be used until such dynamic HECD systems are available.

Prior to assigning an impact value to a landscape type, the landscape type needs to be determined. Prior to the availability of dynamic HECD databases, landscape type determination can be carried out similar to the original product manufacturer (OPM) classification system proposed for products and services. Instead of using OPM-CQR codes to classify the product or service, landscape environmental impact codes (LEI-codes) can be used to classify landscape types and assign impacts compared to their undisturbed ecoregions. Different LEI-codes would be used for wildlife areas at various levels of protection and degradation and to production forests, plantations, croplands and the various types of built-up area in different geographic regions. LEI-codes could be used for a more detailed classification of area types. For example, the category of *built-up areas* would be further classified into residential, commercial (shopping and offices), light industry, chemical & heavy industry, waste treatment, infrastructure, etc. Similar to OPM-CQR codes, the collection of LEI codes will represent a pyramid with the LEI code for "*any landscape type*" at the top, LEI codes for the different ecoregions in middle layers and LEI codes for the various levels of wildlife area degradation for each ecoregion listed on the lowest level.

Based on the geographic location, the LEI-code and remote sensing data collected, default values could be assigned to most E-variables. For each variable, default data should be set to the high (damaging) impact end of their uncertainty range reflecting a lower sustainability (i.e., higher range end values for water extraction, evapotranspiration, soil loss, CO_2 emissions, methane emissions and various pollutants and lower range ends for biodiversity values, carbon storage and soil pH).

Land/area owner could request (and pay for) a local determination or verification of E-variable values. Using such LEI-codes, organizations can decide whether it would make financial sense to spend money on LBI estimation or on accurate LBI determination. Assuming that IRO staff are locally available, the time required for LBI determination at each location will vary with the size and complexity of the organization's area use (land and sea), the buildings, chemical, industrial or farming process equipment installed and other improvements that need to be evaluated. For larger organizations more time will be needed, but due to their larger scale, their costs per unit revenues will be smaller. In order for conservation organizations (wildlife conservation, carbon sequestration, watershed protection organizations) to sell conservation as "title-to-conservation", the most detailed LBI determination and overall impact assessment using ISCS and PSCS are required.

6. Results and Discussion

LBIs typically represent the largest fraction of impacts for materials and products at the resource end of the supply chain, like mined materials, fossil fuels, agricultural and forestry products. For individuals, most impacts originate from supplies and labor used, while LBIs typically represent a small fraction of all environmental impacts. Impacts of products, services and individuals can only be calculated accurately using accurate inputs for the corresponding PSCS and ISCS calculations *(2, 3, 4)* and are referred to as "rated" products, services and salaries. LBIs can be determined with reasonable to good accuracy using remote sensing *(7)* after low costs data products are developed. However, initially no such low costs data products are available. All impacts of products and services calculated using PSCS are stored in (public) databases under a Sustainability Quick Reference code (SQR-code). Impacts of individuals are stored under an identification code (ID-code), in databases that are kept private (under the control of the individual represented by the ISCS). Since PSCS calculations include the impacts of shipping to the store, the store itself and of its employees, seemingly same OPM products will have different impacts and different SQR-codes when sold at different store locations. In absence of SQR and ID-codes, products, services and salaries have to be given an alternative, easily assignable codes representing (initially broad) classes of similar products, services or salaries. The proposed classification system allows classification of products, services and salaries over classes, each represented by a classification quick reference code (CQR-code). Following this coding, impacts need to be estimated for an initial few hundred products and services and for income deciles within the first geographic area of

implementation (country, state), using Life Cycle Analysis (LCA) for products and services and "impacts-per-dollar-income" for salary impacts, processed using Rating Supply Chain Step (RSCS) calculations.
Life cycle analysis (LCA) calculations for an OPM product do not reflect the impacts for a specific product sold at a specific retailer at a specific date, as reflected by rated products, but at best reflects the average impacts for that type of product, sold in a specific geographic area while excluding all impacts contributed by employee labor. LCA calculations thus (at best) reflect the process impacts that are inputs to the PSCS. Ignoring the on average very small LBI inputs to ISCSs, the PSCS diagram can be redrawn to have process-only and labor-only inputs. In this diagram the "All Process" inputs reflect the sum of all LBIs, free of labor impacts, while the "All Labor" impacts reflect the impacts of consumer spending, free of LBIs. Products and services can thus be rated using LCA impacts and labor impacts (the latter on an impact-per-dollar basis for all income deciles used) as inputs, using the otherwise standard PSCS calculations.
Different methods with different uncertainties can be used to estimate impacts, where higher uncertainties lead to higher impact estimates. Higher impacts of participating products translate to higher cost of conservation paid by participating retailers. In order to create an incentive for participants to migrate to more accurate impact estimation methods, methods with smaller uncertainties need to result in lower estimated impacts and thus lower conservation costs. To that end, the impact for each variable is estimated as the sum of the average impact for a sample of a broad group of similar products, plus X times the sample standard deviation ($U_{EstimateUsed} = U_{Average} + X * U_{StandardDeviation}$). The initially broad classes used will result in large impact standard deviations. For transactions without CQR or ID-codes, default impacts are calculated on an impact-per-dollar basis, using the highest estimated impacts found for all products within the geographic area The same is done for services and salaries. The default impact values are thus in almost all cases higher than the impacts for products with CQR codes, while the lowest impact values result from PSCS and ISCS calculations. To lower their product impacts, producers will increasingly request product ratings for their products, leading to SQR codes and the most accurate impacts for their products sold. The SQR-codes will be converted to their corresponding CQR-codes and added to the CQR-impact database. With increasing numbers of impact data for broad products or services groups, groups can be divided in narrower groups, on average leading to more accurate average impacts and smaller standard deviations. Three methods are used to calculate the impacts of products, services and salaries; the Standard Method (SM), Estimation Method 1 (EM1), Estimation Method 2 (EM2) and the default Estimation Method 3 (EM3). While all four methods will be used throughout most of the implementation period, due to the non-availability of accurate input data, the methods will be used in reverse order (EM3 → EM2 → EM1 → SM).
The Standard Method (SM) uses the impact balance calculations over the ISCS and PSCS as indicated in figure 1, using LBI inputs and inputs mostly originating from ISCS and PSCS calculations (SQR-coded). Outputs for products, services and labor are also SQR-coded. Where SQR-coded inputs to the ISCS and PSCS are not available, CQR coded inputs can be used (EM2). For non-CQR non-SQR coded inputs to the ISCS and PSCS, the default impacts based on EM3 are used, leading to the highest impact estimates. When only SM based SQR codes are used for a product or service throughout its supply chain, the impacts resulting from using the SM are most accurate and the lowest of all methods available. On the other hand, when inputs to the ISCS and PSCS originate from EM2 with its high standard deviation impact contributions (or even worse for EM3 default calculated impacts), product and service impacts calculated using EM1 are likely more accurate and represent lower impacts.
Estimation Method 1 (EM1) is based on impact balance calculations over the ISCS and PSCS using figure 5, where the PSCS inputs are split into "All Process" and "All Labor inputs". The "All Process" inputs are calculated using LCA estimates, while the "All Labor inputs" are calculated using impact-per-dollar based impacts for the various salary deciles. The products and services are SQR-coded.
Estimation Method 2 (EM2) calculates the impacts of products and services using database values without looking at supply chain steps. These database values start with the LCA based impacts calculated for the initial 100 to 200 broad CQR classes. This database is then expanded with additional LCA based impact estimates as requested by organizations for selected products and services (EM1) and later by increasing numbers of SM based impact ratings. The estimated impacts are initially high due to the relatively large contribution of the standard deviation term. However, with increasing EM1 and SM based impact estimates, classes and standard deviations with become smaller, lowering the estimated impacts.
The default Estimation Method 3 (EM3) is used in cases where no CQR and no SQR coded inputs to ISCS and PSCS are available. In that case the default impacts for product are set to reflect the highest impacts per dollar value used for all products found in the geographic area. Similar but different default impact value are used for services. This also applies to participating end-user consumers buying non-CQR and non-SQR coded products. The high default impact creates a strong incentive for participating end-user consumers to buy CQR and SQR coded products and services and in turn creates a strong incentive for retailers to ask OPM producers to provide CQR and SQR

codes for their products and services. In addition to the customer demand for CQR and SQR coded products and services, the retailer saves money due to the lower conservation payments for participating products with typically lower impacts.
Prior to the availability of dynamic LBI data, landscape environmental impact codes (LEI-codes) can be used to describe and categorize landscapes and marine area types and assign impacts compared to their undisturbed ecoregions. For LEI-code determination, similar software could be used as proposed for CQR-codes. Similar to CQR-codes, the collection of LEI categories and codes will represent a pyramid with the LEI categories and code for "*any landscape type*" at the top, LEI categories and codes for the different ecoregions in middle layers and LEI codes and categories for the various descriptive levels of wildlife area degradation for each ecoregion listed on the lowest level. LEI-codes would be used in combination with CQR-codes using EM1. During the period where dynamic LBI are set up, LEI-codes updates might be available more frequently. LEI-codes could also be used to update LCA software. With an increasing number of ISCS and PSCS based impact rating for products and services and a more frequent update of LEI-codes and impacts, the use of CQR-codes for products and services and LEI-codes for LBI, would allow a gradual transition from LCA based impacts estimates for products and services to accurate calculated ISCS and PSCS impacts for products, services and persons.

7. References

1. Dert, V. (2024). DETERMINING AND/OR EVALUATING A SUSTAINABILITY OF A PRODUCT, A SERVICE, AN ORGANIZATION AND/OR A PERSON (Patent). Zenodo. https://doi.org/10.5281/zenodo.11205155
2. Dert, V. (2024). Impact Measurement and Application of Conservation (IMACS). Zenodo. 10.5281/zenodo.11206388.
3. Dert, V. (2024). Calculation of Individual Sustainable Absorption under IMACS. Zenodo. 10.5281/zenodo.11211510.
4. Dert, V. (2024). Calculation Of Excess Impact Deduction for Products and Services under IMACS. Zenodo. 10.5281/zenodo.11212346.
5. Dert, V. (2024). Providing Conservation as "Title-To-Conservation" under IMACS. Zenodo. 10.5281/zenodo.11212462
6. Dert, V. (2024). Calculation of Individual and Product Sustainability under IMACS. Zenodo. 10.5281/zenodo.11214090.
7. Dert, V. (2024). Remote Sensing of Environmental Impacts for IMACS. Zenodo. 110.5281/zenodo.11218121.
8. Camboim, S. P., Bravo, J. V. M., & Sluter, C. R. (2015). An Investigation into the Completeness of, and the Updates to, OpenStreetMap Data in a Heterogeneous Area in Brazil. *ISPRS International Journal of Geo-Information*, *4*(3), 1366-1388.
9. Omnicalculator. (n.d.). US Income Percentile Calculator. Retrieved November 16, 2023, from https://www.omnicalculator.com
10. Flood, S., King, M., Rodgers, R., Ruggles, S., & Warren, J. R. (2024). Integrated Public Use Microdata Series, Current Population Survey: Version 9.0. Minneapolis, MN: IPUMS. https://doi.org/10.18128/D030.V9.0
11. IEA (2023), The world's top 1% of emitters produce over 1000 times more CO2 than the bottom 1%, IEA, Paris https://www.iea.org/commentaries/the-world-s-top-1-of-emitters-produce-over-1000-times-more-co2-than-the-bottom-1, Licence: CC BY 4.0
12. Ilgin, M. A., & Gupta, S. M. (2010). Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art. *Journal of environmental management*, *91*(3), 563-591.
13. Egilmez, G., Gumus, S., Kucukvar, M., & Tatari, O. (2016). A fuzzy data envelopment analysis framework for dealing with uncertainty impacts of input–output life cycle assessment models on eco-efficiency assessment. *Journal of cleaner production*, *129*, 622-636.
14. European Commission. (2021, December 16). Recommendation on the use of Environmental Footprint methods. Directorate-General for Environment. Retrieved May 20, 2024, from https://environment.ec.europa.eu/publications/recommendation-use-environmental-footprint-methods_en
15. Degerli, B., Nazir, S., Sorgüven, E., Hitzmann, B., & Özilgen, M. (2015). Assessment of the energy and exergy efficiencies of farm to fork grain cultivation and bread making processes in Turkey and Germany. *Energy*, *93*, 421-434.
16. Dert, V. (2024). Labor and Product Impact Estimation. Zenodo. https://doi.org/10.5281/zenodo.11223930
17. Camboim, S. P., Bravo, J. V. M., & Sluter, C. R. (2015). An Investigation into the Completeness of, and the Updates to, OpenStreetMap Data in a Heterogeneous Area in Brazil. *ISPRS International Journal of Geo-Information*, *4*(3), 1366-1388.
18. Future revision note: Improve figure using subscripts (1, 2, N-1, and N) to indicate that the N "Rs" represent different RSCSs and that all N "Es" represent different ESCSs.
19. Future revision note: Since impacts for products and services are needed to calculate impacts of participating employees, it appears that the paper's "story-line" flows better when the "All Process Impacts" are discussed before the "All Labor Impacts" are addressed.