Title of the Paper: Calculation of Individual and Product Sustainability under IMACS

Author Names: Vincent Dert

Affiliations: Founder of Sustain One World – LLC

Abstract: The methods described allow calculation of individual and product sustainabilities and of human conditions for all products, services and individual labor, in a globally standardized way. Product and service sustainabilities reflect natural resource use, environmental damage done and harmful or inhumane labor and living conditions that existed, to make, transport and sell the product or service. Individual sustainability reflects the degree to which an individual lives sustainable and is determined by the impacts of resource use and damage done due to individual consumption and conservation applied. The methods allow the calculation of product, service and individual sustainabilities per impact variable, for any of a dozen variables distributed over eleven impact groups, for any combination of impacts variables, including the use of a single sustainability value combining all impact variables. The use of a single sustainability value that can be printed on or scanned from the QR code on labels of participating products, makes it easier for consumers to compare and select more sustainable products and services and allows customers to become more sustainable themselves. It will also drive competitors to improve product sustainability, reducing costs and make increasingly more sustainable products available to the public.

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): https://doi.org/10.5281/zenodo.11214091

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

Calculation of Individual and Product Sustainability under IMACS

1. Abstract

The methods described allow calculation of individual and product sustainabilities and of human conditions for all products, services and individual labor, in a globally standardized way. Product and service sustainabilities reflect natural resource use, environmental damage done and harmful or inhumane labor and living conditions that existed, to make, transport and sell the product or service. Individual sustainability reflects the degree to which an individual lives sustainable and is determined by the impacts of resource use and damage done due to individual consumption and conservation applied. The methods allow the calculation of product, service and individual sustainabilities per impact variable, for any of a dozen variables distributed over eleven impact groups, for any combination of impacts variables, including the use of a single sustainability value combining all impact variables. The use of a single sustainability value that can be printed on or scanned from the QR code on labels of participating products, makes it easier for consumers to compare and select more sustainable products and services and allows customers to become more sustainable themselves. It will also drive competitors to improve product sustainability, reducing costs and make increasingly more sustainable products available to the public.

2. Introduction

Methods were described *(17, 4)* to calculate impacts for ten environmental impacts groups and for human conditions for all global products and services using the universal IMAC system. This Impact Measurement and Conservation System (IMACS) calculates the environmental (E) and human condition (H) impacts of products and services sold and allows the application of the required amounts of environmental (E) conservation and human (H) condition conservation/rehabilitation for all purchases made and services provided. Unless specifically addressing E-impacts or H-impacts, "impacts" refer to both environmental and human condition impacts. Impacts include resource-use and damaging impacts as well conserving impacts. Unless specifically addressing E-conservation or H-conservation/rehabilitation, "conservation" refers to both. In order for consumers to easily compare products and services with respect to resources used and damages done, the various impacts need to be expressed as a small number of different types of sustainabilities or as a single sustainability value. No such systems currently exist. Impacts for individuals are calculated by adding all impacts originating from consumption, the location used and the labor provided by the individual, over the Individual Supply Chain Step (ISCS, see figure 1), after which the Individual Sustainable Absorption (ISA) is deducted *(8).* For products and services, location-based impacts, impacts originating from supplies, and impacts from employee labor, are added over the Product Supply Chain Step (PSCS, see figure 2), after which the Excess Impact Deductions (XID) is deducted to correct for a partial recycling of impacts through employee labor *(6).* Conservation can only be purchased by end-used consumer individuals, but is paid for by the sellers. All conservation applied is purchased at market prices. With the automatic purchase of the required conservation, immediately following the primary purchase, all resource use and damage is neutralized and the product or service is transformed to a sustainable product or service. Individual and product sustainabilities need to be calculated for resource use, current damage and all historic damage, as needed to return to pre-industrial environmental conditions.

3. Natural Resource Use and Protection

Some natural resources humans use, have a limited availability. *"Allowance variables*" reflect the use of natural resources for which an individual sustainable amount of the resource used, *"the allowance"* can be defined. Resource use is not sustainable without resource conservation. For allowance variables, a certain amount of resource use is sustainably available (the allowance) under conditions where sufficient resources are conserved. Unless sufficient conservation is applied to the use of a natural resource, the resource use is treated as resource damage or loss. The conservation applied needs to match the corresponding resource use variable type used. Separate sustainabilities are defined for the resource used (indicated with U for *use & damage*) and for conservation applied (indicated with C for *conservation*). The natural resource use sustainability and the natural resource conservation sustainability are combined in the compensated natural resource use sustainability.

Four natural resource types are identified for which per capita "allowances" can be calculated; cultivated land area use, cultivated marine area use, use of precipitation/watershed area (for fresh water use) and soil loss & damage. It is obvious that wildlife areas need to be protected to maintain their biodiversity. This also applies to protection of watershed areas, which need to be protected for the availability of fresh water to nature. It also applies to soils and sediments that need to be protected to maintain their amounts (soil and sediment depths), structure (the various layers) and the natural composition of their layers (natural component fractions and the absence of pollution) to continue the species assemblies living on and in them. For all four natural resource types, the ultimate objective for their protection is to maintain their biodiversity as expressed not only as the current species abundance, but also as the resilience against future environmental shocks.

To protect natural resources, an adequate fraction of each resource needs to be protected in each ecoregion *(1, 2, 3)*. An ecoregion is a large area of land or water that contains a geographically distinct assemblage of natural communities, that share a large majority of their species and ecological dynamics, share similar environmental conditions, and interact ecologically in ways that are critical for their long-term persistence (www.epa.gov/eco-research/ecoregions). The boundaries of an ecoregion approximate the original extent of the natural communities prior to any major recent disruptions or changes. Globally, the WWF has identified 867 terrestrial ecoregions, approximately 450 freshwater ecoregions and 232 marine areas, (see Ecoregion - Wikipedia).

In order to use a natural resource sustainably, a sufficient fraction of the resource needs to be conserved. The ratio R is defined *(4)* as the ratio of the amount of a renewable resource that can be used for cultivated purposes over the amount that needs to be conserved, such that no loss of biodiversity larger than the natural background rates would take place. Ratio R needs to be determined for wildlife area conservation (R_{Bio}), fresh water conservation (R_{Aqua}), and soil & sediment conservation ($R_{S\&S}$). Ratio R is unknown until determined by peer reviewed studies carried out for each ecoregion, for each stream, river and watershed and for each soil and sediment type. Prior to such determination, a lower value for R, the *presumptive standard*, is used. The *presumptive standard ratio* should be set sufficiently low, such that in almost all cases, the *presumptive standard ratio* rises to the value determined in peer reviewed studies for the ecoregion. For the general case, the presumptive standard ratio is defined as:

$$R_{Presumptive,j,k} = U_{A,j,k,SA} / P_{A,j,k,Required} \quad \text{or} \quad U_{A,j,k,SA} = P_{A,j,k,Required} * R_{Presumptive,j,k} \tag{1}$$

where $R_{Presumptive,j,k}$ = presumptive standard ratio for allowance variable j in ecoregion k [ ]
where $U_{A,j,k,SA}$ = sustainable available resource use for allowance variable j in ecoregion k [resource units]
where $P_{A,j,k,Required}$ = required conservation for allowance variable j in ecoregion k [resource units]
Subscript symbol use: A = allowance variable, j = variable used, k = ecoregion number, SA = sustainable available

The available resource $U_{A,j,k}$ is defined as only *sustainably* available if the required conservation $P_{A,j,k,Required}$ is applied. The values for the *presumptive standard ratio* R used will differ strongly for the different allowance variables and will need to be set per variable and per ecoregion by experts in each field. For terrestrial biodiversity protection, roughly half of each ecoregion needs to be protected to prevent biodiversity losses *(19)* and to reduce extinctions to the background rate *(10)*.
For marine areas, the need for protection differs greatly for shallow/near-shore areas and for deep ocean sections. To restock the oceans, to restore the natural (or at least pre-industrial) trophic level pyramid, and to reduce extinctions to the background rate, large sections of shallow and near shore marine waters need to be protected for their biodiversity. According to the Marine Conservation Institute, about 2.8% of the total ocean is protected with about

10% of territorial seas (0–12 nautical miles), 5% of Exclusive Economic Zones (EEZ) (12-200 nautical miles), and 0.14% of the High Seas (beyond 200 nautical miles) within marine protected areas. However, the actual amount of coverage by parks that have permanent protection is a little less, and the coverage of fully no-take areas and other strongly protected and well-enforced areas is even less still (marine-conservation.org). Scientists recommend to protect an area of 30 - 50% of all representative habitats in each biogeographic region *(13, 14, 15).* In order for marine protected areas to yield the desired biodiversity protecting benefits, at least four of five aspects need to be met; "no-take" areas to be located in good habitat locations, efficient enforcement, older (≥10 years), sufficiently large (≥100 km^2), and isolated by deeper water (> 25 m) or sand. The "no-take" areas need to be expanded both in number, size and geographic distribution, while protection enforcement needs to be improved *(11, 12).* Recent studies show that with policy reforms and technological innovation (mostly in more sustainable feed sources) the amount of edible food from the sea could be increased by 36 to 74% by 2050 (16).
Fresh water extractions need to be limited to about 10% of the daily flow in streams to minimize biodiversity losses *(4).* Soil and sediments are continuously formed but typically at very low rates. This means that the sustainable rates of soil and sediments loss are very low *(19).*

4. Individual Sustainability

4.1. General

With goods and services consumed and location-based impacts (LBIs) otherwise created, individuals and organizations have impacts on the environment (environmental damage) and on humans (create inhumane conditions) *(3, 5).* Impacts can be damaging or conserving. Any use of natural resources is by default damaging, unless the amount used is equal or less than the individual allowance, while sufficient protection of the natural resource is applied. As part of the IMAC system, the required conservation is purchased automatically as *title to conservation* (TTC) as a secondary purchase following each primary purchase *(6).*

Individual sustainability is calculated from the total of individual consumptions, i.e., the sum of all impacts form purchases made plus all LBIs created, as reflected by inputs to the individual supply chain step (ISCS). Note that labor hours worked and other human condition impacts of the individual representing the ISCS, that are inputs to the ISCS, are not individual consumptions. Variables representing resource use and damage are indicated as U_m, while variables representing resource use protection and restoration (conservation) are indicated as P_n . The labor hours worked and salary paid are indicated as respectively L and C. Variables U_m, P_n, L and C have units and are indicated using capitals. Hundred percent sustainable conditions for U_m, P_n and L are referred to as "reference" conditions, indicated as $U_{m,Ref}$, $P_{n,Ref}$ and L_{Ref} . The associated C_{Ref} does not reflect 100% sustainable conditions, but average income conditions. Variables can be normalized by dividing the variable value by its value under reference conditions (becoming unitless) and are indicated by small *Italic* letters: $u_m = U_m / U_{m,Ref}$, $p_n = P_n / P_{n,Ref}$, $l = L / L_{Ref}$ and $c = C / C_{Ref}$. The reference individual normalized consumption and labor impacts are shown in figure 3 *(3, 5).*
Reference individual normalized labor output impacts are represented by: $[l, u_m, p_n] | [c] = [1, 0, 0] | [1]$
for all types of impact variables. The reference individual normalized consumption impacts differ per variable type:

- for allowance parameters $[l, u_m, p_n] | [c] = [1, 1, 1] | [1]$
- for current damage variables $[l, u_m, p_n] | [c] = [1, 0, 0] | [1]$
- for historic damage variables $[l, u_m, p_n] | [c] = [1, 1, 1] | [1]$

Allowance variable impact values for $u_m > 1$ reflect non-sustainable conditions.
Current damage variable impact values for $u_m > 0$ reflect non-sustainable conditions.
Historic damage variables impact values for $p_n < 1$ reflects non-sustainable conditions.
Insufficient amounts of conservation applied ($p_n < u_m$) reflects non-sustainable conditions in all cases.
Values for normalized labor hour conditions (l) significantly larger than unity or normalized values for salary paid (c) much lower than unity, such that income C drops below the "local living wage", reflect slave, child and sweatshop labor conditions and thus reflect inhumane conditions.

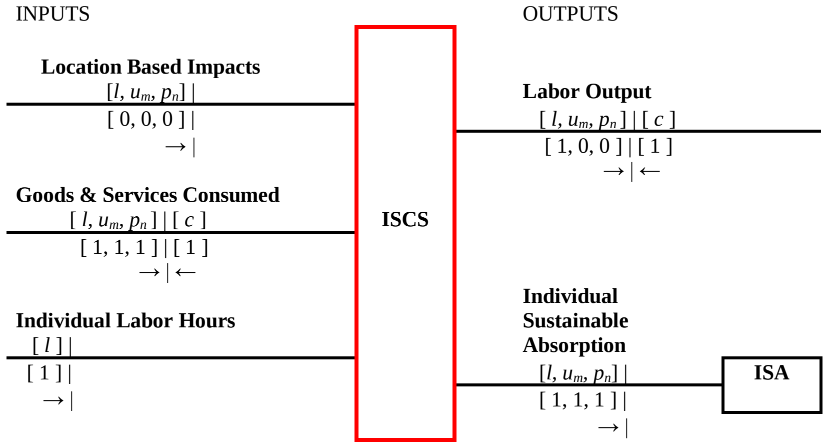

Figure 1: ISCS corresponding to normalized (= unitless) reference conditions for allowance and historic damage variables. Except for financial compensations paid, all impacts flow from left (resources) to right (end-users) through the figure. *l* = labor hours worked, u_m = resources used, p_n = conservation applied and *c* = salary paid and payments made. Under reference conditions, the resource use is equal to the allowance, conservation applied is equal to requirements, while resource use and conservation applied leave the supply chain as Individual Sustainable Absorption, rendering the labor output free of impacts *(7).*

On a global scale and without saving or borrowing money, the sum of payments made for goods and services purchased is equal to the income earned (C_{Global}) *(5).* The average individual income earned is equal to $C_{Average} = C / P$, where C and P can represent global of national incomes and population sizes. This also applies to a future society that is on average sustainable. In that case $C_{Average} = C_{Average,Ref}$ and $c = C_{Average} / C_{Average,Ref} = 1$. The normalized reference individual income $c_{Ref} = 1$ thus reflects the normalized average income of an on average 100% sustainable society. In developed countries the vast majority of the population with below average incomes lives well above the poverty threshold. That continues to be the case in an on average sustainable developed society. The "*Living Wage*" is a better criterion for humane income conditions, and is typically much higher than the poverty threshold income (for US data see: [Living Wage Calculator (mit.edu)](mit.edu)). A living wage provides income for eight basic needs – food, childcare, health care, housing, transportation, civic engagement, broadband, and other necessities. For developed countries $c_{LivingWage} = C_{LivingWage} / C_{Ref} < 1$. This is not the case for many developing countries, where the majority of the population can live below the poverty line and certainly below the living wage. In that case $c_{LivingWage} = C_{LivingWage} / C_{Average,Ref} > 1$. Reference conditions for individual earned income do not indicate a standard of living above the living wage and therefore do not indicate humane income conditions. Values for living wages vary globally strongly per country and even per state or province and for cities compared to villages in the same province. Humane conditions, even in their most basic form, include many variables in addition to labor hours worked and income earned. H-condition variables other than labor hours worked and income earned are represented by use and damage variable u_m , while job benefits not yet carried with the salary (pension plans, health and other insurance) and human recapitalization variables are carried by conservation variable p_n. A large number of human condition variable are identified. The calculation of the overall humane condition and their comparison against 100% humane conditions will be discussed in future publications.

4.2. Individual Resource Use Sustainability

The presumptive standard for R is likely set to a value around unity for land use, to a value smaller than unity for shallow and near shore marine areas, to about 10% for water flow in streams *(4),* and to a very small value ($R_{S\&S} << 1$) for loss of soils and sediments for each ecoregion. For each ecoregion, the sections with the highest biodiversity need to be protected for their biodiversity based on the ratio R_{Bio} , after which the remaining area is sustainably available for cultivated uses. The per capita allowance for resource j in ecoregion k can be calculated as:

$$U_{I,A,j,k,Ref} = U_{A,j,k,SA} / H_{Global} = P_{A,j,k,Required} * R_{Presumptive,j,k} / H_{Global} \quad (2)$$

where $U_{I,A,j,k,Ref}$	= per capita allowance for resource variable j in ecoregion k	[resource units]
where $U_{A,j,k,SA}$	= sustainable available amount for resource variable j in ecoregion k	[resource units]

where $P_{A,j,k,Required}$ = required conservation for allowance variable j in ecoregion k [resource units]
where $R_{Presumptive,j,k}$ = presumptive standard ratio for allowance variable j in ecoregion k [ ]
where H_{Global} = global adult population [p]
Subscript symbol use: I = individual, A = allowance variable, j = variable used, k = ecoregion number, SA = sustainable available

Without trade in products made in different ecoregions, natural resources in each ecoregion are used only by the local population. With trade, natural resources in all ecoregions can effectively be used by anyone living anywhere. The total per capita allowance for resource use j in all ecoregions, is equal to the sum of all per capita resource use allowances j over all ecoregions k:

$$U_{I,A,j,Ref} = \sum_{k=1}^{n} U_{I,A,j,k,Ref}$$

Amounts of individual resources used over the desired accounting period are added. The total actual resource use by individual i, for variable j in all ecoregions is equal to the sum of all resource use j over all ecoregions k by individual i:

$$U_{I,A,j,i} = \sum_{k=1}^{n} U_{I,A,j,i,k}$$

The individual resource use sustainability expresses the relative amount of renewable resource use j compared to the allowance over all ecoregions:

$$S_{I,A,U,i,j} = U_{I.A,j,Ref} / U_{I,A,i,j} \qquad (3a)$$

where $S_{I,A,U,i,j}$ = individual resource use sustainability for individual i for allowance variable j [ ]
where $U_{I,A,j,Ref}$ = per capita allowance for resource use variable j over all ecoregions [resource units]
where $U_{I,A,j,k,Ref}$ = per capita allowance for resource use variable j in ecoregion k [resource units]
where $U_{I,A,i,j}$ = resource use by individual i for variable j over all ecoregions [resource units]
where $U_{I,A,i,j,k}$ = resource use for variable j, by individual i, in ecoregion k [resource units]
Subscript symbol use: I = individual (type), A = allowance variable, j = variable used, k = ecoregion number, i = individual

For individuals, the resource units for cultivated and precipitation areas used and protected, are expressed in Ha, while soil loss is expressed in kg/year. Equation 4 can be normalized by dividing $U_{I.A,j,Ref}$ and $U_{I,A,i,j}$ by $U_{I.A,j,Ref}$. With $u_{I.A,j} = U_{I,A,i,j} / U_{I.A,j,Ref}$, this gives:

$$S_{I,A,U,i,j} = 1 / u_{I,A,i,j} \qquad (3b)$$

where $u_{I,A,i,j}$ = normalized resource use by individual i for variable j over all ecoregions [ ]

Individual Resource Conservation Sustainability

The individual resource conservation sustainability reflects the degree to which conservation is applied to natural resource use. For any resource used, resource use conservation must be applied within the same ecoregion to effectively protect each resource. The individual resource conservation sustainability for allowance variable j in ecoregion k is calculated as:

$$S_{I,A,P,i,j,k} = P_{I,A,i,j,k} / P_{I,A,j,k,Req} \qquad (4)$$

where $S_{I,A,P,i,j,k}$ = individual resource conservation sustainability, for individual i, variable j, in ecoregion k [ ]
where $P_{I,A,i,j,k}$ = individual conservation applied by individual i for allowance variable j in ecoregion k [ ]
where $P_{I,A,j,k,Required}$ = individual conservation required for allowance variable j in ecoregion k [ ]

The individual resource conservation sustainabilities for all ecoregions used can be combined using a weighted average where the resource use amount used is used as the weight. The weighted average is calculated as:

$$\overline{x} = \frac{\sum_{i=1}^{n} w_i \cdot x_i}{\sum_{i=1}^{n} w_i} = \frac{w_1 x_1 + w_2 x_2 + \ldots + w_n x_n}{w_1 + w_2 + \ldots + w_n} \qquad (5)$$

In this formula x_i represents the data values, while w_i represent the weights. The individual resource use conservation sustainabilities for all ecoregions used can be combined using a weighted average where the amount of resource used in each ecoregion is used as the weight.

$$S_{I,A,P,i,j} = \sum_{k=1}^{n} (U_{I,A,i,j.k} * S_{I,A,P,i,j,k}) / \sum_{k=1}^{n} U_{I,A,i,j,k} \quad (6)$$

where $S_{I,A,P,i,j.}$ = individual resource conservation sustainability for individual i , for variable j [ ]
where $U_{I,A,i,j,k}$ = resource use by individual i , for variable j, in ecoregion k [resource units]

Individual Compensated Resource Use Sustainability

The compensated resource use sustainability is the combination of resource use sustainability and resource conservation sustainability.

$$S_{I,A,Comp,i,j} = S_{I,A,U,i,j} * S_{I,A,P,i,j} \quad (7)$$

where $S_{I,A,Comp,i,j}$ = compensated individual resource use sustainability for individual i and allowance variable j [ ]

4.3. Individual Sustainability for Current Damage Variables

Elimination and Neutralization of Environmental Damage

No amount of environmental-humane damage is sustainable and any damaging impacts must be completely restored to meet individual sustainability requirements. Reference conditions reflect zero current damage.
Even when damage can be restored fairly easily (as is the case for carbon sequestration) restoration always costs money, typically requires large investments and it takes time to build restoration capacity and carry out the various environmental restorations in the amounts needed. In addition, any installed capacity intended for restoration of environmental damage done in the past (historic damage) is no longer available if already used to neutralize current damage. In addition, most types of environmental damage done, will increase the overall damage done, even after later full neutralization of primary damaging impacts, due to 2^{nd} and higher order effects. For example; every ton of CO_2 emitted that could have been prevented, will remain in the atmosphere for decades, will increase the peak global warming intensity, increase the duration of the global warming period and increase the total amount of heating of the earth, even after returning to pre-industrial atmospheric conditions. On top of that, restoration is sometimes impossible (when species became extinct) while restoration to historic sustainable conditions can require centuries (restoration of biodiverse wildlife areas). Every extra ton of CO_2 emitted, thus lengthens the period needed to cool Earth down to pre-industrial conditions and increases the exposure time to global warming conditions, and the associated additional biodiversity losses and additional human suffering and death. Damage prevention (and investments associated with damage prevention) are therefore always more sustainable than continuation of doing damage followed by restoration.

Individual Current Damage Sustainability (ICDS)

An individual lives 100% sustainable with respect to current damage when no damage is done and 0% sustainable when the damage done is equal or larger than the average per capita damage done over a representative recent period (e.g., last or recent decade). The representative damage is calculated as:

$$U_{I,CD,j,Rep} = U_{CD,j} / (Y * N_{Global}) \quad (8)$$

where $U_{I,CD,j,Rep}$ = annual per capita damage for current damage variable j relative to period Y [damage/y.p]
where $U_{CD,j}$ = global current damage for variable j over representative period Y [damage]
where Y = representative recent period over which the current damage is determined [y]

where N_{Global} = adult world population [p]
Subscript symbol use: I = individual, CD = current damage variable, j = variable used.

As long as environmental damage is not restored, the damage done typically has 2nd and higher order damage effects. This applies to greenhouse gas emissions, excessive fresh water use and loss and damage to wildlife areas or other biodiversity losses. For example, any required CO_2 sequestration not applied would cause additional global warming and all the types of damage currently associated with climate change like coastal flooding, loss of coastal lands, damage due to more frequent and more severe storms, more forest fires, increased crop failures, additional biodiversity losses and additional human suffering.
Once the relationships between the primary impacts and the 2nd and higher order effects can be estimated, each daily delay of application of conservation, can be expressed as an incremental impact of the original impact type. 2nd and higher order effect impacts can then be accrued daily, leading to increasingly larger additional individual damaging impacts and the corresponding larger amount of conservation required for its neutralization. The original plus accrued amounts of damaging impact can be calculated similar to the calculation of compounding interest on principal for outstanding financial loans. Initially, such 2nd and higher order effect will be ignored.

Amounts of individual current damage collected are added over the desired accounting period. To account for seasonally different current damage done (CO_2 emissions from heating and cooling), the default accounting period is set to one year, but values can be recalculated for monthly or weekly periods. The amounts added are the net amounts of damage remaining after application of conservation. Values for individual current damage can be expressed as normalized variables using the representative current damage:

$$u_{I,CD,j} = U_{I,CD,i,j} / U_{I,CD,j,Rep} \quad (9)$$

where $u_{I,CD,i,j}$ = normalized value for individual i for current damage variable j [ ]
where $U_{I,CD,j,Rep.}$ = annual per capita damage for current damage variable j [damage/y.p]
where $U_{I,CD,i,j}$ = annual value for individual i for current damage variable j [damage/y]

Under representative conditions, $U_{I,CD,i,j} = U_{I,CD,j,Rep}$ and $u_{I,CD,i,j} = u_{I,CD,j,Rep} = 1$. For accounting periods different than one year, the values for $U_{I,CD,j}$ and $U_{I,CD,j,Rep}$ are recalculated. To become sustainable, individuals must reduce their current damage from the representative value or higher ($u_{I,C,j} \geq 1$, 0% sustainable) to zero ($u_{I,C,j} = 0$, 100% sustainable). Preventing negative values, the individual sustainability for net current damage is formulated as:

$$S_{I,CD,i,j} = MAX(0 , 1 - u_{I,CD,i,j}) \quad (10)$$

where $S_{I,CD,i,j}$ = current damage sustainability for individual i for current damage variable j [ ]
where $u_{I,CD,i,j}$ = normalized current damage for variable j for individual i [ ]
Subscript symbol use: I = individual, CD = current damage variable, j = variable used.

Individual Current Damage Mitigation Sustainability

While prevention of current EH damage is always the best option, immediate restoration to original environmental conditions is the next best options. For restoration of current-damage the amount of restoration required is equal to the amount of damage done.

$$P_{I,CD,i,j,Required} = U_{I,CD,i,j} \quad (11)$$

where $P_{I,CD,i,j,Required}$ = restoration required by individual i to neutralize current damage for variable j [impact units]
where $U_{I,CD,i,j}$ = damage done by individual i for current damage variable j [impact units]

Under representative conditions, $P_{I,CD,i,j,Rep} = U_{I,CD,j,Rep}$. Equation (11) can be normalized by dividing by $P_{I,CD,j,Rep}$ and $U_{I,CD,j,Rep}$.

$$P_{I,CD,i,j,Required} / P_{I,CD,i,j,Rep} = U_{I,CD,i,j} / U_{I,CD,i,j,Rep} = p_{I,CD,i,j,Required} = u_{I,CD,i,j} \quad (12)$$

where $p_{I,CD,j,Required}$ = normalized restoration required by individual i to neutralize current damage for variable j [ ]

where $u_{I,C,j}$ = normalized damage done by individual i for current damage variable j [ ]
Subscript symbol use: I = individual, C = current damage variable, j = variable used.

The Individual Current Damage Mitigation Sustainability is defined as 100% if all damage is mitigated by restoration to original conditions and as 0% if no restoration took place at all.

$$S_{I,CD,P,j} = P_{I,CD,Y,j} / P_{I,CD,j,Required} = p_{I,CD,j} / p_{I,CD,j,Required} \quad (13)$$

where $S_{I,CD,P,j}$ = current damage mitigation sustainability for individual i for current damage variable j [ ]
where $P_{I,CD,j}$ = individual restoration applied by individual i for current damage variable j [impact units]
where $P_{I,C,j,Required}$ = restoration required by individual i to neutralize the current damage for variable j [impact units]
where $p_{I,CD,j}$ = normalized restoration applied by individual i to neutralize the current damage for variable j [ ]
where $p_{I,CD,j,Required}$ = normalized restoration required by individual i to neutralize the current damage for variable j [ ]
Subscript symbol use: I = individual, C = current damage variable, j = variable used.

Equation 12 applies to emission of greenhouse gasses and ozone depleting gasses since their atmospheric affects are independent of their location of release. This is not the case for damage or loss of wildlife area or extraction of fresh water or for soil and sediment loss & damage in excess of sustainable available amounts. In that case the restoration must be applied in the ecoregion k where the damage was done.

$$P_{I,CD,i,j,k,Required} = U_{I,CD,i,j,k} \quad (14)$$

where $P_{I,CD,i,j,k,Required}$ = restoration required by individual i for the current damage variable j in ecoregion k [impact units]
where $U_{I,CD,i,j,k}$ = damage done by individual i for current damage variable j in ecoregion k [impact units]

Individual resource conservation sustainability for allowance variable j must be is calculated per ecoregion:

$$S_{I,CD,P,i,j,k} = P_{I,CD,i,j,k} / P_{I,CD,i,j,k,Required} = p_{I,CD,i,j,k} / p_{I,CD,i,j,k,Required} \quad (15)$$

where $S_{I,CD,P,i,j,k}$ = current damage conservation sustainability for individual i for current damage variable j in ecoregion k [ ]
where $P_{I,CD,i,j,k}$ = conservation applied by individual i for allowance variable j in ecoregion k [resource units]
where $P_{I,CD,j,k,Required}$ = individual conservation required for allowance variable j in ecoregion k [resource units]

The individual current damage conservation sustainabilities for individual i , for current damage variable j, can be combined for all ecoregions, using a weighted average where the amount of current damage done in each ecoregion is used as the weight.

$$S_{I,CD,P,i,j.} = \sum_{k=1}^{n} (U_{I,CD,P,i,j.k} * S_{I,CD,P,i,j.k}) / \sum_{k=1}^{n} U_{I,CD,P,i,j,k} \quad (16)$$

where $S_{I,CD,P,i,j.}$ = individual current damage conservation sustainability for individual i for current damage variable j [ ]

Individual Compensated Current Damage Sustainability

The individual current damage sustainability and the individual current damage mitigation sustainability can be combined in the individual compensated current damage sustainability.

$$S_{I,CD,Comp,i,j} = S_{I,CD,U,i,j} * S_{I,CD,P,i,j} \quad (17)$$

where $S_{I,CD,Comp,i,j}$ = individual compensated current damage sustainability for individual i for current damage variable j [ ]
where $S_{I,C,U,i,j}$ = individual current damage sustainability for individual i for current damage variable j [ ]
where $S_{I,C,P,i,j}$ = individual current damage conservation sustainability for individual i for current damage variable j [ ]

4.4. Individual Sustainability for Historic Damage Variables

While the IMAC system includes human condition variables, the system is intended to be forward looking in order to improve environmental conditions for all species populations alive today. Inhumane conditions that existed in the past will not be included under historic damage. However, continuing inhumane conditions resulting from historic inhumane conditions, will be covered under "current" inhumane conditions.

Prior to (the future) date τ_0 , all environmental damage is collectivized and referred to as *historic damage*. The most important types of historic damage are biodiversity damage, atmospheric carbon dioxide emissions, loss of and damage to fresh water reservoirs (non-sustainable extraction and pollution), and loss of and damage to soil and sediments. Where possible, historic damage variables are combined into one variable per E-IMACS impact group.

Spending Based Method of Assigning Historic Damage Impacts

The simplest way to restore environmental damage done in the past is to assign an amount of such damage to products on a per dollar basis and then apply the required conservation to neutralize the historic damage done.
The damaging historic impact value for each variable is calculated by dividing the total historic accumulated damage for each historic damage variable j, by the global annual spending and by the estimated numbers of years needed to carry out the environmental restoration, and return to (the best approximation of) pre-industrial conditions (year 1750). For carbon sequestration, the period $Y_{Rest,C}$ is the period during which the carbon dioxide is removed from atmosphere and oceans and sequestered in amounts needed to reach slightly global cooling conditions. This period excludes the following global cooling period during which Earth temperatures gradually return to pre-industrial conditions and the global glaciers and ice caps are restored (centuries). For biodiversity restoration, the period $Y_{Rest,B}$ reflects the period needed to expand and protect terrestrial and marine wildlife areas, establish safe wildlife corridors, pre-plant areas with native vegetation and re-introduce native species, but excludes the period needed to fully re-establish the approximated pre-industrial biodiversity (centuries). For fresh water system restoration, the period $Y_{Rest,H2O}$ reflects the period needed to reduce water extraction from all rivers and streams to sustainable levels, to install desalination systems needed to support human needs and the additional needs of wildlife systems due to global warming, but excludes the period needed to fully re-establish the pre-industrial underground aquafers and water inventory of lakes, glaciers and ice caps (centuries).
In case enough restoration capacity is available ($f_{Avail,j} = 1$), restorations could take place at constant rates, and the amount of restoration to be applied annually per dollar product sales price can be calculated as:

$$P_{\$,H,j,Ref} = U_{\$,H,j,Ref} = f_{Avail.j} * U_{H,j,Global} / (Y_{Rest,j} * C_{Global}) \quad (18)$$

where $P_{\$,H,j,Ref}$	= annual required historic restoration for variable j per dollar spending	[IU/$]
where $U_{\$,H,j,Ref}$	= annual reference amount of historic damage for variable j per dollar assigned to spending	[IU/$]
where $U_{H,j,Global}$	= global historic damage for variable j	[IU]
where $f_{Avail.j}$	= conservation capacity fraction available for variable j for restoration in $Y_{Rest,j}$ years	[ ]
where C_{Global}	= Global annual spending	[$/y]
where $Y_{Rest,j}$	= period over which all historic damage is targeted to be restored for variable j	[y]

Subscript symbol use: I = individual, H = historic damage variable, j = damage and associated conservation variables used.

In reality, we start with essentially zero carbon sequestration capacity, a very small capacity to restore water flows and inventories and a sizable capacity of wildlife area conservation, that all need to be enhanced to allow selling of certificates of conservation *(7)* to the general public as "Title-To-Conservation" (TCC). In all cases, the required capacity to provide TTC starts at zero and needs to be grown rapidly, and the "conservation capacity fraction available" ($f_{Avail,j}$) will need to grow accordingly. The types of restoration needed to restore damage done in the past are the same as needed to restore damage currently still done; i.e. CO2 sequestration, biodiversity conservation, water conservation and soil & sediment conservation.
All types of current damage done need to be reduced to (essentially) zero as fast as possible, while the capacities to restore current and historic damage need to be ramped up as fast as possible. At some time, an inflection point is reached, where the (increasing) capacity to restore historic damage becomes larger than the (reducing) current damage done. Only after that inflection point is reached, a net reduction of environmental damage will start. Even at

the time of this writing (prior to IMACS implementation) a small fraction of the world population already lives in carbon neutral or negative homes and uses electric transportation powered by solar energy, while Finland's power production turned carbon neutral in May 2023. Soon after IMACS implementation, an increasing fraction of the world population will be able to buy low CO_2 emitting products and have very low to zero carbon footprints. In order to effectively allow these low carbon emitting individuals to use their per capita available capacity of carbon sequestration, historic damage needs to be assigned to products well before this carbon dioxide inflexion point is reached, possibly from the start.
The amounts of historic damage are enormous. For example; the historic CO_2 emissions, currently stored in atmosphere and oceans, are about 46 times larger than the 2022 CO_2 emissions *(9).* The carbon sequestration capacity required needs to be created ASAP. The same applies to different extents to all other types of conservation needed. Starting with a small initial capacity certified to sell conservation as Title-To-Conservation, the amounts of historic damage assigned to products need to be continuously increased by increasing factor $f_{Avail,j.}$, to make sure that the growing restoration capacity is used. It would be even better to set the amount of historic damage assigned at slightly higher levels than the restoration capacities, to allow the delivery of conservation on multi-year delivery contracts. This would create an apparent additional market demand and entice conservation organizations to grow their capacities as fast as possible.
The required conservation is equal to the historic damage assigned and collected with the products bought and is acquired with a secondary purchase immediately following the primary purchase, as is done for resource use conservation and to neutralize current damage. Since the historic damage per dollar spending is continuously (possibly daily) increased with increasing restoration capacity (using $f_{Avail.j}$), the sum of all historic damage needs to be calculated for all products and services purchased over the accounting period (year is default). All historic damages assigned to products and services over the accounting period are added. The same is done for all conservation applied to historic damage. The amount of restoration required to be 100% sustainable with respect to historic damage is equal to the amount of historic damage collected with products and services purchased.

$$P_{I,H,i,j,Required} = U_{I,H,i,j} = \sum_{p=1}^{N} U_{\$,H,i,j,p,Ref} * C_{p,i} \quad (19)$$

where $P_{I,H,i,j,Required}$ = conservation annually required by individual i to restore historic damage for variable j [IU]
where $U_{I,H,i,j}$ = historic damage assigned to individual i for variable j over annual accounting period [IU]
where $U_{\$,H,i,j,p,Ref}$ = reference historic damage per dollar spending at time of purchase of product p of N [IU/$]
where $C_{p,i}$ = price of product p, purchased by individual i [$]

The amount of historic damage to be restored varies with spending, while the amounts of conservation are made available on a per capita basis and are thus the same for all individual participants. The per individual available restoration is first applied to current damage for each type, after which the remainder is applied to historic damage of the same type. While for participants with no current damage, the entire available amount of restoration is applied to historic damage, nothing may be left available for application to historic damage for individuals with high current damage. The historic restoration sustainability for individual i for historic damage variable j is equal to the restoration purchased divided by the restoration required and can be normalized by dividing both by $P_{I,H,j,Ref}$, the conservation required by the reference individual to restore historic damage for variable j

$$S_{I,H,i,j} = P_{I,H,i,j} / P_{I,H,i,j,Required} = p_{I,H,i,j} / p_{I,H,i,j,Required} \quad (20)$$

where $S_{I,H,Comp,i,j}$ = historic restoration sustainability for individual i for historic damage variable j [ ]
where $P_{I,H,i,j}$ = conservation purchased by individual i to restore historic damage for variable j [IU]
where $P_{I,H,i,j,Required}$ = conservation required by individual i to restore historic damage for variable j [IU]
where $p_{I,H,i,j}$ = normalized conservation purchased by individual i to restore historic damage for variable j [ ]
where $p_{I,H,i,j,Required}$ = normalized conservation required by individual i to restore historic damage for variable j [ ]
Subscript symbol use: I = individual, H = historic damage variable, i is individual assigned, j = damage and associated conservation variables used, IU = impact units

The above applies to emission of greenhouse and ozone depleting gasses since their atmospheric affects are independent of their location of release. This is not the case for damage or loss of wildlife area or extraction of fresh water in excess of sustainable available amounts or for soil and sediments losses. In those cases, the restoration must be applied in the ecoregion (and at the very location) where the damage was done. Individual historic damage sustainability for allowance variable j must first be calculated per ecoregion:

$$S_{I,H,P,i,j,k} = P_{I,H,i,j,k} / P_{I,H,j,k,Required} = p_{I,H,i,j,k} / p_{I,H,j,k,Required} \quad (21)$$

where $S_{I,H,P,i,j,k}$ = historic damage conservation sustainability for individual i for current damage variable j in ecoregion k [ ]
where $P_{I,H,i,j,k}$ = conservation applied by individual i for historic damage variable j in ecoregion k [IU]
where $P_{I,H,i,j,k,Required}$ = individual conservation required for individual i for historic damage variable j in ecoregion k [IU]
where $p_{I,H,i,j,k}$ = normalized conservation applied by individual i for historic damage variable j in ecoregion k [ ]
where $p_{I,H,i,j,k,Required}$ = normalized conservation required for individual i for historic damage variable j in ecoregion k [ ]
Subscript symbol use: I = individual, H = historic damage variable, i is individual assigned, j = damage and associated conservation variables used, IU = impact units

The individual historic damage conservation sustainabilities for individual i, for historic damage variable j, in all ecoregions k, can be combined using a weighted average where the amounts of historic damage done in each ecoregion are used as weights:

$$S_{I,H,P,i,j.} = \sum_{k=1}^{n} (U_{I,H,P,i,j.k} * S_{I,H,P,i,j.k}) / \sum_{k=1}^{n} U_{I,H,P,i,j,k} \quad (22a)$$

Division of numerator and denominator by $U_{I,H,P,i,j,Ref}$ gives the normalized version :

$$S_{I,H,P,i,j.} = \sum_{k=1}^{n} (u_{I,H,P,i,j.k} * S_{I,H,P,i,j.k}) / \sum_{k=1}^{n} u_{I,H,P,i,j,k} \quad (22a)$$

where $S_{I,H,P,i,j.}$ = individual historic damage conservation sustainability for individual i for current damage variable j [ ]
where $U_{I,H,i,j,k}$ = damage done by individual i for historic damage variable j in ecoregion k [IU]
where $U_{I,H,i,j}$ = damage done by representative individual i for historic damage variable j in all ecoregions [IU]
where $u_{I,H,P,i,j.k}$ = normalized damage done by individual i for historic damage variable j in ecoregion k [ ]

5. Product Sustainability

5.1. Product Sustainability - Introduction

Product sustainability is determined by the impacts of the product or service as offered for sale and purchased by the buyer. Since conservation is purchased by the end-user-consumer in a secondary transaction, immediately following the primary transaction, the primary product is sold without conservation. Product sustainability can most easily be envisioned applied to an annual product portfolio as consumed by end-user-consumers. Since almost all products are assemblies of parts forming one product, the annual product portfolio can also be envisioned as an assembly forming a single product. This product portfolio would contain all products and services consumed annually by an individual as delivered by a retailer. In addition to groceries, these would include apartment rental, car lease, home mortgage services, repairs and maintenance, insurances, education, government services (as paid by taxes) and anything else an individual would need during a year. This annual product portfolio could be delivered and billed in multiple smaller amounts (monthly, weekly or even daily).
Reference conditions are defined as the 100% sustainable condition, where 100% sustainable individuals, buy a reference portfolio of goods and services (100% sustainable in resource use and without current damage), for which they buy the required conservation, transforming the reference portfolio of goods and services purchased to a 100% sustainable portfolio. Under reference conditions, a product portfolio purchased by a reference individual, would represent the reference amounts of natural resource use, while representing no current damage. Since the environmental restoration capacity will be initially zero and will be limited during the entire global environmental restoration period, the amount of historic damage assigned to products will be increased gradually. To facilitate the calculation of product sustainability, all types of natural resource use and current damage are expressed per unit sales price. The reference product portfolio is represented in normalized supply chain step diagram notation by:

A. $[l,u_m,p_n]$ | $[c]$ = [1,1,0] | [1] for allowance variables
B. $[l,u_m,p_n]$ | $[c]$ = [1,0,0] | [1] for current damage variables
C. $[l,u_m,p_n]$ | $[c]$ = [1,1,0] | [1] for historic damage variables

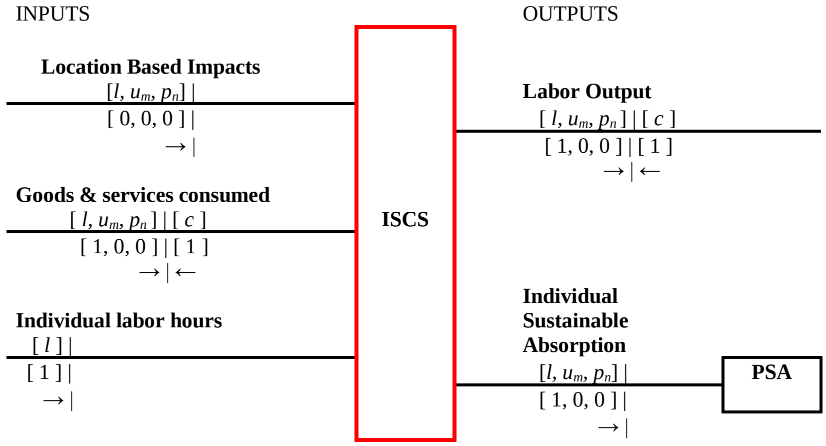

Figure 2: ISCS corresponding to normalized (= unitless) reference conditions for current damage variables. Except for financial compensations paid, all impacts flow from left (resources) to right (end-users) through the figure. l = labor hours worked, u_m = current damage done, p_n = conservation applied and c = salary paid. Any current damage done must be neutralized by an equal amount and matching type of conservation applied (limited to availability of conservation). Amounts of conservation applied matching the current damage done leave the supply chain as Individual Sustainable Absorption, rendering the labor output free of impacts.

For allowance variables, the normalized ratio of resource use over the price paid for the product portfolio is equal to unity (u_m / c =1) under reference conditions, but for natural resource use larger than reference conditions ($u_m \geq 1$), this ratio is larger than unity ($u_m / c \geq 1$). For current damage variables, the normalized ratio of damage done over the price paid is zero ($u_m / c = 0$) under reference conditions, but for any current damage done ($u_m \geq 0$), this ratio is larger than zero ($u_m / c \geq 0$). Both resource use and damage done per dollar spending differ per product or service purchased. This is not the case for historic damage, since historic damage is assigned to products and services on a per dollar sales price basis. For each incrementally increased amount of historic damage, the damage assigned per dollar value $U_{P,HD,j,p}$ is equal to its reference value $U_{P,HD,j,Ref}$ and thus $u_{P,HD,j,p} = U_{P,HD,j,p} / U_{P,HD,j,Ref} = 1$ for all assigned amounts of historic damage. Since the $u_{P,HD,j,p}$ does not differ (but is unity) for all products and services, product sustainability does not apply to historic damage impacts.
For each rated product or service, the resource use and current damage are calculated and provided with the product data sheet. For non-rated products and services, all resource use and current damage are estimated.

5.2. Product Sustainability for Allowance Variables

The resource use of the reference product portfolio, purchased by the reference individual, earning (and spending) the reference (= average) income, is used as the benchmark for product sustainability. The 100% benchmark for product resource use is calculated by dividing the global per capita sustainably available resource use for each allowance variable j by the global per capita income or by dividing the global sustainably available resource use for variable j by the global world income (GWI).

$$U_{P,A,\$,j,Ref} = A_G / I_G = (A_G / N_G) / (I_G / N_G) = A_{Ref} / C_{Ref} \quad (23)$$

where $U_{P,A,\$,j,Ref}$ = reference product resource use for variable j per dollar global spending [Resource-use.y /$]
where A_G = global sustainably available resource use for variable j [Resource-use]
where I_G = global world income (GWI) [$/y]
where A_{Ref} = global per capita sustainably available resource use for variable j [Resource-use/c]
where C_{Ref} = global per capita (= reference) income [$/y.c]
where N_G = global adult population [c]
Subscript symbol use: P = product, A = allowance variable, $ = per dollar spending, j = variable used.

For every rated product p, the resource use $U_{P,A,j,p}$ for each variable j is calculated from the impact balance over the product supply chain step. The resource use per dollar value is calculated by dividing the resource use $U_{P,A,j,p}$ by the price C_p of product p:

$$U_{P,A,\$,j,p} = U_{I,A,j,p} / C_p. \quad (24)$$

The resource use product sustainability is calculated as the ratio of the *reference* product resource use for variable j per dollar global spending and the *actual* product resource use for variable j per dollar global spending for product p:

$$S_{P,A,\$,j,p} = U_{P,A,\$,j,Ref} / U_{P,A,\$,j,p} \quad (25a)$$

$$\text{with } u_{P,A,\$,j,p} = U_{P,A,\$,j,p} / U_{P,A,\$,j,Ref} \rightarrow S_{P,A,\$,j,p} = 1 / u_{P,A,\$,j,p} \quad (25b)$$

where $S_{P,A,\$,j,p}$ = product resource use sustainability for variable j for product p [ ]
where $U_{P,A,\$,j,Ref}$ = reference product resource use for variable j per dollar global spending [Resource-use.y /$]
where $U_{P,A,\$,j,p}$ = product resource use for product p for variable j per dollar global spending [Resource-use.y /$]
where $u_{P,A,\$,j}$ = normalized product resource use for variable j per dollar global spending for product p [ ]

Looking at cultivated area (CA) use as an example, the globally per capita terrestrial surface area sustainably available for cultivation (A_{Ref}) is about 0.75 hectare per capita (0.75 Ha/c). Using 2020 data, the average global income was about 10,000 $/y.c. The reference product resource use for variable j per dollar global spending is thus:

$$U_{P,A,\$,CA,Ref} = A_{CA,Ref} / C_{Ref} = (0.75 \text{ Ha.y/y.c}) / (10{,}000 \text{ \$/y.c}) = 0.75 \text{ m}^2\text{.y/\$}$$

The reference individual spending of 10,000 $/y.c on (on average) reference products, thus has area of 0.75 m^2.y/$ * 10,000 $/y.c = 7500 m^2/c in continuous use. A product with a cultivated area use of 1 m^2.y and a price of 1 dollar thus has a cultivated area use per dollar global spending ($U_{P,A,\$,CA,p}$) of 1 m^2.y/$. With $u_{P,A,\$,CA,p} = U_{P,A,\$,CA,p} / U_{P,A,\$,CA,Ref}$ = 1/ 0.75 = 1.333, the product sustainability for cultivated area use is then:

$$S_{P,A,\$,j,p} = U_{P,A,\$,j,Ref} / U_{P,A,\$,j,p} = (0.75 \text{ m}^2\text{.y/\$}) / 1 \text{ m}^2\text{.y/\$} = 0.75 = 75\%$$

$$\text{Or,} \quad S_{P,A,\$,j,p} = 1 / u_{P,A,\$,j,p} = 1 / 1.333 = 0.75 = 75\%$$

Equations 23a and 23b can be used to compare products offered for sale expressed as a sustainability percentage. Comparing products, some products have a very high resource use (beef, lamb, butter and cheese), while some have no cultivated area or water use expressed in m^2.y/$. The latter is the case for services provided by sustainable individuals working by themselves, only selling their hourly services (consultants, handymen, home cleaners and servants). By living sustainable and working for their own single-worker-organization, their services provided are not weighted down by a larger non-sustainable organization.
For all rated products, the resource use $U_{P,A,\$,j,p}$ can be calculated and compared to the reference value $U_{P,A,\$,j,Ref}$. Force ranking all products from high to low resource use per dollar price, we find that:

- all products with a resource use $U_{P,A,\$,j,p} > U_{P,A,\$,j,Ref}$ or $u_{P,A,j,p} > 1$ are non-sustainable.
- all products with values for $U_{P,A,\$,j,p} \leq U_{P,A,\$,j,Ref}$ or $u_{P,A,j,p} \leq 1$ are sustainable

Even an on average 100% sustainable society will consume products with a very wide distribution of product sustainabilities, where the consumption of the non-sustainable fraction of products in the sustainable mix is only sustainable due to the high sustainability of the sustainable fraction of products consumed. Improvement of product sustainability for allowance variables has the largest effect, if the highest resource inputs to the PSCS are reduced.

5.3. Product Sustainability for Current Damage Variables

A product is 100% sustainable with respect to current damage when no damage is done and 0% sustainable when the current damage per dollar price is equal to the average over a representative recent period (i.e. recent decennium). Current damage larger than average remains at 0% sustainability.

$$U_{P,CD,\$,j,Repr} = U_{CD,j,Global,Period} / (Y_{Recent,j} * GWI) \quad (26)$$

where $U_{P,CD,\$,j,Repr}$ = representative annual value for current damage variable j for products & services [damage/$]
where $U_{CD,j,Global,Period}$ = value for global current damage for variable j over period $Y_{Recent,j}$ [damage]
where GWI = global world income [$/y]
where $Y_{Recent,j}$ = recent period over which the current damage for variable j is determined [y]
Subscript symbol use: P = product, CD = current damage variable, $ = per dollar spending, j = variable used.

For every rated product p, the current damage $U_{P,CD,j,p}$ for each variable j is calculated from the EH balance over the PSCS. The current damage per dollar value is calculated by dividing the current damage $U_{P,CD,j}$ by the price C_p of product p:

$$U_{P,CD,\$,j,p} = U_{I,CD,j,p} / C_p \tag{27}$$

The associated current damage variable j sustainability for product p is calculated as:

$$S_{P,CD,U,j,p} = MAX(0\ ,\ 1 - U_{P,CD,\$,j,p} / U_{P,CD,\$,j,Rep}\ ) = MAX(0\ ,\ 1 - u_{P,CD,\$,j,p}) \tag{28}$$

where $S_{P,CD,U,\$,j,p}$ = current damage sustainability for current damage variable j for product p [ ]
where $U_{P,CD,\$,j,p}$ = current damage attributed to product p for variable j [damage/$]
where $U_{P,CD,\$,j,Rep}$ = representative damage for current damage variable j [damage/$]
where $u_{P,CD,\$,j,p}$ = normalized damage attributed to product p for current damage variable j [ ]

6. Results and Discussion

For location specific environmental resource use, damage done and restoration applied, any local resource use and damage done needs to be neutralized by local conservation. This would apply to the about 1550 WWF defined ecoregions. However, since initially no Title-To-Conservation (TTC) is available, and will only become available gradually, the required matching granularity of "locations" needs to start "global" and become more granular is levels, until TTC is available for all 1550 WWF defined ecoregions. This mean that at first start conservation in any ecoregion will be accepted as "matching" for any natural resource use of damage in any other ecoregion.

While minimization of natural EH resource use and damage impacts and maximization of conservation impacts are important for all EH impact groups, there is a single EH impact group that trumps all other groups in importance: biodiversity protection. Life on Earth will become increasingly more difficult and ultimately impossible for an increasing fraction of species (including humans), unless all environmental variables in all impact groups are optimized to maximize the remaining biodiversity. The rates of biodiversity recovery versus permanent losses (extinctions) are the most important interim indicators for a successful outcome.
Environmental-humane sustainability values reflect an individual or a product with respect to sustainability and/or humane conditions for a single or for a combination of impact variables. Sustainability values are first calculated per metric impact variable and then combined per metric impact group.

Sustainability values can be calculated for the combined impacts for each of the ten environmental impact groups. In a similar fashion, human conditions can be calculated for the combined impacts of the human condition impact group. For products, services and individuals alike, impacts can be combined in and expressed as different "types" of sustainabilities (see table 1). Such averages can be calculated using weighted averages, geometric averages and exponential geometric averages or any combination of such averages. Alternatively, the impacts from all eleven impact groups can all be combined in a single sustainability value. The latter will be the most convenient option for sustainability indications ("labeling") on products, for services offered and to evaluate progress towards individual sustainability. However, based on the excessive use of natural resources and amounts of current damage done (especially in developed countries), both product and individual sustainability values will be very low, in many cases close to zero. The addition of a *relative product sustainability* value comparing sustainabilities for each product to "*best in similar class*" products would make the selection of more sustainable products much easier and stimulate both the marketing and selection of such "more sustainable" products.

Combined Sustainabilities	Products & Services	Individuals
A. Humane conditions or Humane condition sustainability	Reflects the human conditions under which a product was made	Reflects the human conditions of products and services consumed by the consumer

B.	Resource use sustainability	Reflects the degree to which resources were used sustainably	Reflects the degree to which resources were used sustainably
C.	Current damage sustainability	Reflects the degree to which current damage was done.	Reflects the degree to which current damage was done.
D.	Resource conservation sustainability		Reflects the degree to which resource protection was applied by the individual
E.	Current damage restoration sustainability		Reflects the degree to which restoration was applied to current damage by the individual
F.	Historic restoration sustainability		Reflects the degree to which restoration was applied to historic damage by the individual

Table 1: Six combined sustainabilities that can be calculated for products, services and individuals.

For weighted and exponential geometric averages, the weight factors and exponents for each of the variables are used to give appropriate weights to each variable, such that they best reflect the natural sustainability supporting dynamics and interactions between abiotic and biotic environmental systems. This would require multi-factorial modeling of the most important (if not all) environmental impacts and their effects on future global biodiversity and human conditions. In order to minimize extinctions and maximize the rate of biodiversity recovery, the model parameters need to be optimized, such that biodiversity losses at the end of the restoration period (ages) are minimized. The starting values for these model parameters are unlikely to be the optimum values, but are likely to give directional guidance. In turn, early optimized values are likely to change depending on the number of EIMACS groups and variables implemented, the relative sustainability improvement reached and the actual trajectory followed. Large amounts of carbon dioxide need to be removed to reach pre-industrial conditions, while (with increasing global warming) increasing amounts of fresh water need to be pumped to critical wildlife areas (and up mountains) to prevent habitat losses due to forest fires. In addition, large investments are needed to protect critical wildlife areas from marine flooding due to sea level rise. All three types of conservation require large investments (thousands of carbon sequestration facilities, water desalination plants and dike systems). Multi-factorial modeling of future conservation trajectories may be able to find the preferred spending ratios, at any given moment, for the various types of conservation to be applied, maximizing the biodiversity recovery, using the always limited funding available.

To facilitate an easy use and understanding by the general public, the calculated product, service and individual sustainabilities for each natural resource used can best reflect the inverse number of planets Earths that would be required. This mean that the sustainability for each natural resource variable is expressed as 1/E, where E represents the number of planets Earth needed to provide each natural resource, when no more resources are used than are sustainably available on each planet. In addition to expressing a sustainability number resulting from 1/E as a percentage, the actual number of "planets Earth" needed, could be used on packaging to simplify the message. A depiction of "10 planets Earth" would mean that the resource use per dollar spending would require "10 planets Earth" if all global spending would reflect the resource use of the product or service sold.

Combined sustainability values can be limited to the variables implemented or include variables not yet implemented. In the latter case, the same temporary estimated sustainability values for the non-implemented EH impact variables need to be used for all products, services and individuals. However, these estimated sustainability values can be different for different geographic areas.

While the "package of historic damage" has the same distribution of damages over all ecoregions for all, the "size of the package of historic damage" differs per individual based on the amount of spending. For current damage, the amount of damage collected differs based on the amount of spending and on the relative amount of current damage incurred with the products and services purchased. With conservation made accessible on a per capita basis, and all conservation automatically first applied to resource use and current damage done, the accessible amounts of conservation that remain available to apply against historic damage will vary widely per individual consumer.

Due to the high resource use and damage done for currently available products and services, all sustainability values will initially be very low and hard to improve quickly. Prevention of all types of current damage is initially more important than reduction of resource use, since it is so difficult, time consuming and often costly to restore damage done. While protected wildlife areas represent about 35% of all terrestrial areas, a much smaller fraction (20% or less, *(19)* are mature wildlife areas, protected for their biodiversity, with no or negligible damage. The fraction of first growth biodiverse wildlife areas is even smaller *(19).* If these mature wildlife areas would disappear or be severely damaged at a relative rate of 1% per year, all mature wildlife areas would be lost in 100 years. Even a loss of 0.1 % per year would result in a 10% loss over 100 years. While losses cannot be reduced to zero immediately, they should be reduced to well below 1% per year (say 0.01% per year) ASAP. (See figure 3). Reducing current damage, as reflected by the "Current Damage Sustainability", is therefore critically important. Since such loss of mature wildlife areas is caused by lack of effective protection, wildlife area protection tops the list of environmental actions to be taken. This is followed in importance by the building the capacity to sequester carbon dioxide from the atmosphere, produce fresh water using reverse osmosis and to build dike systems to prevent lands from flooding, especially highly biodiverse wildlife areas). These would all be reflected by their respective "Current Damage Restoration Sustainabilities". Since the world's poor are expected to bear the brunt of damaging effects of climate change and biodiversity losses, these actions would also minimize inhumane conditions.

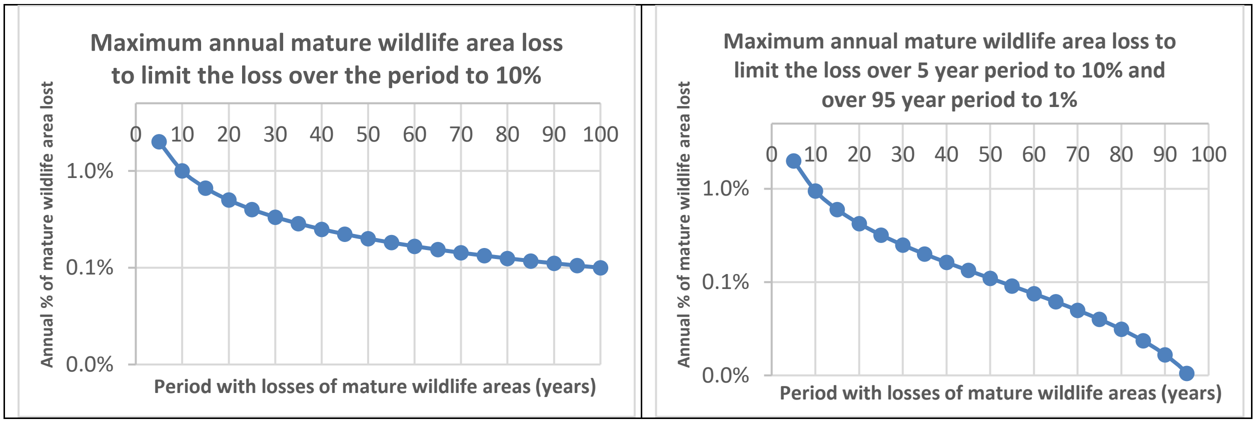

Figure 3: The maximum annual loss of mature wildlife area to limit the loss over the period to 10% (left) and (right) to 10% for the first 5-year period, gradually dropping to 1% over the 95-year period.

While all impact and sustainability values for products and services would be listed in publicly available (internet accessible) product and service data sheets, a much more limited amount of sustainability information would be printed on product packaging to facilitate comparing similar products during shopping and would be standardized world-wide at any given time.
Once made available with the weight factors and exponents optimized to maintain the highest biodiversity, the overall formulas for individual and product sustainability, can be used by all organizations to evaluate the most sustainable path forward. It would allow optimization in timing and amounts of investments between different sustainable objectives (minimizing cultivated area use of buildings by using more floors, versus changes to carbon neutral systems or minimization of water use and erosion). Since higher sustainabilities are associated with lower costs, such overall formulas also allow calculation of the lowest cost path to the most sustainable future of organizations and societies. In addition, product and individual sustainabilities are likely used as a future basis of taxation ("sustainability-based taxation"). The calculation of the overall humane condition and their comparison against 100% humane conditions will be discussed in future publications.

7. References

1. Omernik, J. M., & Griffith, G. E. (2014). Ecoregions of the conterminous United States: evolution of a hierarchical spatial framework. *Environmental management*, *54*, 1249-1266.
2. Bailey, R. G. (1998). Ecoregions. *New York*.
3. Olson, D. M. & E. Dinerstein (1998). The Global 200: A representation approach to conserving the Earth's most biologically valuable ecoregions. *Conservation Biol.* 12:502–515.
4. Dert, V. (2024). Impact Measurement and Application of Conservation System (IMACS). Zenodo. https://doi.org/10.5281/zenodo.11206389
5. Richter, B. D., Davis, M. M., Apse, C., & Konrad, C. (2012). A presumptive standard for environmental flow protection. *River Research and Applications*, *28*(8), 1312-1321.
6. Dert, V. (2024). Calculation Of Excess Impact Deduction for Products and Services under IMACS. Zenodo. https://doi.org/10.5281/zenodo.11212347
7. Dert, V. (2024). Providing Conservation as "Title-To-Conservation" under IMACS. Zenodo. https://doi.org/10.5281/zenodo.11212463

8. Dert, V. (2024). Calculation of Individual Sustainable Absorption under IMACS. Zenodo. https://doi.org/10.5281/zenodo.11211511
9. Friedlingstein, P., O'sullivan, M., Jones, M. W., Andrew, R. M., Gregor, L., Hauck, J., ... & Zheng, B. (2022). Global carbon budget 2022. *Earth System Science Data Discussions*, *2022*, 1-159.
10. De Vos, J. M., Joppa, L. N., Gittleman, J. L., Stephens, P. R., & Pimm, S. L. (2015). Estimating the normal background rate of species extinction. *Conservation biology*, *29*(2), 452-462.
11. Edgar, G. J. (2011). Does the global network of marine protected areas provide an adequate safety net for marine biodiversity? *Aquatic conservation: marine and freshwater ecosystems*, *21*(4), 313-316. (Including Journal Contribution posted on 2023-05-21)
12. Edgar, G. J., Stuart-Smith, R. D., Willis, T. J., Kininmonth, S., Baker, S. C., Banks, S., ... & Thomson, R. J. (2014). Global conservation outcomes depend on marine protected areas with five key features. *Nature*, *506*(7487), 216-220.
13. Airamé, S., Dugan, J. E., Lafferty, K. D., Leslie, H., McArdle, D. A., & Warner, R. R. (2003). Applying ecological criteria to marine reserve design: a case study from the California Channel Islands. *Ecological applications*, *13*(sp1), 170-184.
14. Roberts, C. M., Andelman, S., Branch, G., Bustamante, R. H., Carlos Castilla, J., Dugan, J., ... & Warner, R. R. (2003). Ecological criteria for evaluating candidate sites for marine reserves. *Ecological applications*, *13*(sp1), 199-214.
15. Jefferson, T., Costello, M. J., Zhao, Q., & Lundquist, C. J. (2021). Conserving threatened marine species and biodiversity requires 40% ocean protection. *Biological Conservation*, *264*, 109368.
16. Costello, C., Cao, L., Gelcich, S., Cisneros-Mata, M. Á., Free, C. M., Froehlich, H. E., ... & Lubchenco, J. (2020). The future of food from the sea. *Nature*, *588*(7836), 95-100.
17. 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
18. Note for future revisions: Initially I defined the ratio $R_{Bio} = A_{WA} / A_{CA}$, the minimum required ratio of wildlife area within each ecoregion to be protected for its biodiversity over the total area. In my later papers I used the inverse ratio to make the formulas looking a bit less complex. This definition should be standardized across all papers. It would probably be best to the use R_{Bio} as defined above and use $R_{CA} = 1/R_{Bio}$ where this would make formulas look simpler.
19. Note for future revisions: List references