Title of the Paper: The Impact Measurement and Application of Conservation System (IMACS): A Review of a Framework for Impact Measurement, Application of Conservation and a Return to Sustainable Conditions

Author Names: Vincent Dert

Affiliations: Founder of Sustain One World – LLC

Abstract: The Impact Measurement and Application of Conservation System (IMACS) was recently described in ten preprint papers. IMACS represents the first "first principals" based system for measurement of damaging and conserving impacts and the calculation of sustainabilities for products, services and individuals. IMACS distinguishes "participating" and "non-participating" individuals, organizations and their products and services. IMACS automatically assigns damaging impacts to individuals, products and services. Under IMACS, each generator of impacts "owns" their impacts, while impacts are transferred with products sold or distributed. For the fully implemented and participating world, all impacts will be determined accurately using a combination of (mostly) remote sensing and (increasingly less) ground/sea level-based verification and straightforward calculations. For the initial application, all impacts will be estimated using a statistical approach, where products, services and individuals with higher impact uncertainty are assigned higher impacts. Participating organizations can select lower cost estimation methods leading to higher estimated impacts and vice versa. Under IMACS, each event creating additional impacts, represents an additional supply chain step. This makes it easy to follow each product throughout the supply chain until it's purchase by the end-user consumer. Due to the level of automation used, the impact estimation/determination can be done at very low costs, much lower than using life cycle assessment (LCA) or input-output analysis methods. Resource using, damaging, protecting and restoring impacts are distributed over eleven impact groups. Conservation is made available by for-profit and non-profit organizations and distributed by IMACS licensed organizations as "Title-to-Conservation" (TTC). Neutralizing amounts of conservation are applied to participating products and services purchased by participating consumers. Due to the shortage of conservation as TTC, initially none to very little TTC can be applied, leading to initially very low retailer or supply chain costs expressed as percentage of sales. However, the sale of TTC at market prices will allow the exponential growth of the conservation industry and create strong incentives for reduction of resource using and elimination of damaging impacts throughout the supply chain. Increasing consumer demand for products "free of impacts" (after impact neutralization through application of TTC) will force supply chain participation, creating a "new normal" where the supply chain pays for the costs of conservation. Using this approach and a twenty-year transition period to full societal participation, return to pre-industrial atmospheric conditions can be achieved in 40 – 60 years, greatly limiting damage from climate change, while saving costs. The same applies to all impact groups, greatly limiting environmental damage, biodiversity loss and reducing human suffering and premature deaths. A review of marketing studies indicates that the model assumptions used for societal participation are conservative. The use of certified and licensed for profit businesses for most tasks within IMACS allows a rapid global roll-out and scale-up of IMACS functionality. The system has the potential to create very large amounts of funding for conservation, and potentially allows a relative fast return to pre-industrial environmental conditions, while improving human conditions and saving costs. By participating in IMACS, individuals and organizations can eliminate current CO_2 emissions, neutralize historic CO_2 emissions, provide adequate fresh water for ecosystems, protect wildlife areas and their biodiversity, save money and improve their competitive position. IMACS, by assigning the costs of conservation (protection and restoration) to individuals and organizations responsible for the damage done, can effectively address and solve the classic *"tragedy of the commons"*.

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

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Corresponding Author:
Name: Vincent Dert
Email: leedert@gmail.com
Twitter account: @vincentdert1

The Impact Measurement and Application of Conservation System (IMACS): A Review of a Framework for Impact Measurement, Application of Conservation and a Return to Sustainable Conditions

1. Abstract

The Impact Measurement and Application of Conservation System (IMACS) was recently described in ten preprint papers. IMACS represents the first "first principals" based system for measurement of damaging and conserving impacts and the calculation of sustainabilities for products, services and individuals. IMACS distinguishes "participating" and "non-participating" individuals, organizations and their products and services. IMACS automatically assigns damaging impacts to individuals, products and services. Under IMACS, each generator of impacts "owns" their impacts, while impacts are transferred with products sold or distributed. For the fully implemented and participating world, all impacts will be determined accurately using a combination of (mostly) remote sensing and (increasingly less) ground/sea level-based verification and straightforward calculations. For the initial application, all impacts will be estimated using a statistical approach, where products, services and individuals with higher impact uncertainty are assigned higher impacts. Participating organizations can select lower cost estimation methods leading to higher estimated impacts and vice versa. Under IMACS, each event creating additional impacts, represents an additional supply chain step. This makes it easy to follow each product throughout the supply chain until it's purchase by the end-user consumer. Due to the level of automation used, the impact estimation/determination can be done at very low costs, much lower than using life cycle assessment (LCA) or input-output analysis methods. Resource using, damaging, protecting and restoring impacts are distributed over eleven impact groups. Conservation is made available by for-profit and non-profit organizations and distributed by IMACS licensed organizations as "Title-to-Conservation" (TTC). Neutralizing amounts of conservation are applied to participating products and services purchased by participating consumers. Due to the shortage of conservation as TTC, initially none to very little TTC can be applied, leading to initially very low retailer or supply chain costs expressed as percentage of sales. However, the sale of TTC at market prices will allow the exponential growth of the conservation industry and create strong incentives for reduction of resource using and elimination of damaging impacts throughout the supply chain. Increasing consumer demand for products "free of impacts" (after impact neutralization through application of TTC) will force supply chain participation, creating a "new normal" where the supply chain pays for the costs of conservation. Using this approach and a twenty-year transition period to full societal participation, return to pre-industrial atmospheric conditions can be achieved in 40 – 60 years, greatly limiting damage from climate change, while saving costs. The same applies to all impact groups, greatly limiting environmental damage, biodiversity loss and reducing human suffering and premature deaths. A review of marketing studies indicates that the model assumptions used for societal participation are conservative. The use of certified and licensed for profit businesses for most tasks within IMACS allows a rapid global roll-out and scale-up of IMACS functionality. The system has the potential to create very large amounts of funding for conservation, and potentially allows a relative fast return to pre-industrial environmental conditions, while improving human conditions and saving costs. By participating in IMACS, individuals and organizations can eliminate current CO_2 emissions, neutralize historic CO_2 emissions, provide adequate fresh water for ecosystems, protect wildlife areas and their biodiversity, save money and improve their competitive position. IMACS, by assigning the costs of conservation (protection and restoration) to individuals and organizations responsible for the damage done, can effectively address and solve the classic *"tragedy of the commons"*.

2. Introduction

The sustainable production and use of goods and services is increasingly important in order to return to sustainable global conditions. A growing world population and a reduction of poverty lead to a growing demand for products, services and living space. This increases the land and marine areas in cultivated use ("cultivated areas") leading to habitat fragmentation and reduction while increasing pressure on protected wildlife areas and the biodiversity these represent. The current rate of species extinction is far above the background extinction rates *(25, 26, 27).* Climate change will make habitats areas less or unsuitable for their current species assemblies further increasing extinction rates and may pushed ecosystems past tipping points from which no return is possible *(2).* A large number of methods are published and/or used for sustainability measurement of organizations *(3).* Such reporting is retrospective and typically annually. These systems are not designed for sustainability measurement of goods, services or individuals. Different products and services require different inputs of materials, energy and employee labor. For each of these inputs, the environmental and human impacts vary and will change over time. Ultimately all products and services are consumed by end-user consumers. In order to become (more) sustainable, end-user consumers must be able to select (increasingly more) sustainable products and services *(4).* For products and services, two sustainability measurement systems were developed over the last decades: Product Lifecycle Assessment (P-LCA) *(5)* and environmentally extended input-output life-cycle assessment (EEIO-LCA) *(6).* LCA is widely applied to building products. The limited number of E-impacts currently used could be expanded and it could be applied to all products *(7).* However, LCA methods use historic E-impact averages for their inputs and do not reflect EH-impact differences in supply routes and distribution. With the transitioning to carbon neutrality and prevention of other negative Impacts, LCA methods cannot quickly catch improvements made along the supply chain. Calculation of EH-impacts using classic LCA for all products for all brands sold would also represent significant costs. In addition, LCA methods exclude human condition (H) impacts, ignore EH-impacts of the labor used, and do not assign costs to damaging EH-impacts, providing little incentive for improvement. This paper describes a system for the calculation of environmental (E) and human condition (H) impacts and sustainabilities for all products, services and individuals as a set of universally standardized methods, earlier published as a patent application *(1).* Prior to this patent publication, no universal method existed capable to measure EH impacts and EH sustainabilities, for all products, services and individuals, in a universally standardized way, in real time and low costs along their paths along the supply chain while applying conservation.

3. Summary of Each Work

3.1. Supply Chain Step Calculations

The first three papers describe the supply chain step (SCS) calculations needed to calculate the impacts of products, services and individuals. The 1st paper *(8),* introduces the concepts of individual reference conditions (100% sustainable individual conditions), product portfolio reference conditions (the annual product portfolio consumed by reference individuals) and impact normalization. The 1st paper gives an overview of the impact calculations for the individual supply chain step (ISCS, one for each individual), and process supply chain steps (PSCS for products and services provided). Four types of impacts variables are defined; allowance, current damage, historic damage and conservation variables. Allowance variables are impact variables for which an individual allowance exists. This applies to the use of cultivated areas (all land and marine areas in cultivated use). For land use the individual allowance is calculated by dividing the sustainable available fraction of each ecoregion (expressed as an area) by the global population. The sustainable available fraction is the fraction of the ecoregion that can be used for cultivated purposes (based on ecological studies) while protecting the rest for its biodiversity such that no further biodiversity loss takes place. These fractions need to be determined for all ecoregions, prior to which a default value of 50% is used. The 2nd allowance variable is fresh water consumption; all fresh water evapotranspired, evaporated or diverted from its natural flow through the watershed and drained to a salt sink. This excludes fresh water pumped to sea to prevent flooding of low-lying lands. Water consumption is expressed as the precipitation area used for each section of a watershed. This means that the consumption of 1 liter of water withdrawn in a region with little rain and high evaporation (e.g. the Sahel region) would represent a much higher precipitation area than one liter water consumed and withdrawn from low lying lands with high precipitation (e.g. polders in the Netherlands) and where fresh water needs to be pumped to sea to prevent flooding. The 3rd allowance variable is soil consumption; the amount of soil and sediments that can be sustainably "consumed" (lost to other than the original area) by an individual's consumption. In order to be sustainable, all resource use must be neutralized by area protection corresponding with the requirements for each of the ecoregions where resources are used, while all current damage done should be zero or neutralized by the application of required amounts of restoration. All types of current damage must be reduced to zero (no allowances exist), while historic damage is added on a per dollar cost price basis to products and services sold, once the restoration capacity exceeds current damage done. This applies to individuals, products and services. The 2nd paper *(9)* describes the individual sustainable absorption (ISA); the amounts of impacts that were used and were sustainable available and need to be removed from the individual supply chain step (ISCS). The remaining impacts are carried with the individual labor output and transferred to the employer (or payer of income). The 3rd paper *(10)* describes the excess impact reduction (XID); the impact amounts that need to be deducted under non-sustainable conditions to prevent double counting of impacts otherwise leading to supply chain accumulation of impacts.

Acronym	Description	Acronym	Description
ASHP, HP	Air source heat pump, heat pump	LCOE	levelized costs of energy
CQR code	Classification Quick Reference code	LCA	Live Cycle Assessment
DACCS	Direct Air Capture and CO_2 Sequestration	OPM	Original product manufacturer
E	Environmental (impacts) or electronic (vouchers) or electric (cars)	P-LCA	Product Life Cycle Assessment (for products and services)
EEIO-LCA	Environmentally extended input-output life-cycle assessment	PSCS	Product supply chain step (SCS for products and services)
ECO	Environmental Conservation Organization	PV	Photo voltaic
GDP	Gross domestic product	QR	Quick reference
GSHP	Ground source heat pump	RE	Renewable energy
H	Human (for impacts)	SCS	Supply chain step
IRO	Impact Rating Organization	SMO	Sustainability maintenance organizations
ISA	Individual sustainable absorption	TTC	Title to conservation
ISCS	Individual supply chain step (SCS for individuals)	XID	Excess impact deduction
LBI	Location based impacts		

Table 1: Acronyms used in this paper.

3.2. Providing Conservation as "Title-to-Conservation (TTC)

The 4th paper *(11)* describes the methods to provide conservation (protection and restoration) to products and services purchased. In order to allow the sustainable use of resources, a sufficient fraction of the resource must be protected. This fraction differs per ecoregion. For damage done, sufficient restoration must be applied to neutralize the damage done. The various types of conservation are provided by Environmental Conservation Organizations (ECOs) like wildlife protection/restoration organizations, carbon sequestration organizations, precipitation area protection organizations and coastal flooding area protection organizations. The conservation provided is sold daily in bulk by each ECO to sustainability maintenance organizations (SMOs), who make the conservation available as TTC in small fractional amounts to end user consumers. Since the consumer receives the resource use and damage done with each product bought, the TTC is purchased in name of the consumer, but paid by the retailer using electronic (E) vouchers. Within the supply chain, participating suppliers need to forward such (E) vouchers to their buyers until they reach the retailers. Ultimately, everybody thus only pays conservation costs for his own resources used and damages done. ECOs need to be certified, licensed and bonded (have a liability fund) to provide a financial guarantee such that losses can be restored after they occur (damage to or loss of wildlife area, CO_2 leaked from storage facilities, flooding of dike protected areas). For wildlife areas, initially most of the receipts paid to the ECO are withheld and stored in the associated liability fund, until the fund is sufficiently large to cover all future losses. While wildlife protection organizations exist and commercial (> 1 million-ton CO_2 per year) carbon sequestration facilities are currently under construction, currently no certified, licensed and bonded ECOs exist. Conservation capacity of all types will be in short supply throughout the global restoration period.

3.3. Calculation of Sustainabilities

The 5th paper *(12)* describes the methods used to calculate individual, product and service 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 few 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.

3.4. Remote Sensing of Environmental Impacts

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 are distributed in a dynamic fashion over the products made and services rendered using these areas. The 6th paper *(13)* focuses on remote sensing instrument systems used to accurately measure the underlying variables needed for parcel and designated area delineation and for 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, emission of materials causing atmospheric ozone layer damage and include all applicable types of conserving impacts, including wildlife area conservation, carbon storage and protection of coastal areas from flooding due to sea level rise. Using currently available remote sensing technology and after training using ground data, area mapping, parcel delineation and the measurement of most environmental impact variables can be done using satellites, by using aerial sensors or by using combinations. Implementation of IMACS requires the development of data products that combine remote sensing based environmental data with civic databases (users of parcel and designated areas), allowing easy, automated and low-cost extraction of LBI data.

3.5. Impact Estimation and Product Classification

The data products needed to measure LBIs for all areas needed using remote sensing are initially not available. LBIs are distributed in a dynamic fashion over the products made and services rendered using these areas. The 7th paper *(14)* focuses on the use of methods to estimate impacts of the underlying variables needed for parcel delineation and the environmental impacts (LBIs) taking place on them. 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, release of substances leading to 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 (LBIs). The use of such classification methods would allow a gradual transition from static and more crudely estimated impacts for products, services (using LCA) and personal labor (using statistical analysis) to more accurately calculated dynamic impacts at higher levels of participation and is expected to significantly shorten the transition period to sustainable conditions. Accurate impact determination for products costs more money than a rough estimate. Supply chain partners would benefit more from accurate determination of impacts of the already most sustainable products they sell. For example; before we spend time on PSCS calculations for a product sold by a retailer of which nothing is known (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 (no impacts are determined based on the production process used). 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.). To create this CQR code, the most relevant information should be “selectable” in the software used, like country of manufacturing, net product weight (for foods), gross weight and sizes (for shipping purposes), etc. This could be expanded to ten or more selection rows, with each multiple section options. Visually (when printed on paper) the selectable options would resemble a pyramid with “impact source” at the top and the actual product, service or salary selection to be made somewhere at the bottom row. The system can start with LCA based database values and no more than a few hundred additional LCA determinations for impacts of products and services to fill the data gaps. Initially product and service categories will be defined broadly, both with respect to product types and geographic areas, resulting in relatively large differences between product averages and relatively large standard deviations. Impacts estimated by impact rating organizations (IROs) based on process conditions will be added to the database. Supply chain partners can always choose to use more accurate (or the most accurate) impacts estimation methods at higher cost, but this will likely be limited to a few of the most sustainable and most sold products. Under default conditions (costs free) impacts are estimated using the category average + 3 standard deviations. This would happen when a participating consumer would by a non-rated but CQR coded product. Non-rated non-CQR coded product would be assigned the highest impacts due to their highest uncertainty. With increasing numbers of IRO impacts available, the product and service categories will become more numerous and narrower with smaller differences between their averages and with smaller standard deviations. Using the crude default impact estimation method, this will now lead to lower estimated impacts for all products and services for which no IRO estimated/determined impacts are available. The inputs of both ISCS and PSCS will thus be a combination of increasingly better IRO estimated/determined impacts and increasingly better non-IRO estimated impacts, leading to lower IRO estimated/determined impacts for products, services and labor outputs. LBIs will be treated the same, initially using broad areas and later narrower area, once remote sensing data products become increasingly available.

3.6. Savings and Avoided Costs of Living Carbon Negative

In order to prevent the biodiversity losses anticipated under business-as-usual conditions, and to prevent the associated enormous financial and human losses *(16),* the world has to transition to carbon negative economies, where for decades more CO_2 will be sequestered than emitted. To abate and possibly reverse global warming, we need to both transition from fossil fuels to renewables (mainly photo voltaic or PV, solar and wind) and remove CO_2 from the atmosphere (Direct Air Capture and CO_2 Sequestration or DACCS), preferably to levels close to pre-industrial conditions. This means changing the built environment using carbon negative buildings. I define carbon negative buildings as buildings that emit no CO_2 and produce more RE than they need for the building and its inhabitants, including their electric transportation needs. The 8th paper *(15)* addresses the savings and avoided costs of living carbon negative. Renewable energy (RE) is already cheaper than fossil-fuel-based energy *(17),* but based on investments needed for electric utilities and due to increased costs (sunk investment in fossil fuel power plants), the price of electricity paid by end users is likely to rise *(15).* End users can save on the cost of energy by installing roof PV solar in combination with the use of heat pumps (HP) and electric cars and trucks (E-cars). For the US, savings vary on PV panel orientation, type of HP and car used. For South facing PV panels, using ground source HPs (GSHP) and E-cars, the savings in the levelized costs of energy (LCOE) are 80 percent *(15),* compared to the combination of using natural gas for heating, using utility provided electricity and using fossil fuels for transportation. For areas with on average higher prices for electricity, natural gas and car fuels and lower prices for roof PV solar (i.e. the EU) the savings would be larger. Carbon negative building codes are needed to guarantee that all new buildings have good insulation, 100% South facing (or flat) roofs, roofs fully covered by PV solar and use HPs (preferably GSHPs) for all heating and cooling needs. For existing buildings, codes should require that fossil fuel energy systems are replaced by carbon neutral or negative ones at the end of their economic life. Based on the 20-year economic life cycle of heating, ventilation, air conditioning and hot water systems, this transition can be completed in 20 years. Buildings typically need major renovations about 50 years after construction *(18, 19).* At that time roofs can be adapted to be flat or face mostly South. For the US, the total of roof solar electricity produced by all buildings (South PV azimuth) would be equivalent to 2.6 times the electricity sold in the US in 2022. However, due to intermediate and seasonal storage needs, and the remaining H_2 needs (replacing natural gas), the total electricity used for a US H_2 based RE economy requires 3.8 – 5.6 times the 2022 consumption, depending on the H_2 system efficiencies reached *(15).* If all global RE would be generated using PV solar and installed on cropland (using US per capita energy usage globally), this would cover 39 – 58% of global croplands for an 8-billion population and 49 - 72% for a 10-billion world population. However, agricultural lands are needed to feed the world and installation of solar farms on lands suitable for agriculture is not sustainable since it would lead to stark deteriorating human conditions. Remaining RE needs can be covered by wind energy (anywhere, including on agricultural lands) and utility scale solar in areas with no agricultural value (deserts) after the ecologically required fraction of the ecoregion is protected for its biodiversity. In 2021 the total US spending on energy was 5.73% of the US gross domestic product (GDP). Using the combination of most cost effective RE and RE using systems (south facing roof PV solar, GSHP and E-cars), this could be reduced to 2.11% % of GDP, saving 3.62% of GDP. This is a conservative number and actual savings could be larger when GSHPs, Very High Temperature HPs and High Lift HPs are applied in the commercial and industrial sectors *(15).* These potential savings are larger than the average annual costs of DACCS (0.7 – 1.8% of global GDP) for a return to pre-industrial atmospheric conditions in 40 years. The 3.6% potential GDP savings only result from roof PV solar and not from field mounted utility scale PV solar or wind energy. These savings are not made if electricity users continue to buy their power from electric utilities; in the latter case their cost are expected to go up. Based on the average projected costs of DACCS over 25-year, the societal DACCS costs avoided for PV solar systems are larger than their installation cost; 1.1 -1.3 for utility scale PV solar (South facing), 1.8 – 2.0 for east and west facing roof PV solar and 2.4 – 2.7 for south facing roof PV solar Governments could pay in full for roof PV solar and still create society wide saving of 1.4 -1.7 times the system costs *(15).* In order to speed up the rate of roof PV solar installation over the full roof area available, and allow home and other building owners to reap the savings from roof solar systems, net-metering agreements must be extended to apply to "Roof Solar Production & Use Associations", where association members invest in PV solar on roofs of members and pay no cost to the power distributing utility for the fractions of power sent to and withdrawn from the grid by members. By focusing on laws and regulations that save energy for building owners, investments made towards a RE future are earned back quickly. If not done so, energy costs will become a drag on economies; the transition to a RE future will be slow and cause large biodiversity, financial and human losses that could have been avoided.

3.7. Can We Reverse Global Warming?

The 9th paper *(20)* represents an example of the application of IMACS. Climate Change was chosen as the example impact group, since it has very large negative effect by itself and negatively affects impacts of all other impacts groups. Without mitigation, Climate Change is expected to cost large amounts of money *(16),* cause vast amounts of human suffering and death and threatens the survival of countless species *(15).* In combination with other factors (population growth, increasing water stress, coastal flooding, loss of coastal land, increasing forest fires, loss of wildlife areas and insufficient wild-life corridors), Climate Change could lead to a collapse in ecosystem services, estimated at almost twice the global GDP *(16).* The loss of ecosystem service is estimated to already cost globally 5 trillion $/y, while according to the world economic forum (WEF), over half the global GDP (44 trill $/y) depends on highly functioning ecosystem services *(21).* For humans, these combined factors would increase poverty, famine, starvation and cause mass migration. Under the Paris Accord, countries agreed to limit Climate Change to 1.5 degrees. This limit was not set because it was "safe" for biodiversity or humanity, but because lower limits were considered "unachievable". However, a relatively quick reversal of global warming would minimize all damages that would occur over the next centuries under Climate Change. Besides the return to pre-industrial atmospheric conditions, minimizing loss of human lives and minimizing damage to wildlife areas and the biodiversity these represent, this would also allow a gradual restoration of mountain snow and ice caps, restoring melt water flows, reduce water stress and minimize coastal flooding. Governments treat the changes needed to transition to a carbon neutral world as "costs" instead of "investments". Here I show how the use of renewable energy (especially roof PV solar), ground source heat pumps and electric cars combined with massive application of direct air capture and sequestration of CO_2 (DACCS) can reverse global warming in 40 to 60 years while saving massive amounts of money (about 3.62% of GDP). A critical element in doing this is the use of the Impact Measurement and Conservation System (IMACS) as the business model. The IMAC system puts consumers, retailers and organizations in general in charge of selling and buying incrementally less damaging and more sustainable products and services, while being rewarded for their actions. Under IMACS, current and historic damaging impacts are calculated and assigned to participating products, services and individual labor. For participating sellers, damaging impacts and associated sustainabilities are accurately calculated per product and service per sales location (and daily adjusted) using automated and low costs methods. For non-participating competitor products, the impacts cannot be calculated accurately and are set to the statistic upper damage limit for each damage type for the product group. Sellers who start participation will therefore almost always see large reductions in damaging impacts and large increases in reported sustainabilities for their products and services. This could dramatically accelerate the rate of change towards a sustainable world. Participation in IMACS is voluntary and cost-free for individuals. In order for products to become (more) sustainable, damaging impacts like greenhouse gas emissions must be eliminated or must be offset by CO_2 sequestered in permanent storage locations. For the society as a whole, becoming carbon neutral saves large amounts of money compared to not doing so, even when the costs of CO_2 sequestration are included.

Under IMACS, the purchase of neutralizing amounts of sequestered CO_2 are paid for during the product purchase with an electronic voucher provided by the retailer. This only applies to participating products and services sold by participating retailers to participating customers. For a 40-year global warming reversal period, the average DACCS costs for the base and conservative DACCS cost scenarios are respectively 0.60 – 1.67% of GDP, but drop to 0.25 – 0.68% of GDP over 100 years. For carbon neutral sellers, the average DACCS costs (neutralizing historic emissions) are 0.95 – 2.66% of sale, but reach 1.63 – 4.52% of sale for the peak year. The ratio of cumulative energy cost savings over cumulative DACCS costs for a 40-year global warming reversal are 1.7 - 4.6 over the 40-year period and 4.8 – 13.3 over 100-year *(20, 22).* Early participating sellers will receive all or most of these savings. Since under IMACS, the saving from carbon neutral operations throughout the supply chain go hand in hand with the DACCS payments for remaining and historical CO_2 emissions, the DACCS costs can be paid easily out of the savings from carbon neutral operations. The compound annual growth rate (CAGR) for the DACCS industry, as needed to reverse global warming, is in line with the currently expected CAGR for the DACCS industry between 2023 and 2032 (42 – 70% on production basis). A 63% growth rate under default model conditions maintained for 26 years would lead to global warming reversal in model year 41 *(22).*

3.8. Marketing Aspects for IMACS

In addition to measuring environmental and human condition impacts, the Impact Measurement And Conservation System (IMACS) automatically applies conservation to participating products sold by participating retailers and purchased by participating consumers, such that all damaging impacts are neutralized and the consumer takes home a 100% sustainable product. Under default model conditions, global warming would be reversed in 40 years. Fresh water withdrawals would be limited to sustainable available amounts, restoring the fresh water flows through watersheds, using reverse osmosis systems to provide the balance of fresh water needed. Wildlife areas would be restored to the scientifically required area fractions for each ecoregion in the same 40-year period, but it would likely take 1 – 2 centuries for global biodiversity to stabilize around the new lower biodiversity level. Except for the actual implementation, all technical aspects needed for this global restoration system are already fully developed (wildlife area protection and restoration, reverse osmosis) or sufficiently developed to start their use now (DACCS, remote sensing of impacts). The existing approach to protect biodiversity and reduce global warming relies entirely on government action, varies strongly per country and is largely ineffective; extinction rates are about 100 times higher than background extinction rates, while global warming will not be limited to 1.5 ºC, further increasing extinction rates. Implementation of IMACS would add a bottom-up approach by asking consumers to buy more sustainable products. The critical assumption made is that there is enough consumer demand to drive the growth of consumer participation in IMACS from 0% to 100% in 20 years. In the10th paper *(23),* I review the marketing aspects of selling more sustainable products and services. Under IMACS, the sustainability transition is in part driven by cost savings throughout the supply chain due to the use of roof PV solar, geothermal heat pumps, and electric transportation. These cost savings are much larger than the retailer's (and supply chain) costs to provide conservation, and the remaining savings can be split between consumers (lower prices) and retailers (higher profit margins). For non-participating retailers and non-participating consumers, the costs of utility provided energy are expected to increase due to the need for intermediate (days – weeks) and seasonal energy storage (H_2 electrolyzers, H_2 storage and H_2 fuel cells). This difference in costs of energy by itself will create an incentive for IMACS participation in addition to motivation based on environmental and human condition aspects. The conclusion is that there is already a large consumer demand for sustainable products globally. Consumers are even willing to pay higher prices for products that are more sustainable or that are made under acceptable or better human conditions. Since under IMACS participating consumers do not pay a higher but the same price as non-participating consumers, the percentage of consumers willing to participate would even be larger than when the more sustainable products were more expensive. The model assumptions of a 5% annual increase in consumer participation appears therefore conservative and a return to pre-industrial atmospheric conditions in 40 years appears feasible.

4. Organization and Scalability

No paper was yet written about the core IMACS organization and the scalability of the overall hybrid organization. This section functions as a preview. The overall hybrid organizational structure needed to implement IMACS should preferably be a mix of non-profit and for-profit organizations. The core IMACS organization should be non-profit in order to adhere to and improve its mission. In addition, the core IMACS organization should develop procedures, specify the software needed, create and maintain scientific boards for each of the eleven impact groups, fund additional research to improve its mission and maintain the overall integrity of the overall organization. In case of a for-profit IMACS organization, there would likely be pressures to abandon its true mission in order to make profits earlier and make larger profits later. The core IMACS organization should be kept as small as possible, but all supporting functions should be carried out by for-profit organizations. These should include IROs (impact rating organizations), ECOs (environmental conservation organizations) like wildlife area protection organizations, carbon sequestration organizations, precipitation area protecting organizations, soil and sediment conservation organizations, etc. and the SMOs (sustainability maintenance organizations) distributing the conservation in small fractional TTC amounts ("title to conservation") to participating consumers. The hundreds of large computer centers needed globally, should be under IMACS management, but could be maintained and operated by for-profit organizations. Likely thousands of IMOs would be needed globally servicing different regional and language markets. All for-profits would compete within their own categories, where the lowest cost service providers would typically also be the most sustainable. The non-profit IMACS organization would also carry out training, certification, licensing, carry out audits (determine whether impact assessments were made within the required error margin) and apply penalties where errors are found larger than the allowed margin. These penalties would be both financial and (more importantly) carry a damaging impact increasing factor (a value > 1.0) to be applied to the products of all current and future products and services rated by the IRO. While the IMACS organization would need to design the content of the training modules, the actual training course and the testing could be carried out by for-profit organizations. All certified and licensed for-profit organizations operating within the larger IMACS structure as well as all other participating supply chain and governmental organizations all pay a small licensing fee (a percentage of revenues) to the non-profit IMACS organization to fund its costs, mostly spent on computer hardware, software, maintenance, bandwidth, energy, buildings, licensing and legal. Since the IMACS organization can be kept very small, and the global organizational revenues are very large, these fees would be miniscule for a non-profit IMACS organization. However, a "back-of-the-envelope" calculation shows that a same size for-profit core IMACS organization would be extremely profitable (asking higher license fees), but this would put the IMACS system at risk of greenwashing. The creation (and funding) of a non-profit core IMACS organization is thus highly preferrable. The use of a large number of smaller for-profit organizations within overall organizational hybrid structure strongly improves the scalability and reduces investment costs and liability for the non-profit core IMACS organization.

5. Discussion

The IMAC system as discussed in the ten preprints and summarized here has the potential to relatively quickly improve environmental conditions globally, resulting in a potential reversal of global warming conditions in about 40 years and restore wildlife areas such that further losses in biodiversity (especially extinction above background rates) are first reduced and later revert to background rates. This is possible, since IMACS offers a business model that enlists consumers to participate in a market where the fraction of consumes willing to buy more sustainable products is already larger than the required annual percentages needed to participate over the first 5 - 10 years. Since IMACS represents a globally uniform system of methods applicable to all environmental and human conditions impacts, it can be applied to impacts for all eleven impacts groups. The ten papers address all elements critical for IMACS. However, "*The devil is in the details*" and I am sure that during implementation there will be lots of details for which solutions need to be found. For most research projects, here are follow-up projects to hammer out additional questions, uncertainties and details before any implementation is attempted. This can take many years. In this case, where global biodiversity losses are rapidly rising, further aggravated by global warming and increases in human suffering and deaths are projected due to the reduction of all aspects of sustainability, there is no time to lose. Project implementation should start immediately, with as many as possible project aspects running in parallel. A modified "design-build" process could best be used *(24),* where the many design & development steps are just one step ahead of the implementation of each step. That is possible for the IMACS project, since the initial technical requirements needed to start are much less demanding than the later requirements needed for full implementation. We can start very simple with CQR software and crudely estimated impacts for a few variables and expand accordingly to more accurate methods and more impact variables. The most urgent tasks to start and complete are building a project team, project funding, patent prosecution, marketing & communication (website, social media presence, press contacts, university contacts, politician contacts), support from universities, support from environmental organizations, making business plans for the various project stages, legal advice (what is the best legal form to use for the hybrid organization), creation of the various legal entities, writing the CQR software, running a pilot scale experiment, and the selection of early adopter countries. While it is important to eliminate any potential large errors from the preprint publications (mainly to prevent misinforming the public), the actual publication of the above ten papers in peer reviewed journals is less important. Funding for patent prosecution is especially important, since not having patent protection would allow many other businesses to feed off license fees for "IMACS-like" system software versions, creating a myriad of greenwashed systems with different standards, thwarting the potential a single uniform IMACS system could have for a 40 – 60 year reversal of global warming and the associated biodiversity protection we all need.

6. References and Notes

1. Dert, V. (2023). *Determining and/or evaluating a sustainability of a product, a service, an organization and/or a person* (International Patent Application No. WO 2023/146525 A1). US Patent and Trademark Office. 10.5281/zenodo.11205154.
2. Scheffer, M. (2020). *Critical transitions in nature and society* (Vol. 16). Princeton University Press.
3. Mura, M., Longo, M., Micheli, P., & Bolzani, D. (2018). The evolution of sustainability measurement research. *International Journal of Management Reviews*, *20*(3), 661-695.
4. Dahl, A. L. (2012). Achievements and gaps in indicators for sustainability. *Ecological indicators*, *17*, 14-19.
5. 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.
6. 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.
7. Recommendation on the use of Environmental Footprint methods, 16 December 2021, Directorate-General for Environment Recommendation on the use of Environmental Footprint methods (europa.eu)
8. Dert, V. (2024). Impact Measurement and Application of Conservation System (IMACS). Zenodo. https://doi.org/10.5281/zenodo.11206388
9. Dert, V. (2024). Calculation of Individual Sustainable Absorption under IMACS. Zenodo. https://doi.org/10.5281/zenodo.11211510
10. Dert, V. (2024). Calculation Of Excess Impact Deduction for Products and Services under IMACS. Zenodo. https://doi.org/10.5281/zenodo.11212346
11. Dert, V. (2024). Providing Conservation as "Title-To-Conservation" under IMACS. Zenodo. https://doi.org/10.5281/zenodo.11212462
12. Dert, V. (2024). Calculation of Individual and Product Sustainability under IMACS. Zenodo. https://doi.org/10.5281/zenodo.11214090
13. Dert, V. (2024). Remote Sensing of Environmental Impacts under IMACS. Zenodo. https://doi.org/10.5281/zenodo.11218121
14. Dert, V. (2024). Impact Estimation and Product Classification under IMACS. Zenodo. https://doi.org/10.5281/zenodo.11225057
15. Dert, V. (2024). Savings and Avoided Costs of Living Carbon Negative. Zenodo. https://doi.org/10.5281/zenodo.11284389
16. Kurth, T., Wübbels, G., Portafaix, A., Meyer zum Felde, A., & Zielcke, S. (2021). The biodiversity crisis is a business crisis. *Boston Consulting Group: Boston, MA, USA*.
17. Lazard, 2023 levelized costs of energy, April 12 2023. 2023 Levelized Cost Of Energy+ | Lazard. Web capture 3/17/2024
18. Stuart Feldstein, Building age data year-end 2023, SMR Research Corporation, Enhanced Commercial Property Database (commbuildings.com). Web capture 3/17/2024.
19. How long are commercial buildings designed to last? How Long are Commercial Buildings Designed to Last? | Alpine (knockitdown.com). web capture 3/17/2024
20. Dert, V. (2024). Can We Reverse Global Warming? Zenodo. https://doi.org/10.5281/zenodo.11289414
21. World Economic Forum. (2023, February). Biodiversity loss poses a fundamental risk to the global economy. Biodiversity loss poses a fundamental risk to the global economy | World Economic Forum (weforum.org) Retrieved from WEF. 6/14/2024.
22. Dert, V. (2024). Excel Model for DACCS Capacity and Cost for Global Warming Reversal under IMACS. Zenodo. https://doi.org/10.5281/zenodo.11579907
23. Dert, V. (2024). Marketing Aspects for IMACS. Zenodo. https://doi.org/10.5281/zenodo.11549042

24. Jethva, S. S., & Skibniewski, M. J. (2022). Agile project management for design-build construction projects: A case study. *Int. J. Appl. Sci. Eng*, *19*(1), 1-11.
25. Jantz, S. M., Barker, B., Brooks, T. M., Chini, L. P., Huang, Q., Moore, R. M., ... & Hurtt, G. C. (2015). Future habitat loss and extinctions driven by land-use change in biodiversity hotspots under four scenarios of climate-change mitigation. *Conservation Biology*, *29*(4), 1122-1131.
26. Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M., & Palmer, T. M. (2015). Accelerated modern human–induced species losses: Entering the sixth mass extinction. *Science advances*, *1*(5), e1400253.
27. Ceballos, G., & Ehrlich, P. R. (2023). Mutilation of the tree of life via mass extinction of animal genera. *Proceedings of the National Academy of Sciences*, *120*(39), e2306987120.

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