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REPORT

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PREFACE

Corporates and financial services are undergoing a transformation towards a more just, sustainable economic paradigm. A key challenge along this path is better integrating the external effects of business activities into corporate governance, decision making, steering, planning, and disclosures – because disregarding positive and negative external effects in the global market economy leads to distortions in market prices. Consequently, identifying the true value or true cost of business models is increasingly important.

For the past 15+ years, pioneering companies have been actively engaged in calculating (measurement) and evaluating in monetary terms (valuation) the external effects or "impacts" of their business activities on society and the environment. The aim of initial innovators like GIST Impact, Trucost, PwC, or KPMG have been to better connect and integrate this impact information into corporate financial accounting and reporting. Early actors like WifOR envisaged evidence-based decision making in politics and business to enable sustainable social, environmental, and economic development of global society grounded in valid and comparable data. Ever since these beginnings, other organisations like the Capitals Coalition, Valuing Impact, CE Delft, Chalmers University, and the German Environmental Agency (Umweltbundesamt -UBA) contributed in to play very important roles in this paradigm shift. The ultimate objective is a convergence of financial, human, social, and natural capital into a unified system – in accordance with the principle of double materiality – aligning corporate activities and investment with the concept of sustainable value creation.

Over the past five years, this movement has gained new momentum under the banner of Impact Accounting. Policymakers such as the EU Commission with initiatives such as the Transparent project - Natural Capital Management Accounting (NCMA), international organizations, like the OECD, and governments in Germany, the UK, France, and Japan are initiating targeted regulatory measures. Standard setters such as GRI or EFRAG are addressing the issue of the financial effects of sustainability and discussing the potential applications of Impact Accounting, e.g. in materiality analyses. And there is growing investor interest in monetized impact information within financial markets, leading to the intensive involvement of data providers and rating agencies in the topic. Meanwhile, organisations like the WEF or the WBCSD are closely monitoring the developments and establishing related workstreams.

Due to multiple value factors and underlying methodologies available in the ecosystem with varying degrees of public accessibility, the need for transparency related to these value factors and the comparability of results led to several key developments in the market. First, under the guidance of the Capitals Coalition, the Value Commission was established by over 30 experts from around the world to drive transparency and accountability in the use of value factors by standard setters and other organisations. The Value Commission includes all the leading organisations working together in this area to deliver a Value Accountability Framework with transparency requirements, confidence criteria, and value notes.

Second, to allow for comparable results by creating a global baseline for impact accounting the International Foundation for Valuing Impacts (IFVI) was established and formed a partnership with the Value Balancing Alliance (VBA). IFVI, with the VBA, is developing a public good best practice impact accounting methodology that serves as baseline to make impact information of companies and financial institutions comparable and to scale

the practice of Impact Accounting for both decision making and impact disclosure. The public good methodology aims to build off of and expand upon existing developments in the ecosystem, along with sustainability reporting disclosures. To ensure the robustness and credibility of methodology, a rigorous due process and an independent governance body (the Valuation Technical and Practitioners Committee – VTPC) comprised of many experts in the ecosystem oversees the methodology.

The VBA inter alia unites companies with experts in impact measurement and valuation, serving as a preparers' forum and practitioner knowledge hub for Impact Accounting. In response to ongoing changes in regulation, standardisation, financial markets, and corporate practices, and the experience gained from the Impact Sprint pilot together with the Oxford University and the Hong Kong University of Science and Technology (HKUST), we conducted another sprint to offer an updated overview of Impact Accounting from a practical standpoint. Over an eight-week period, key stakeholders collaborated to assess the current state of methods for calculating physical KPIs, their monetary valuation, and practical applications. Their findings are compiled in this publication.

With this publication, we aim to highlight the current state of opportunities and challenges in practice with the goal of raising awareness of Impact Accounting among various stakeholders, accelerating uptake, and informing the different processes in the field of standardisation and integration. Please note that this publication uses the Transparent Natural Capital Management Accounting (NCMA) framework developed by VBA, the Capitals Coalition,WBCSD, and European Commission's DG Environment as starting point and introduces the VBA' methodology where no standardized methodology of IFVI/VBA is available yet.

We extend our heartfelt gratitude to all participants for generously sharing their insights, relevant experiences, and for consenting to the publication of these invaluable results. Their time and contributions are deeply appreciated. The substantial number of participants and active contributions underscore the timeliness and significance of this work.

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Abbreviations

AERMOD -	Air Quality Dispersion Model
AP -	Acidification potential
AR -	Assessment Report
As -	Arsenic
AQUASTAT -	FAO's Global Information System on Water and Agriculture
AWARE -	Available WAter REmaining
BOD -	Biological Oxygen Demand
BRICK	Berkeley-Rochester Institute for Climate Knowledge
Cd -	Cadmium
Cedefop -	European Centre for the Development of Vocational Training
CH4 -	Methane
CO2 -	Carbon Dioxide
CO2eq -	Carbon Dioxide Equivalent
CSRD -	Corporate Sustainability Reporting Directive
DALY -	Disability-Adjusted Life Year
DEI -	Diversity, Equity, and Inclusion
DICE -	Dynamic Integrated model of Climate and the Economy
DSCIM -	Data-driven Spatial Climate Impact Model
Ecoinvent -	Life Cycle Inventory Database
EDGAR -	Emission Database for Global Atmospheric Research
EEIO -	Environmentally Extended Input-Output
EMEP -	European Monitoring and Evaluation Programme
EPS -	Environmental Performance System
ESAPOD -	European Statistics on Accidents at Work and Occupational Diseases
ESVD -	Ecosystem Services Valuation Database
ESRS -	European Sustainability Reporting Standards
EUROSTAT -	Statistical Office of the European Union
EXIOBASE -	Extended Input-Output Database
EXIOPOL -	Multi-regional Input-Output database for environmental analysis
FAO -	Food and Agriculture Organization
FAOSTAT -	Food and Agriculture Organization Corporate Statistical Database
FaIR -	Finite Amplitude Impulse Response (a climate model)
FTE -	Full-Time Equivalents
FUND -	Climate Framework for Uncertainty, Negotiation and Distribution
GBD -	Global Burden of Diseases
GCAM -	Global Change Analysis Model
GDP -	Gross Domestic Product
GEMS -	Global Environmental Management Services
GGGI -	Global Green Growth Institute
GHG -	Greenhouse Gas
GLAM -	Global LCIA Guidance
GPG -	Gender Pay Gap
GIS -	Geographic Information System
GIST -	Global Impact for Sustainable Tomorrow
GIVE -	Greenhouse Gas Impact Value Estimator

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GII -	Gender Inequality Index
GNI -	Gross National Income
GRI -	Global Reporting Initiative
GWP -	Global Warming Potential
GWQMD -	Global Water Quality Monitoring Database
HARAS -	Hazard Rating System
HTP -	Human Toxicity Potential
HUI -	Health Utility of Income
HYBRID -	A version of EXIOBASE
IAM -	Integrated Assessment Model
IEA -	International Energy Agency
IFVI -	International Foundation for Valuing Impacts
IIASA -	International Institute for Applied Systems Analysis
ILO -	International Labour Organization
ILOOSH -	International Labour Organization Occupational Safety and Health
IPCC -	Intergovernmental Panel on Climate Change
IPBES -	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
ISO -	International Organization for Standardization
ISSA -	International Social Security Association
ITUC -	International Trade Union Confederation
IUCN -	International Union for Conservation of Nature
IWA -	Impact Weighted Account
LANCA -	Land Use and Climate Analysis
LCA -	Life Cycle Assessment
LCIA -	Life-Cycle Impact Assessment
MESSAGEix-GLOBIOM -	Model for Energy Supply Strategy Alternatives and Planning – Global Biosphere Management
MSA -	Mean Species Abundance
MSW -	Municipal Solid Waste
NCMA -	Natural Capital Management Accounting
NGFS -	Network for Greening the Financial System
NDC -	Nationally Determined Contribution
NEEDS -	National Energy Efficiency Data-Framework
NER -	National Emissions Registry
NGFS -	Network for Greening the Financial System
NH3 -	Ammonia
NMVOC -	Non-Methane Volatile Organic Compounds
NOAA -	National Oceanic and Atmospheric Administration
NOx -	Nitrogen Oxides
N-tot -	Total Nitrogen
N2O -	Nitrous Oxide
ODP -	Ozone Depletion Potential
OECD -	Organisation for Economic Co-operation and Development
OHS -	Occupational Health and Safety
PAGE -	Policy Analysis of Greenhouse Effect
PAHs -	Polycyclic Aromatic Hydrocarbons
P-tot -	Total Phosphorus

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PDF -	Potentially Disappeared Fraction of Species
PM2.5 -	Particulate Matter with a diameter of 2.5 micrometres or less
PM10 -	Particulate Matter with a diameter of 10 micrometres or less
PPP -	Purchasing Power Parity
PwC -	PricewaterhouseCoopers
ReCiPe -	Recipe for the European Life Cycle Assessment
REMIND -	REgional Model of Investment and Development
Remind-MagPie -	REgional Model for INfrastructure Development and Management -Multi-Actor, Global Policy Analysis
Safe Work Australia -	Australian Government Workplace Health and Safety agency
SCC -	Social Cost of Carbon
SETAC -	Society of Environmental Toxicology and Chemistry
SDGs -	Sustainable Development Goals
SO2 -	Sulfur Dioxide
SSP -	Shared Socioeconomic Pathways
TEEB -	The Economics of Ecosystems and Biodiversity
TEAP -	Technology and Economic Assessment Panel
UBA -	German Environmental Agency
UNDP -	United Nations Development Programme
UNEP -	United Nations Environment Programme
UNESCO -	United Nations Educational, Scientific and Cultural Organization
UNICEF -	United Nations International Children's Emergency Fund
UNIDO -	United Nations Industrial Development Organization
USEPA -	United States Environmental Protection Agency
USEtox -	USEtox Model for Life Cycle Impact Assessment
USGS -	US Geological Survey
VBA -	Value Balancing Alliance
VOCs -	Volatile Organic Compounds
VSL -	Value of Statistical Life
WFN -	Water Footprint Network
WHO -	World Health Organization
WifOR Institute -	Scientific Institute for Infrastructure and Resource Management (*Wissenschaftliches Institut für Infrastruktur und Ressourcenmanagement*)
WIOD -	World Input-Output Database
WRI -	World Resources Institute
WTP -	Willingness-to-Pay
WUI -	Wellbeing Unit Income
WULCA -	Water Use in Life Cycle Assessment
YLL -	Years of Life Lost

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Sprint Team and Roles

BMW	BMW is a renowned German automotive manufacturer known for luxury vehicles, motorcycles, and engines, emphasising performance, innovation, and sophisticated design.	Team Member
BNP Paribas	BNP Paribas is a leading European bank with a global presence, offering a wide range of financial services including banking, investment, and asset management solutions.	Team Member
Bloomberg	Bloomberg is a global provider of financial data, analytics, and news. It offers a comprehensive platform for professionals to access real-time market information and make informed decisions.	Solution Owner
CaixaBank	CaixaBank is a leading Spanish financial institution offering a range of banking and financial services. It serves millions of customers worldwide with a focus on innovation and customer satisfaction.	Team Member
Capitals Coalition	Capitals Coalition is an organisation promoting natural and social capital accounting. It fosters collaboration among stakeholders to integrate impact measurement into decision making for sustainability.	Observer
Carbon10BX	Carbon10bx is an initiative aiming to combat climate change by incentivising carbon reduction through a blockchain-based carbon credit marketplace, fostering sustainability and environmental responsibility.	Team Member
Chalmers University of Technology	Chalmers University of Technology is a renowned Swedish university focusing on engineering, technology, and natural sciences, dedicated to fostering innovation, sustainability, and global collaboration in research and education.	Solution Owner
d-fine	d-fine is a European consulting firm focused on analytical and quantitative challenges and the development of sustainable technological solutions. The combination of over 1,500 employees with a strong scientific background and many years of practical experience enables us to provide tailor-made, efficient and reliable solutions for more than two hundred clients from every sector of the economy.	Solution Owner
Effectual Capital	Effective capital allocation for the transformation to a sustainable economy.	Team Member
Ernst & Young (EY)	Ernst & Young (EY) is a multinational professional services firm providing assurance, tax, consulting, and advisory services to clients worldwide, helping them navigate complex business challenges and opportunities.	Solution Owner
GIST Impact	GIST Impact is a leading provider of impact platforms and datasets empowering companies and investors with comprehensive, geographically	Solution Owner

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	precise impact data to drive sustainable decision making and investment strategies.	
German Environment Agency (UBA)	The German Environment Agency (UBA) is a federal authority responsible for environmental protection and sustainability in Germany, providing scientific expertise and policy advice for environmental conservation and regulation.	Solution Owners
HACE	HACE defines a company's child labour performance in three ways: company disclosure, public perception and supply chain.	Team Member
The International Foundation of Valuing Impact (IFVI)	The International Foundation of Valuing Impact (IFVI) is an impact accounting provider committed to building and scaling the practice of impact accounting to promote decision making based on risk, return, and impact.	Observer
International Finance Corporation (IFC)	The International Finance Corporation (IFC) is a member of the World Bank Group offering investment, advisory, and asset management services to promote sustainable private sector development in emerging markets.	Observer
IP Group plc	IP Group plc is a leading intellectual property commercialisation company partnering with universities and businesses to develop and commercialise innovative technologies across various sectors globally.	Team Member
Novartis	Novartis is an innovative medicines company that works to reimagine medicine to improve and extend people's lives so that patients, healthcare professionals, and societies are empowered in the face of serious disease. Novartis' medicines reach more than 250 million people worldwide.	Team Member
OECD (Organisation for Economic Co-operation and Development)	OECD is an intergovernmental organisation promoting economic prosperity and social well-being worldwide through policy dialogue and collaboration, offering insights and recommendations on diverse economic and social issues.	Observer
Skoll Centre at Oxford University Saïd Business School	Skoll Centre at Oxford University Saïd Business School is a leading centre for education, research, and entrepreneurship in impact and sustainability, fostering global leaders and driving innovation in business practice.	Team Member
Oxford Economics	Oxford Economics is a leader in global forecasting and quantitative analysis helping navigate economic uncertainty and find growth opportunities in a challenging world economy.	Team Member
The Upright Project	The Upright Project offers the world's first open-access platform for impact data, enabling smarter decision-making for investors and companies by measuring the sum of a company's positive and negative impacts on the environment, health, society, and knowledge.	Solution Owner
UBS	UBS is a global financial services firm providing wealth management, asset management, and	Team Member

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	investment banking services, committed to delivering sustainable solutions for clients worldwide.	
Value Balancing Alliance	Value Balancing Alliance is a multinational coalition advocating for the integration of social and environmental impacts into financial reporting, aiming to drive sustainable business practices globally.	Sprint Master
WifOR Institute	WifOR Institute, established in 2009, conducts economic research. It collaborates with universities and ensures quality through renowned researchers' oversight.	Solution Owner

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Solution Owners and Data Providers

The following organizations provided insights into their valuation approaches throughout the sprint.

GIST Impact

For over 16 years, GIST Impact has specialized in measuring and quantifying impact, aiding leading corporations and investors in making sustainable decisions. With a dedicated team of over 100 experts, including scientists, engineers, and economists, GIST Impact offers cutting-edge impact platforms and datasets covering 13,000+ companies worldwide. Collaborating with pioneering companies and investors representing over $8 trillion in assets under management, GIST Impact also partners with major ESG data providers and fintech platforms to facilitate impact measurement across global markets.

https://gistimpact.com/

Transparent

The Transparent Project (led by the Value Balancing Alliance (VBA), the Capitals Coalition, the World Business Council for Sustainable Development (WBCSD) and the European Commission's DG Environment) has been funded by the EU Life Programme to develop a standardized Natural Capital Management Accounting (NCMA) methodology for business in line with the ambition of the European Green Deal.

The focus of this methodology is to measure and value how business activities affect societies through changes in natural capital and ecosystem services, and how businesses can identify their dependencies on natural capital through ecosystem services (incorporating double materiality logic). To this end, the NCMA methodology focuses on the application of natural capital accounting in a business decision-making context, that is, in a management accounting rather than an external reporting capacity.

https://capitalscoalition.org/publication/the-natural-capital-management-accounting-methodology/

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The Upright Project

The Upright Project offers the world's first open-access platform for impact data, enabling smarter decision-making for investors and companies by measuring the sum of a company's positive and negative impacts on the environment, health, society, and knowledge. Upright is on a mission to equip investors, customers, employees, and companies themselves with common sense impact data to enable more fact-based decision-making and to make it financially more attractive to run a net positive company than a net negative one.

https://www.uprightproject.com/

Value Balancing Alliance

We are an alliance of multinational companies dedicated to creating a new metric that measures and compares the value of businesses' contributions to society, the economy, and the environment. Our goal is to translate environmental and social impacts into comparable financial data, enabling more conscious decision-making and fostering sustainability. Commissioned by the EU and collaborating with organizations like the OECD, we aim to establish internationally recognized Green Accounting Principles for calculating reliable sustainability metrics, with support from major accounting firms, researchers, and standard setters.

https://www.value-balancing.com/

WifOR Institute

Established in 2009, WifOR Institute originated from TU Darmstadt's Department of Finance and Economic Policy, led by Prof. Dr. Dr. h.c. Bert Rürup. Managed by Prof. Dr. Dennis A. Ostwald, WifOR Institute maintains close ties to research through Dr. Ostwald's professorship at Steinbeis University Berlin and collaborations with institutions like Harvard University. The organization upholds research quality with a high number of dissertations and an expert committee of renowned researchers.

https://www.wifor.com/

International Foundation for Valuing Impacts (IFVI)

The momentum for impact accounting surged with the endorsement of mandatory accounting for impact by the G7 Impact Taskforce. In response, IFVI emerged as an independent organization, led by global experts like Sir Ronald Cohen and George Serafeim, to scale the practice of translating company impacts into currency. Leveraging research from IWA, IFVI aims to establish impact accounting as the cornerstone of a more equitable economy, driving towards a future where social and environmental impacts are valued alongside financial metrics.

https://ifvi.org/

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EXECUTIVE SUMMARY

This document summarises the results of eight organised informal dialogues between corporates, the financial sector, public bodies, and impact valuation[1] providers (solution providers) on assessing a company's value to society across environmental and social value factors. The exercise served two purposes:

- First, to embed impact valuation within the broader market environment of sustainable finance to understand relevant use cases for impact valuation in financial markets.
- Second, to receive a better sense of the main methodological commonalities across impact methodologies in identifying material value factors and linked activity data.

Impact valuation stands apart from conventional market practices in several key respects:

- Firstly, it extends the risk horizon beyond the typical five-year span, thereby accommodating a more comprehensive assessment of long-term implications. This expanded timeframe not only aids in quantifying materiality effectively but also facilitates the identification of pertinent stakeholders, equipping them with a foundational comprehension of the operational context of the reporting entity.
- Secondly, the holistic nature of impact valuation enables a balanced evaluation across diverse sectors, impact drivers, and projects, fostering a nuanced understanding of societal contributions and comparability with traditional financial reporting via monetarization.
- Moreover, it emphasizes the significance of incorporating data from the indirect value chain, transcending traditional metrics to encompass factors spanning different tiers. These distinctive characteristics collectively underscore the transformative potential of impact valuation within the broader landscape of financial evaluation and decision-making processes.

The operational mechanism of impact valuation is structured around a straightforward impact measurement and valuation methodology. Ideally, reported data in activity metrics are multiplied by corresponding impact value factors to derive valued impact. Alternatively, when reported data is lacking or insufficient, estimations based on the same metrics are employed, which are then multiplied by the same value factors. Hence, the data source may shift but the valuation technique remains the same.

In navigating the landscape of impact valuation, several challenges emerge. Foremost among these is the limited availability of granular data, particularly concerning activity metrics and value factors, often compounded by the absence of location-specific data. Furthermore, the presence of multiple approaches to impact valuation poses a significant hurdle, as these approaches may vary widely in methodology and outcomes, leading to limited comparability between assessments.

To address the complexities of impact valuation, various solutions have been proposed. One such solution involves a strategic trade-off between bottom-up and top-down methodologies, where the choice between granularity, coverage, and comparability is carefully

[1] Impact valuation is the process of assessing the value of measured impacts from the perspective of affected stakeholders or society.

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balanced. Additionally, leveraging input-output tables and artificial intelligence presents promising avenues to overcome data granularity limitations, thereby enhancing the accuracy and reliability of impact assessments.

While a bottom-up approach offers detailed insights into specific activities and impacts, it may sacrifice broader coverage and comparability. Conversely, a top-down approach provides a broader assessment across sectors, enhancing coverage and comparability, albeit potentially at the expense of granularity. Additionally, leveraging input-output tables and artificial intelligence shows promise in overcoming data granularity limitations, facilitating more comprehensive datasets for informed impact valuation practices. Combinations of these approaches are possible as well.

To better understand the landscape of impact accounting and the user cases that apply the value factors, the document follows the following structure: The first part briefly introduces impact valuation as a concept. The second part documents the impact valuation techniques and methodologies applied by impact valuation providers. The individual chapters are introduced with a general overview and relevant description of the individual value factors and activity data, followed by separate descriptions for each valuation technique by value factor and provider name. The providers chose different degrees of granularity in documenting their methodological approaches, input data, and valuation techniques.

Various methodologies assess measured activity data, considering externalities like mitigation or damage costs, as well as objective well-being metrics, such as health, and subjective well-being measures. Market prices are often insufficient due to missing markets, except for carbon credit markets. Some methods evaluate costs involved in product or service creation beyond market dynamics. Frameworks like those from IPCC and IPBES guide general, environmental, and social cost analysis, as applicable.

1.1 State-of-the-art-Assessment of Value Factors

The Impact Valuation Sprint is the second version of the multi-stakeholder project comprising experts from the impact ecosystem, corporate entities, financial markets and the public sector, working together to advance the development of impact valuation.[2]

Impact valuation elevates non-financial parameters to the same level of relevance as financial parameters. Among the general benefits of impact valuation, we find comparability across the social, environmental, and economic impact dimensions for decision making. Thanks to impact valuation, instead of considering a variety of “non-financial” parameters in isolation, all business activities affecting society are brought into one joint view, and the effects are expressed in common units.

Value factors vary depending on the specific use case. Users determine these factors based on their needs, beginning with internal decision making and management reporting, and expanding into areas such as external reporting and stock selection over time. Recalling that value factors can also deviate due to different scopes of analysis, e.g., local trade-offs vs. global views, the conversion of non-financial variables into monetary terms relying on these value factors can results in different outcomes depending on the intended application. For this

[2] West, Dennis and Euler, Dimitrij – Agile Sustainable Development: A Primer on Corporate Impact Indicators and Valuation Factors via Agile Models (August 2023). Available at SSRN: https://ssrn.com/abstract=4545204 or http://dx.doi.org/10.2139/ssrn.4545204.

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reason, there are variations in the value factors used and in the results achieved by impact valuation practitioners. In response, this Impact Valuation Sprint aims to compare value factors, clarify differences in their calculations, and illustrate how these variations could be linked to various use cases.[3] Hence, when applying impact valuation, it is important to provide reasons for the use of specific value factors to avoid cherry picking.

1.2 Goal of the Impact Valuation Sprint

The objective of the sprint is to maintain a descriptive approach, capturing the current status, best practices, uncertainties, and gaps. The focus is not to introduce new valuation techniques or factors.

1. Explore the outline for the Impact Valuation Sprint ("Sprint").
2. Consider the coverage of impact drivers ("Driver") within the Sprint, taking into account data availability and methodological transparency.
3. Explore potential business applications derived from the outcomes of the Sprint.
4. Envision impact metrics and valuation techniques utilised in the analysis.
5. Suggest and discuss a structure to organise each impact driver.

To achieve this goal, various providers of value factors have collaborated to present information in a uniform and accessible manner, outlining the impact pathways for each factor, explaining the calculation methodology and specifying the sources of information used for estimates. Additionally, the impact ecosystem has compiled the primary use cases for impact information, highlighting key strengths, identified gaps, and anticipated future developments for impact valuation.

1.3 Scope and Process of the Impact Valuation Sprint

The Sprint conducted an assessment of value factors, analysing their commonalities, uncertainties, and gaps along the Transparent "Natural Capital Management Accounting (NCMA)" methodology 2023 and enhanced with other methodologies in the following eight sessions:

- Week 1: Defined concepts for valuation factors and established a market analysis framework.
- Week 2: Identified and validated environmental impact valuation factors (GHG, Other Emissions, Water, Waste).
- Week 3: Integrated valuation factors and adapted based on user preferences (GHG, Other Emissions, Water, Waste).
- Week 4: Identified social impact valuation factors (Training, Living Wage, Occupational Health & Safety).
- Week 5: Integrated valuation factors and adapted based on user preferences (Training, Living Wage, Occupational Health & Safety).
- Week 6: Validated and refined outcomes of week Sprints 2-5.
- Week 7: Developed documentation and user guides.
- Week 8: Reviewed and finalised deliverables.

[3] For details, see Annex – "Integration of Impact Valuation in Decision Making".

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1.4 Understanding Value Factors: Definition, Use-Cases, and Variability

Value factors help to translate physical or social impacts (also referred to as impact drivers[4]), measured in tonnes of pollution, m³ of water consumption or number of cases, into monetary figures.

These value factors are primarily provided by GIST Impact, WifOR Institute, Upright Project, and VBA / IFVI and cover myriad impact dimensions including Greenhouse Gas Emissions (GHG), Air Pollution, Waste, Water Consumption, Water Pollution, Land Use, Biodiversity, Occupation Health and Safety, Training, Wages, Child and Forced Labour, Human Capital, and Diversity, Equity and Inclusion.

- Environmental Impact
    - GHG Emissions
    - Air Pollution
    - Waste
    - Water Consumption
    - Water Pollution
    - Land Use
    - Biodiversity
- Social Impact
    - Occupational Health and Safety
    - Training
    - Wages
    - Child and Forced Labour
    - Human Capital
    - Diversity, Equity and Inclusion

To provide clarity on impact valuation techniques, each value factor was contextualised within the decision journey. Decisions made based on impact valuation vary across sectors, from product development to investment strategies and corporate governance. This analysis underscores the importance of bespoke approaches in presenting information to decision makers, considering the diverse needs and preferences across stakeholders. Businesses, governments, and stakeholders employ various communication channels and technologies to document, share, and improve impact data, fostering collaboration and sustainability efforts. Depending on the use case, one value factor may be more appropriate than others. Thus, it is important to call out the main use cases and define which qualitative characteristics are more important for each of them.

- Business Processes
    - Investment Strategy and Asset Portfolio Management
        - Asset Owner: requires comparable, relevant, timely data for thematic approaches and due diligence.
        - Asset Management: needs comparable, relevant, timely information for thematic approaches and due diligence.

[4] See Capitals Coalition: Natural, Social & Human Capital Protocol, 2021; Transparent: Natural Capital Management Accounting (NCMA) methodology, 2023; IFVI & VBA: General Methodology 1, 2024.

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- Strategic Management and Board Governance
  - Board Member: seeks comparable, timely data on strategic objectives and risks via dashboards.
  - Company Secretary: requires comparable, accurate, timely insights into strategic objectives via dashboards.
- Stewardship / Engagement
  - C-Level: requires comparable, accurate data on strategic objectives and risks via dashboards.
  - Asset Management: needs comparable, accurate, timely data for alternative, long-term objectives via comprehensive performance reports.
- Procurement and Supply Chain Management
  - Procurement and Supply Chain Management: requires verifiable, comparable, timely information for stakeholder preferences via interviews, audits, and ratings.
- Product Development
  - Product and Development: seeks comparable information for stakeholder preferences, alternatives, and long-term risks via engineering and science channels.
- Research and Development
  - Research and Development: needs comparable information for stakeholder preferences, alternatives, and long-term planning via engineering and science channels.
- Operations and Technology
  - Operations and Technology: requires verifiable, comparable, timely information for stakeholder preferences and alternatives via engineering and science channels.
- Human Resource
  - Human Resources: requires comparable, timely information for stakeholder preferences, impact profiles, and internal messages.
- Investment Banking
  - Investment Banking: needs verifiable, comparable, timely information for impact profiles and risk profiles via due diligence, terminal.
- Customer Service
  - Customer Service: requires comparable, timely information for stakeholder preferences via feedback analysis and performance metrics.
- Claims
  - Claims: needs verifiable, accurate, timely information for risk profiles, impact profiles via disputes and mediation.
- Risk Management
  - Risk Management: requires verifiable, accurate, relevant, timely data for risk profiles, impact profiles via risk assessment and mitigation strategies.
- Financial Planning
  - Finance: requires relevant, accurate data for risk profiles, long-term planning via financial analysis, and investment strategies and is also a provider of underlying data for stakeholders to determine impact materiality under CSRD/ESRS.

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- Sales and Marketing
  - Sales and Marketing: seeks comparable, relevant information for impact profiles via lead generation and market research.
- Disclosure
  - Compliance and Legal: needs accurate, relevant, timely data for risk profiles via regulatory compliance, and risk management, e.g. supports disclosure of regulatory requirements such as CSRD/ESRS.
  - Quality Assurance: requires accurate, relevant, timely data for risk profiles via regulatory compliance and risk management.
  - Finance and Accounting: needs accurate, relevant, timely data for risk profiles via regulatory compliance and risk management.
- Communications and Public Affairs
  - Investor Relations: requires comparable, relevant, timely data for impact profiles via stakeholder communication and investor engagement.
  - Rating Agencies: need accurate, verifiable, timely data for long-term, alternatives via credit assessment and industry comparisons.
  - Customer Experience: requires comparable, relevant, timely data for deciding among alternatives, impact profiles, risk via journey mapping, and satisfaction surveys.
  - Customer Service: need accurate, verifiable, timely data for deciding alternatives, impact profiles, risk via issue resolution, and satisfaction monitoring.
- Others

- Government Areas
  - Policy and Regulation
  - Investment and Strategic Planning
  - Promoting Social and Environmental Practices and Ensuring Corporate Accountability
  - Others
- Civil Society Organisations
  - Promote Transparency and Trust-Building
  - Ensuring Stakeholder Accountability
  - Promote Social and Environmental Conduct
  - Others

Each value factor provider responds to its unique purpose; differences have been identified in the following areas:

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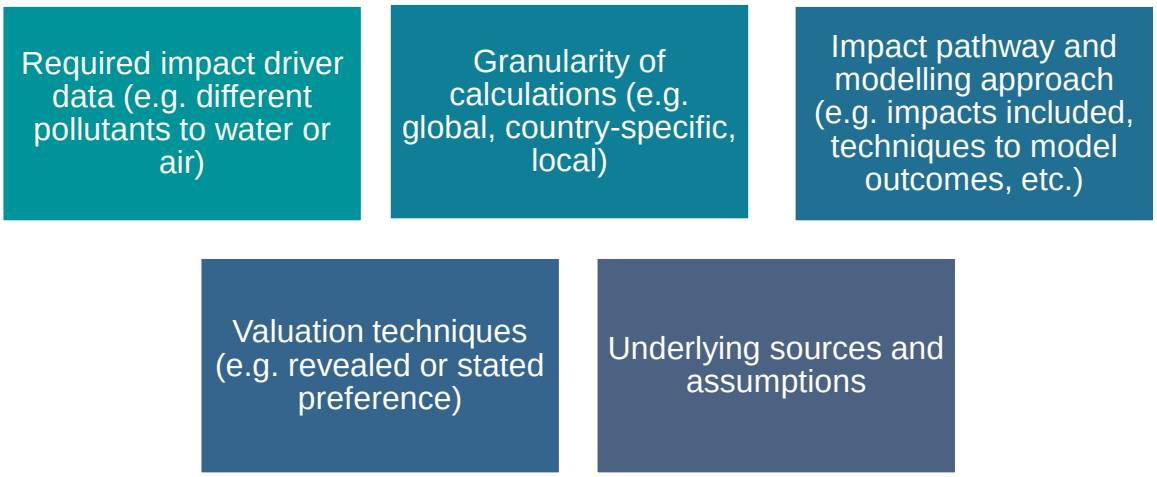

To help impact valuation practitioners in their analysis, this document presents the detailed methodologies of each value factor provider on each topic following a common structure:

- Introduction and Impact Pathway
- Calculation Logic
- Data Sources

1.5 Environmental Impact Valuation

Overall, environmental value factors present more robustness and consistency across providers than value factors for social topics. The starting point for the comparison of environmental value factors is the Transparent Project and its Natural Capital Management Accounting Methodology, developed under the mandate of the EU Commission and subjected to a public consultation.

GHG: Various methodologies, such as NGFS models (MESSAGEix-GLOBIOM, GCAM, Remind-MagPie), GIST Impact, and WifOR Institute, demonstrate significant similarities in assessing greenhouse gas emissions. These approaches effectively integrate energy and land use systems while employing economic valuation techniques. Despite challenges, like uncertainties in parameters and incomplete representation of feedback mechanisms, these methodologies showcase promising advancements in climate modelling.

The methodologies discussed for valuing the effects of GHG emissions share numerous commonalities, offering a comprehensive approach to assessing their impact. They prioritise evaluating GHG emissions based on their GWP and seamlessly integrate energy and land use systems. Utilizing IAMs and cost valuation techniques, they provide a holistic view of impacts across various sectors. Recent advancements in IAM models, including the integration of climate adaptation and the incorporation of up-to-date research, signify promising steps towards addressing these challenges and enhancing the effectiveness of climate modelling efforts.

Air Pollution: Value factor distributors for air pollution employ monetization approaches to assess environmental impacts, primarily focusing on human health considerations. However, there is an opportunity to expand these assessments to incorporate non-monetary values such

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as cultural and ecological impacts, enhancing the comprehensiveness and inclusivity of the evaluation process.

Value factor providers for other air pollution demonstrate a commendable commitment to assessing the impact of air pollutants comprehensively. Their approaches encompass a wide range of pollutants, including NH3, NOX, PM10, PM2.5, and SOX, reflecting a thorough understanding of the diverse environmental challenges posed by air pollution. Notably, these providers consistently prioritize human health considerations while also addressing visibility and agriculture impacts along the impact pathway. Additionally, some providers employ standard valuation techniques, such as stated or revealed preference approaches, to ensure robust estimations that can be adapted to various geographical regions. Furthermore, certain approaches offer value factors with detailed population density considerations, showcasing a nuanced understanding of localized environmental dynamics. While there is room for improvement in considering cultural or ecological impacts, these efforts underscore a positive trajectory toward more holistic assessments of air pollution impact.

Solid Waste: Approaches for waste disposal impact assessment, such as Transparent, VBA, GIST Impact, and WifOR Institute, provide comprehensive analyses but face gaps in assessing broader social and economic impacts and incorporating stakeholder perspectives.

The investigated methodologies for assessing the impact of solid waste treatment, share commonalities in their analysis of waste treatment methods, monetization of impacts, and focus on environmental and health factors. They leverage diverse data sources, models, and frameworks to provide evaluations of waste management practices. In an analogous way to air pollution, some methodologies incorporate country-specific data and adjust for population density to offer tailored insights. There are gaps, such as the limited consideration of broader social and economic impacts, incomplete assessment of environmental impacts beyond air and water pollution, and challenges related to data transparency and accessibility.

Water Consumption: Methods for valuing water consumption impacts, like Transparent, VBA, GIST Impact, and WifOR Institute, vary in coverage and applicability, with differences in methodologies and considerations of contextual factors like purchasing power parity and water scarcity.

The Transparent approach demonstrates a commendable focus on prioritising human health and resource costs, showcasing a commitment to addressing fundamental environmental and societal concerns. Employing stated preferences and cost-based valuation techniques, this approach ensures robust assessments while offering transparency in its methodology. Similarly, VBA's country-level summation method enables a comprehensive evaluation of impacts, including considerations such as malnutrition, water-borne diseases, and future resource costs. GIST Impact and WifOR Institute employ sophisticated models and monetization methods, respectively, reflecting a dedication to providing versatile solutions applicable across various impacts and sectors. Despite their differences, all approaches exhibit a holistic understanding of impact dimensions, leveraging external data sources and models to enhance accuracy and reliability. Furthermore, their adjustments for factors like purchasing power parity and future costs underscore their adaptability and forward-thinking approach. Additionally, the consideration of regional water scarcity levels further enhances the granularity and relevance of the value factors, highlighting a commitment to contextualizing impact assessments for diverse geographical contexts.

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Water Pollution: Assessment approaches for water pollution by Transparent, VBA, GIST Impact, and WifOR Institute monetize impacts but differ in data transparency, impact scope, valuation techniques, and consideration of contextual factors.

The methodologies employed in evaluating water pollution demonstrate a commendable commitment to comprehensively understanding its multifaceted impacts. Each approach meticulously considers a diverse array of consequences, ranging from human health and property values to biodiversity and water treatment costs, ensuring a thorough assessment of the repercussions of water pollution. By incorporating specific value factors to monetize these impacts, they facilitate a clearer understanding of the financial implications associated with pollutant quantities. While variations exist in the scope of impact assessment, valuation techniques, and consideration of contextual factors like purchasing power parity and water scarcity, these differences underscore the adaptability and flexibility of the approaches to diverse environmental contexts.

Land Use: Land use impact assessment approaches by Transparent, VBA, GIST Impact, and WifOR Institute encompass economic productivity, human health, and ecosystem services but lack explicit clarity on valuation methods and consistency in considering health impacts and cultural values.

The evaluation of land use impacts by various value factor providers demonstrates a commendable breadth of considerations, encompassing economic productivity, property values, human health impacts, cultural values, and changes in ecosystem services. These assessments are underpinned by a meticulous blend of data sources and analytical techniques, including LCA databases, EEIO models, reported datasets, and GIS processing, ensuring a robust and scientifically rigorous measurement process. While different valuation methods are employed to suit the diverse impacts associated with varying land types and locations, the implicit use of valuation techniques underscores a commitment to accurately capturing the financial implications of land use decisions. Moreover, the varying approaches to addressing health impacts reflect a nuanced understanding of the multifaceted nature of land use effects, demonstrating adaptability to different assessment contexts. Although there are discrepancies in the explicit consideration of cultural values and the allocation of impacts based on economic or environmental factors, these variations signal opportunities for further refinement and enhancement of assessment methodologies. By addressing these nuances, the potential exists to enrich the comprehensiveness and transparency of land use impact assessments, ultimately facilitating more informed decision making in land management practices.

Biodiversity: The approaches used to quantify human activity impacts on biodiversity using different methodologies may lack comprehensive consideration of socioeconomic factors and dynamic ecosystem processes, indicating potential gaps in their approaches.

1.6 Social Impact Valuation

Health and Safety: Different methodologies are used to value occupational health and safety incidents, with one focusing more on monetary aspects and the other incorporating monetary metrics.

Training: In training activities, one approach emphasizes adjustments based on education and socioeconomic parameters, while the other highlights economic benefits such as higher wages and productivity.

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Wages: Various methodologies for evaluating wages prioritise equity and well-being but face challenges like data availability and subjectivity.

Child Labour and Forced Labour: The approaches used assess the impacts of child labour and forced labour, with one using a net present value approach and the other focusing on mental health repercussions and financial exploitation. Valuation approaches differ as some methodology strictly assess their supply chain or portfolio, disregarding own operations. This leads to estimated valuations due to insufficient reported data.

Diversity, Equity, and Inclusion: One method quantifies the impact of gender pay disparities on societal well-being using DALYs, highlighting the economic costs of gender inequality.

Additional Social Impacts: Different frameworks evaluate business impacts on human capital, with one leaning towards quantitative metrics and the other offering a broader evaluation, including diversity and inclusion outcomes.

1.7 Outlook

Value factor providers prioritise understanding their users' needs and advocate for increased confidence in value factor application, considering philosophical, worldview, and valuation technique nuances, including the value transfer mechanism. Embracing these criteria represents a significant stride for the impact accounting community. It is expected that, in other arenas such as the Global Value Commission, a more user-centric approach will soon be adopted.

While data providers offered full transparency regarding impact pathways and insights into value factor calculation logic, there remains a need for more comprehensive information to establish an independent calculation logic and value transfer mechanism. Enhancing transparency in these aspects could significantly boost confidence in impact accounting methodologies and will further increase comparability and accuracy.

During this Sprint, value factor providers predominantly employed a bottom-up approach, with attention now turning to industry-specific impacts, commonly known as "product impacts". While some approaches touch on uncertainty analyses, there is an opportunity to increase confidence by integrating comprehensive uncertainty assessments into value factor methodologies.

1.8 Items for Future Sprint / Backlog

User-centric Approach: Value factor providers prioritise understanding users' needs and advocate for increased confidence in application, considering philosophical, worldview, and valuation technique nuances.

Stocks and Flows: Implement value factor methodologies that address both needs of the value factor community.

Advocate for Transparency: While data providers offer transparency regarding impact pathways and value factor calculation logic, there is a need for more comprehensive information to establish independent calculation logic and value transfer mechanisms.

Industry-specific Focus: Value factor providers predominantly employ a bottom-up approach, shifting attention to industry-specific impacts, known as "product impacts".

Address Uncertainty: There is an opportunity to increase confidence by integrating comprehensive uncertainty assessments into value factor methodologies.

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Impact on the Accounting Community: Embracing user-centric criteria represents a significant stride for the impact accounting community, with a more user-centric approach in arenas like the Global Value Commission expected soon.

Addressing the Theory of Change: While, to allow for different use cases and experimentation, there should not be one single methodology, there is also need for comparability and broader access to a consistent, credible, methodology for broad uptake and adoption.

Establishing a Credible Public Good Methodology: There ought to be one foundational credible public good methodology that can enable this broad adoption and comparability.

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2 SUMMARY OF THE CHAPTERS

ENVIRONMENTAL

2.1 Greenhouse Gas (GHG) Emissions

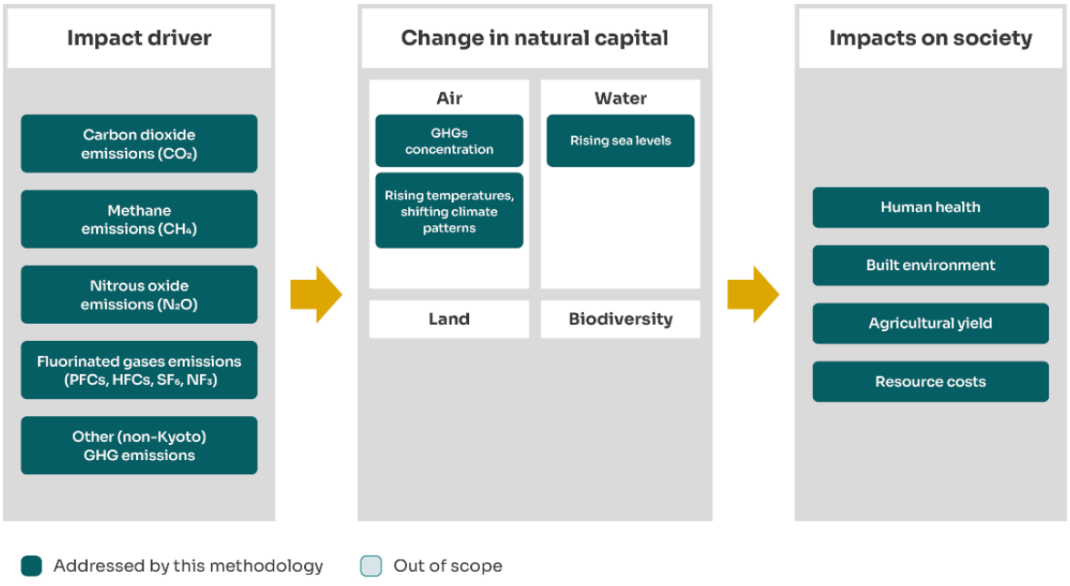
2.1.1 Challenge

The challenge of GHG presented revolves around the significant role greenhouse gases (GHGs) play in climate change, a phenomenon driven by human activities such as burning fuels and deforestation. These gases, including carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), contribute to global warming and consequential climate-related impacts, such as altered weather patterns and rising sea levels. Addressing this challenge aligns with Sustainable Development Goal (SDG) 13, which aims to combat climate change by reducing GHG emissions globally and enhancing resilience to its impacts. Key international bodies like the IPCC and the UNEP provide essential scientific evidence and assessments to inform climate policies and actions worldwide.

Collecting activity data for own operations, upstream and downstream, involves gathering quantitative information about topics like energy consumption and fuel usage from respective departments, while collaboration with external stakeholders is necessary for obtaining data on Scope 3 emissions along the value chain. This meticulous process ensures a comprehensive approach to greenhouse gas accounting and is crucial for accurate emission calculations and alignment with industry standards.

2.1.2 Transparent Natural Capital Management Accounting (Transparent)

The Transparent Natural Capital Management Accounting (NCMA) methodology underscores the critical role of the Earth's atmosphere in supporting life and highlights concerns over recent atmospheric changes leading to global warming. The methodology outlines approaches for quantifying the economic impact of greenhouse gas emissions, suggesting the use of either social costs of carbon or marginal abatement costs to compute a monetary value of the impacts.



[Source: GHG Impact Pathway / Transparent]

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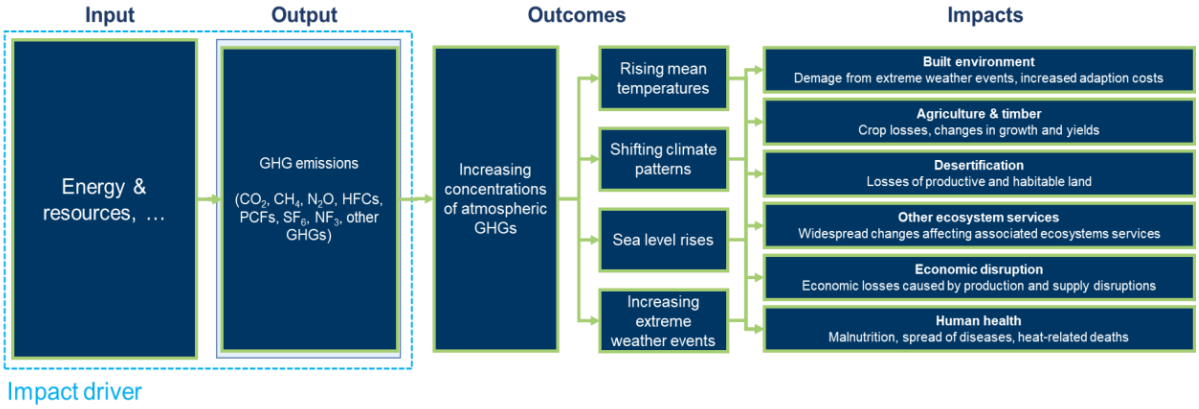
2.1.3 WifOR Institute

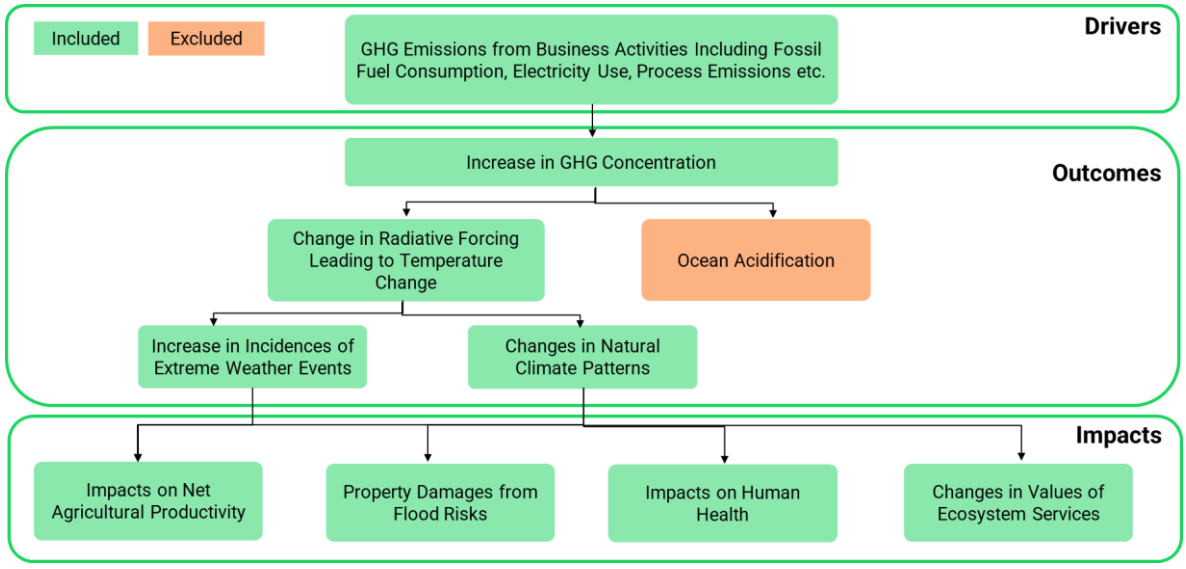
The WifOR Institute approach for valuing greenhouse gas emissions involves assessing the impacts of CO2, CH4, and N2O based on their GWP over a 100-year period. Activities per country/sector are aggregated into CO2eq using GWP factors, and the monetized impact is calculated by multiplying the activity data by the value factor (social cost of carbon). The valuation considers various impacts such as economic damage to the built environment, agriculture, ecosystem services, and human health, with data sourced from the UBA and modelled using the IAM model FUND, resulting in a global monetary valuation of environmental damage.



[Source: GHG Impact Pathway / WifOR Institute]

2.1.4 GIST Impact

The framework adopted by GIST Impact for valuing GHG emissions employs the SCC approach, considering the damage costs associated with global warming and its impacts. This method factors in the investment needed to mitigate future damage from current GHG emissions, accounting for the incremental concentration of GHGs and the global nature of climate change impacts. Utilising IAMs such as FUND, DICE, and PAGE, projections and long-term impacts of GHG emissions are estimated. The calculation logic involves determining the cost or benefit of GHG release based on quantities emitted or avoided in a year and the associated social cost of GHGs, sourced from reputable studies and technical documents including those from USEPA and the White House.



[Source: GHG Impact Pathway / GIST Impact]

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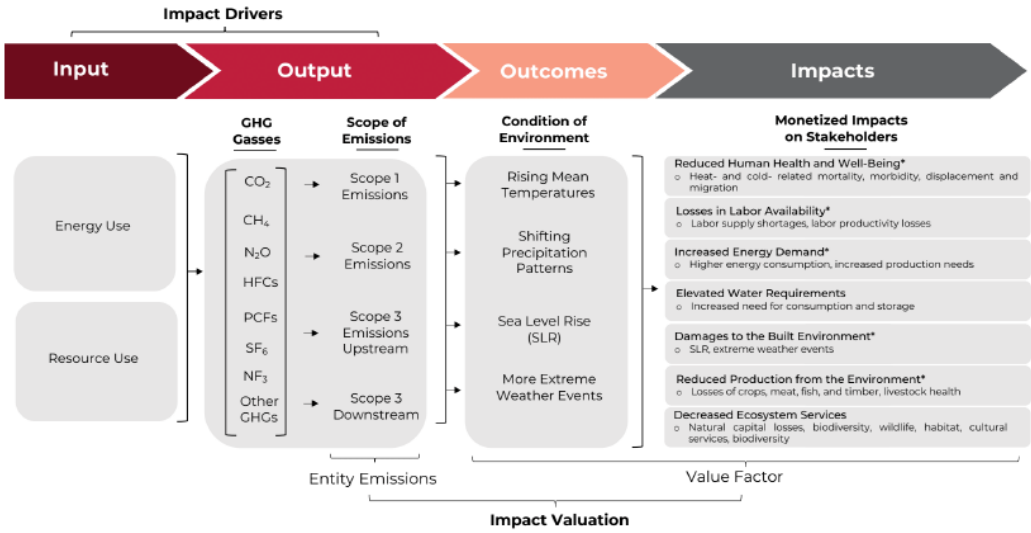
2.1.5 Upright Project

Upright utilises a proprietary net impact model to generate GHG emission data for companies, employing a top-down approach to allocate emissions accurately. The monetary impact of emissions is calculated by multiplying the sum of CO2 equivalent activity data by the global SCC. The monetization factor of USD 417 per tonne of CO2 is based on the study published in Nature Climate Change in 2018 by Ricke, Drouet, Caldeira, et al., titled “Country-level social cost of carbon” and serves as the foundation for Upright's valuation, with thorough consideration given to various authoritative sources and mainstream research on SCC, ensuring consistency and reliability in their calculations. Geographical differences in monetizing GHG emissions are not currently accounted for in Upright’s methodology.

2.1.6 IFVI / VBA

The approach outlines the process of valuing GHG emissions using the SCC approach, which considers impacts on human health, energy demand, infrastructure, and more. Two models, the Greenhouse Gas Impact Value Estimator (GIVE) and the Data-driven Spatial Climate Impact Model (DSCIM), are utilised to determine the value factor for GHG emissions, integrating various modules such as socioeconomic, climate, damage, and discounting considerations. These models assess the societal costs associated with each metric tonne of CO2 equivalent emitted, providing a comprehensive framework for understanding the economic impacts of GHG emissions on a global scale.



[Source: GHG Impact Pathway / IFVI / VBA]

2.1.7 CE Delft

CE Delft utilises various databases including NER, GGGI, and EDGAR, for GHG emission data. They apply the ReCiPe method to convert emissions into CO2 equivalents, considering factors like GWP. Additionally, they incorporate improvements from the EEA 2021 methodology and provide environmental prices from their publications for valuation purposes.

2.1.8 NGFS MESSAGEix-GLOBIOM

The MESSAGEix-GLOBIOM IAM is a comprehensive tool used for analysing energy systems, land use, and climate change, allowing for the assessment of various scenarios and policies. It has been employed in several IPCC reports, including the Fifth and Sixth Assessment Reports, utilising SSPs to depict different future scenarios ranging from *sustainability* to *regional rivalry*. Global carbon prices derived from the model's simulations depict diverse

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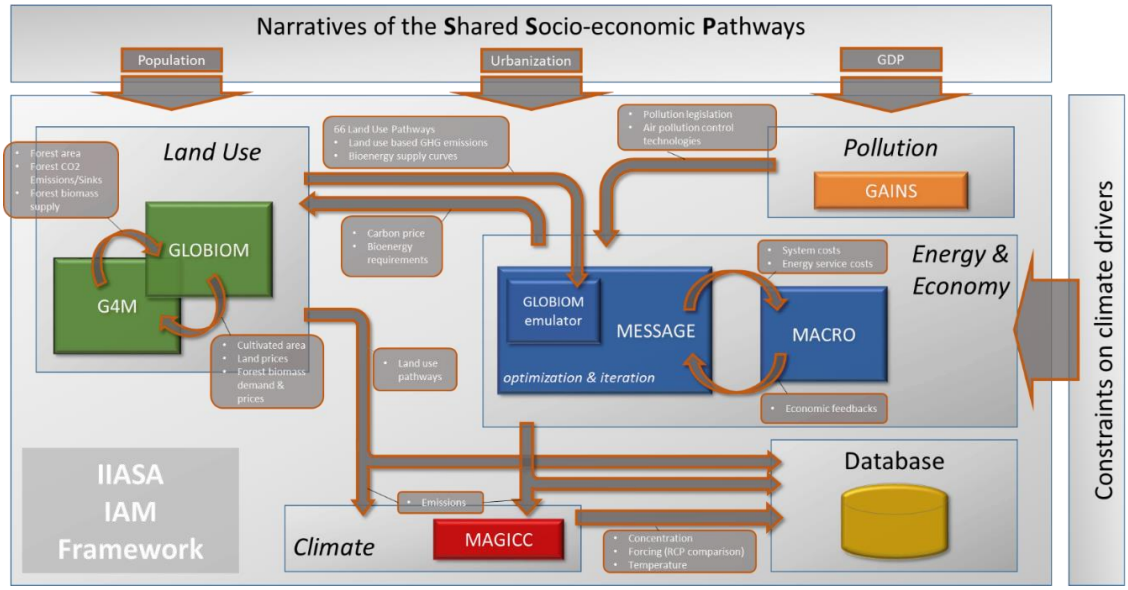
trajectories based on different scenarios, reflecting varying levels of ambition and policy implementation, such as net-zero commitments and current policies.



[Source: MESSAGEix-GLOBIUM, github]

2.1.9 NGFS-GCAM

The GCAM (Global Change Analysis Model) integrates modules for the macroeconomy, energy systems, agriculture, land use, water systems, and the physical Earth system, enabling comprehensive analysis of climate change mitigation pathways and transition risks. Utilising three SSPs from the IPCC, the NGFS GCAM 6.0 model explores scenarios ranging from *ambitious climate action* to *fragmented global cooperation*, providing insights into global carbon prices and region-specific carbon pricing trajectories aligned with different climate goals. These simulations depict varying carbon prices over time, reflecting the impacts of different policy scenarios on emissions mitigation and the transition to a low-carbon economy.

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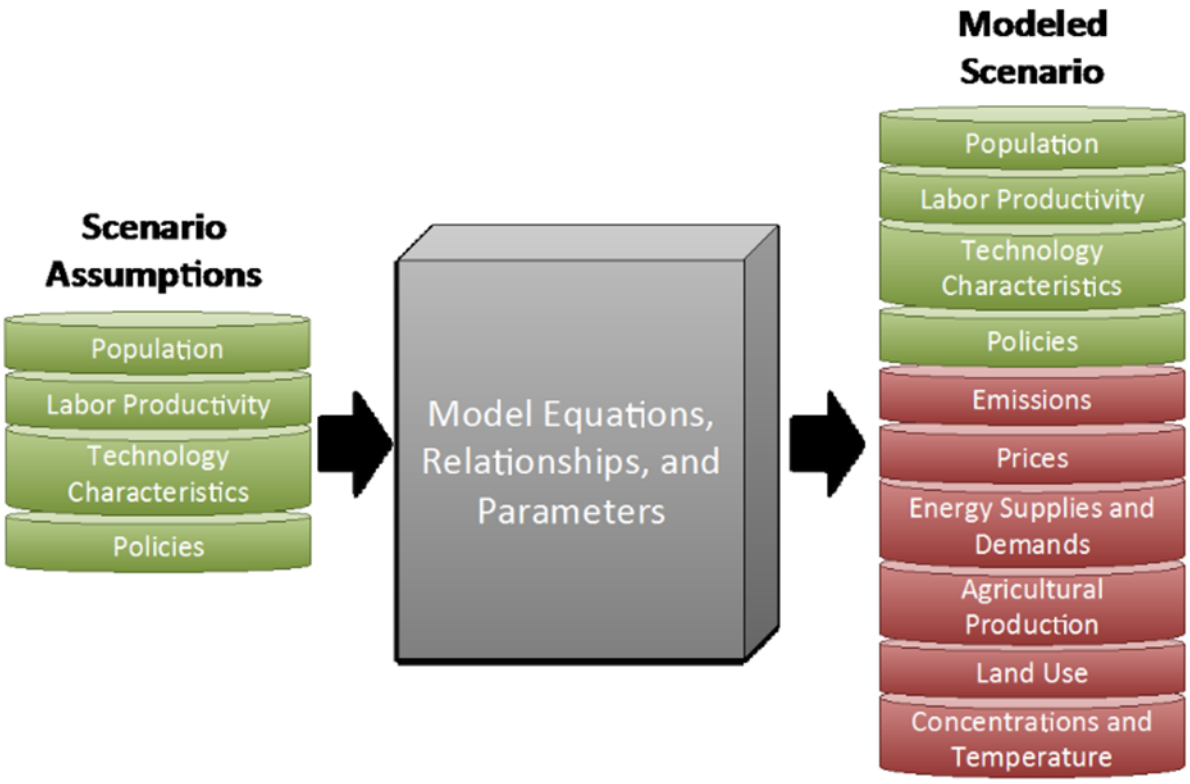
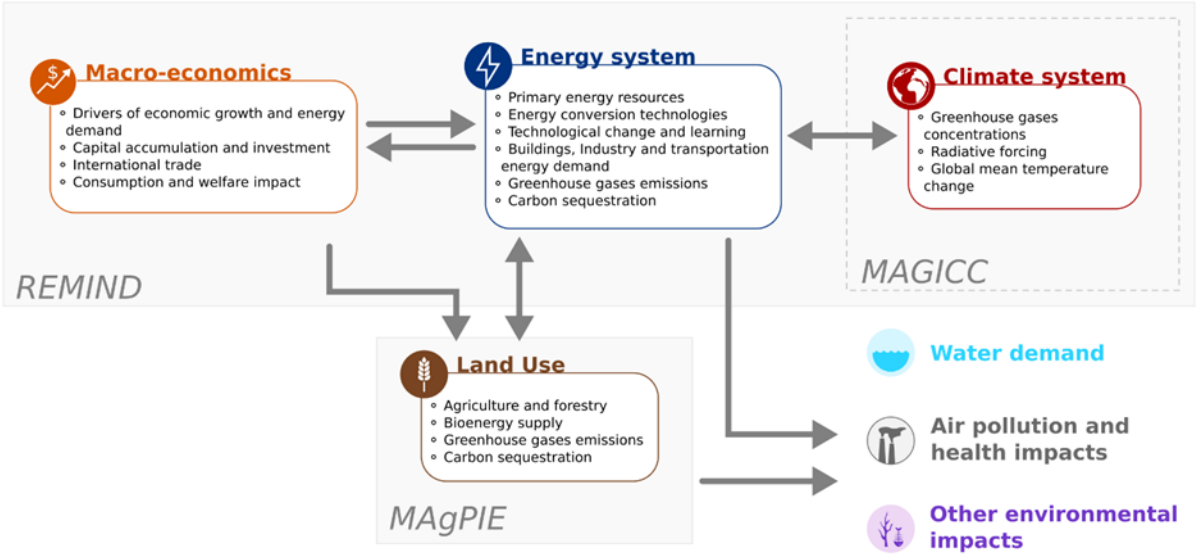


[Source: https://jgcri.github.io/gcam-doc/overview.html]

2.1.10 REMIND-MAgPIE

REMIND (REgional Model of Investment and Development) is an IAM designed to project future global economic and energy sector developments while considering climate implications. It aims to optimise investments across various regions by factoring in population dynamics, technological advancements, policy frameworks, and regional trade patterns. REMIND encompasses all human-induced greenhouse gas emissions in its modelling approach.



[Source: https://www.pik-potsdam.de/en/institute/departments/transformation-pathways/models/remind]

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2.1.11 EPS, Chalmers

The impact of CO2 emissions extends to various environmental and health factors, including climate change, ocean acidification, and adverse effects on human health like cardiovascular diseases and undernutrition. Significant pathways of impact include YLL due to heat stress, undernutrition, and flooding, with undernutrition and decreased working capacity being major contributors to the overall damage cost. Additionally, CO2 emissions affect agricultural productivity, sea levels, extreme weather events, and water quality, highlighting the comprehensive nature of their environmental impacts.

2.1.12 Analysis

The NGFS models, including MESSAGEix-GLOBIOM, GCAM, and Remind-MagPie, employ IAMs to evaluate GHG emissions' impacts on energy, land use, economy, and climate, with a focus on economic valuation techniques and the social cost of carbon. GIST Impact and WifOR Institute also utilise IAMs but emphasise estimating GHG impact costs and benefits across sectors like agriculture, human health, and infrastructure. However, existing methodologies face challenges, such as uncertainties in parameters and assumptions, incomplete representation of feedback mechanisms, data constraints, and limited integration of social and behavioural factors, which could affect the accuracy and comprehensiveness of their assessments.

2.2 Air Pollution

2.2.1 Challenge

Air pollution, originating from industrial activities, involves various pollutants such as PM2.5, PM10, NOx, SO2, VOCs, and NH3, which impact human health, visibility, and agricultural yields locally. Unlike greenhouse gases, these pollutants contribute to local issues like smog and acid rain, aligning with SDGs 3, 11, and 13, which prioritise reducing deaths and illnesses from pollution, improving urban air quality, and addressing climate change. Leading organisations like WHO, EPA, and IPCC have extensively documented the global impacts of air pollution, highlighting the pervasive nature, significant health toll, and urgent need for mitigation to safeguard human health and promote sustainable development.

2.2.2 Activity Data

Collecting activity data for assessing air pollution involves two main methods: direct measurement within facilities for precise, real-time data and the use of standardised emission factors for estimation. Each of the two has its advantages and limitations. A recommended approach integrates both methods to ensure a comprehensive and evolving assessment process, considering resource availability, pollutant specificity, and evaluation precision.

2.2.3 Transparent

The NCMA methodology to calculating the monetized impact of non-GHG air emissions involves using activity data for pollutants like NH3, NOx, PM10, PM2.5, SOx, and VOC/NMVOC, multiplied by corresponding value factors. These value factors encompass components such as human health, visibility (optional), and agricultural yield (optional), with impacts quantified using air dispersion models to reflect local conditions and dose-response functions to assess human health impacts. The final step involves valuing these impacts in monetary terms, utilizing stated or revealed preference approaches for human health and visibility, and market prices for agricultural yield, ensuring a comprehensive assessment of the societal costs associated with air pollution.

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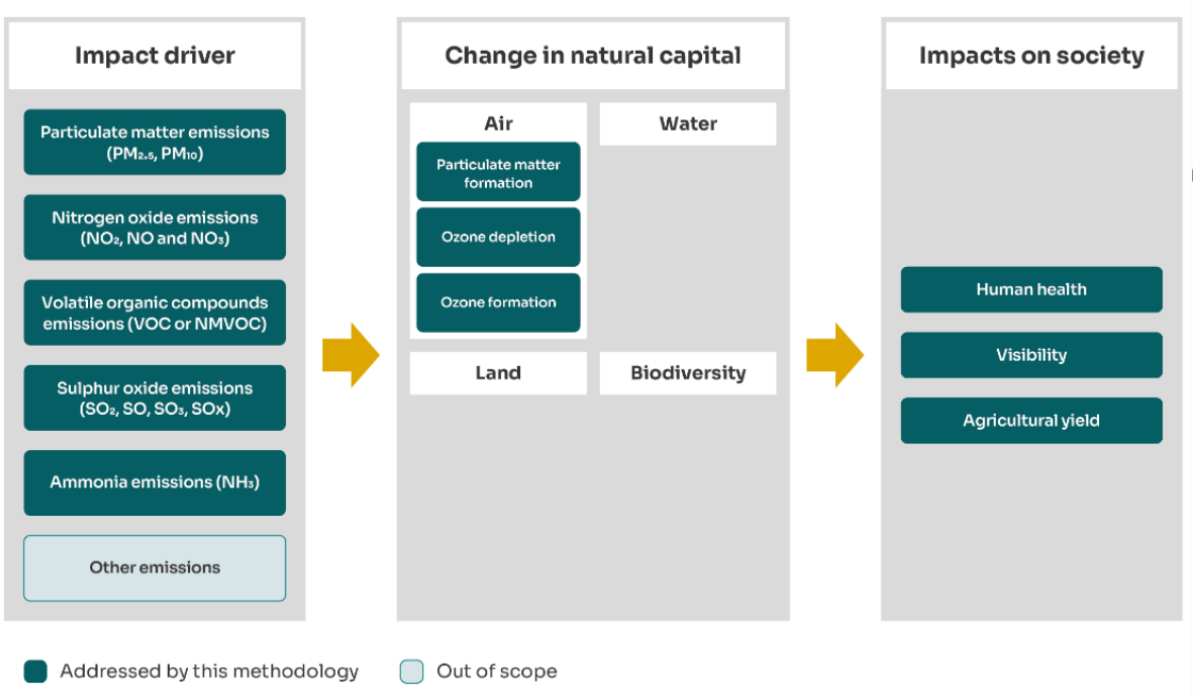

[Source: Air Pollution Impact Pathway / Transparent]

2.2.4 WifOR Institute

The WifOR Institute approach to air pollution assessment emphasises the diverse sources and impacts of pollutants, including PM2.5, PM10, NOx, SOx, NMVOC, and NH3, originating from household combustion, vehicles, industries, and forest fires. Utilising activity data from sources like EXIOBASE 3.8.1., EDGAR, and Eurostat, the method employs simple multiplicative formulas or country/sector-specific approaches to calculate monetized impacts. Valuation methods encompass health damage measured through HUI/DALY, biodiversity loss using the preservation cost approach, crop/harvest damage, and material/infrastructure damage assessed economically. Geographical differences are considered in valuation by incorporating factors like population density, economic dependency on agriculture, and red-listed species count, with Germany serving as a baseline and adjustments made based on population density and biodiversity variations. Overall, the WifOR Institute approach aims to comprehensively evaluate the global damage of air pollution, with estimates reaching up to USD 9.1 trillion in 2020, utilising environmental prices for valuation.

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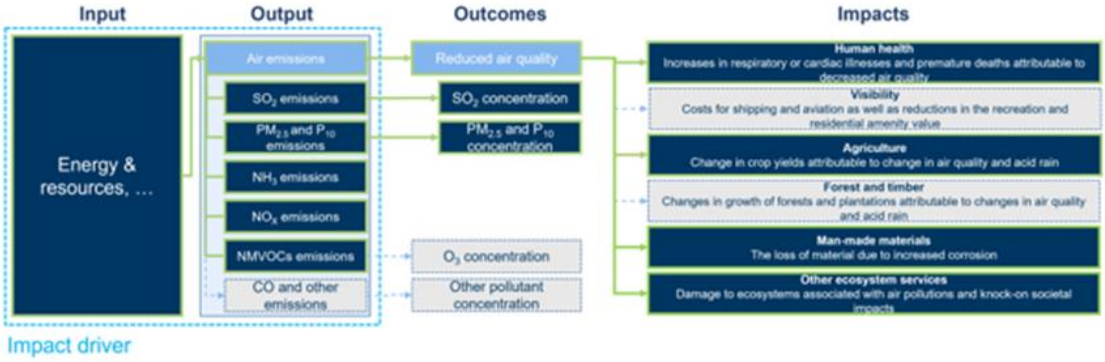
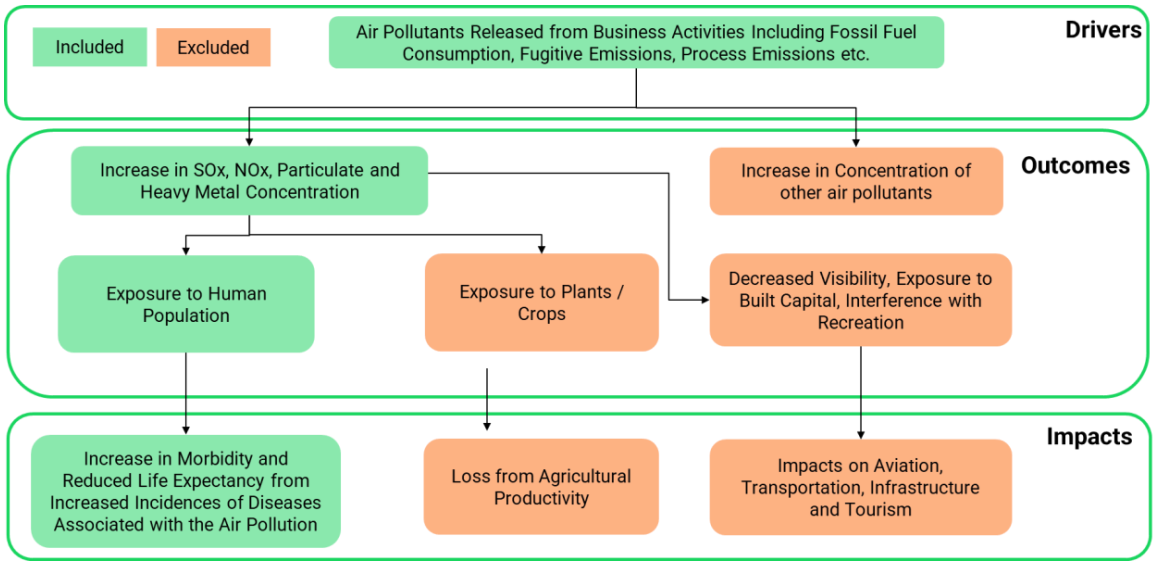


Figure 4: Impact Pathway of air pollution (source: own illustration)

[Source: Air Pollution Impact Pathway / WifOR Institute]

2.2.5 GIST Impact

The GIST approach to evaluating impacts from air pollutants encompasses a comprehensive framework involving multiple stages: understanding drivers of pollutant release, estimating biophysical changes in local environments due to increased pollutant concentrations, and assessing subsequent impacts on human health and other systems. Utilising sources such as emissions data and air dispersion modelling via AERMOD, the method quantifies exposures and health effects associated with pollutants like PM2.5, NOx, and SOx, focusing primarily on human health impacts due to their significant impact contribution. Economic valuation of health impacts is conducted using the hybrid human capital approach, considering both direct costs like medical expenses and indirect costs such as lost DALYs. The GIST approach draws from various reputable sources, including health studies, environmental agencies, and modelling datasets, to provide a comprehensive assessment of air pollution impacts and their economic ramifications.



[Source: Air Pollution Impact Pathway / GIST Impact]

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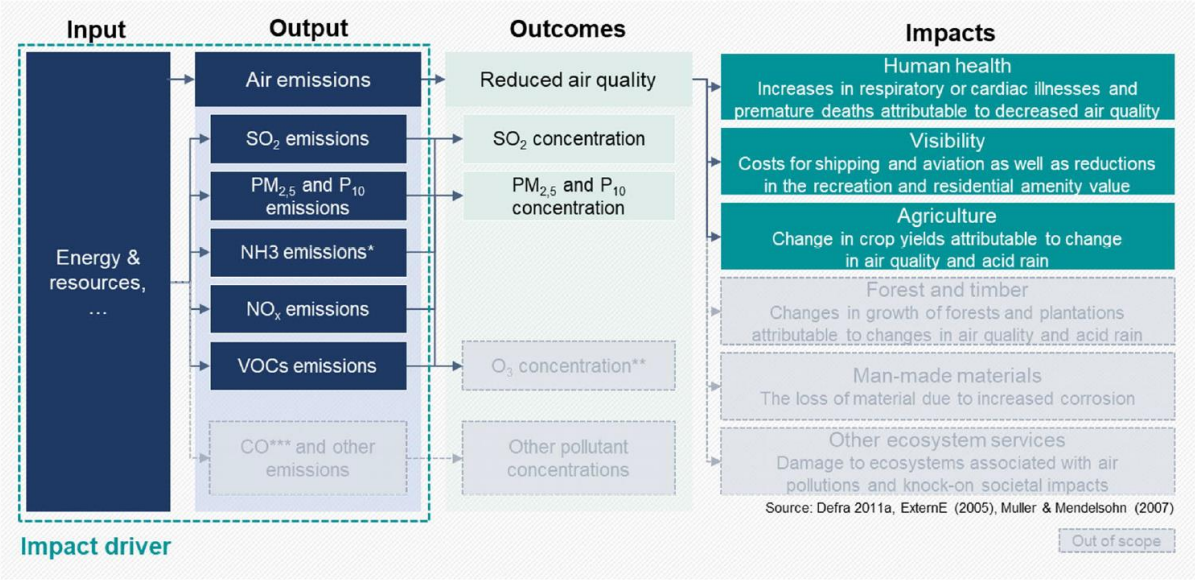
2.2.6 Upright Project

The Upright approach to assessing air pollution focuses on non-greenhouse gas (non-GHG) emissions, consolidating pollutants like particulate matter, heavy metals, and ammonia under this category. Currently, Upright primarily considers the impact of air pollution on human health, utilising sources like the GBD platform and the Lancet Commission on Pollution and Health for data on mortality and health impacts. The monetization of air pollution impacts involves multiplying disability-adjusted life years (DALY) attributed to air pollution by a DALY cost of USD 12,000, providing a quantifiable measure of the health burden associated with different emissions. Upright aims to incorporate additional impacts such as ecosystem damage, built environment degradation, and agricultural effects when reliable sources become available, enhancing the comprehensiveness of its assessment. The approach utilises a top-down methodology to estimate the global cost of air pollution, which can then be allocated to private-sector entities for further analysis.

2.2.7 Value Balancing Alliance

The VBA approach to air pollution assessment focuses on quantifying the societal costs associated with emissions of non-greenhouse gas pollutants. This includes pollutants such as NH3, NOx, PM10, PM2.5, SOx, and VOCs, which can have detrimental effects on human health, visibility, and agricultural productivity. The methodology integrates various models, including air dispersion modelling using Sim-Air ATMOS 4.0, to estimate changes in pollutant concentrations and subsequent impacts on human health, visibility, and agriculture. Valuation of these impacts involves employing dose-response functions for health effects, transferring willingness-to-pay estimates for visibility impairment, and adjusting marginal damage costs for agriculture internationally based on PPP. The approach provides a comprehensive framework for assessing the societal costs of air pollution across different regions and impact drivers.



[Source: Air Pollution Impact Pathway / VBA]

2.2.8 EPS, Chalmers

The EPS Chalmers approach classification of aerosols into dispersion and condensation types aids in understanding their behaviour and impact. Smaller particles, particularly those below 2.5 µm, can deeply penetrate the lungs, exacerbating health risks. However, classification and measurement are challenging due to the diverse nature of aerosols and measurement

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uncertainties, especially at emission sources. Environmental impact factors and monetary valuations for various pollutants like PM2.5, PAHs, arsenic, cadmium, and chromium offer insights into the societal costs associated with exposure, with uncertainties accounted for through log-normal distributions and assumed factors due to limited quantitative knowledge. These factors play a crucial role in understanding and mitigating the impacts of air pollutants on human health and the environment.

2.2.9 Analysis

Five solution providers: Transparent, VBA, GIST Impact, WifOR Institute, and EPS Chalmers, analyse various air pollutants, including NH3, NOX, PM10, PM2.5, and SOX, indicating a comprehensive understanding of environmental impacts. They value aspects such as human health, visibility, and agriculture, showcasing recognition of broader societal and economic consequences beyond health considerations. Employing a monetization approach, they calculate impacts in monetary terms using activity data and value factors for pollutants, ensuring comparability across different impacts.

2.3 Waste

2.3.1 Challenge

Measuring and managing solid waste, both hazardous and non-hazardous, is critical for assessing environmental impacts and ensuring transparent reporting. Solid waste disposal leads to various environmental consequences, including air pollution, climate change, landscape degradation, and soil and water contamination, affecting public health and agricultural yields. Sustainable waste management practices are vital for regulatory compliance, informed decision making, and achieving SDGs related to inclusive cities, resilient infrastructure, economic growth, and sustainable consumption (SDG 11 aims to foster inclusive, safe, resilient cities with Target 11.6 to reduce environmental impact, while SDG 9 promotes sustainable industrial development with Target 9.5 focusing on early warning systems for climate change, alongside SDG 8 advocating for decent work with Target 8.8 emphasising safe working environments including waste management, and SDG 12 promoting sustainable consumption with Target 12.3 concentrating on reducing food waste in the supply chain). International organisations such as UNEP, OECD, WHO, ILO, and UNIDO provide valuable insights and strategies to address global waste management challenges and promote sustainable practices for a healthier and more resilient future.

2.3.2 Activity Data

To comprehensively evaluate the environmental impact of waste, systematic collection of primary data is vital, including categorisation into hazardous and non-hazardous types, differentiation of disposal methods, and adherence to emission factors and local regulations.

2.3.3 Transparent

Transparent focuses on the environmental impacts of solid waste disposal, emphasizing its adverse effects on natural capital and human well-being. It outlines the key factors influencing these impacts, including the type of waste and disposal method. The methodology considers impacts on society through human health, agricultural yield, and amenity. Impacts due to GHG and non-GHG emissions are modelled based on the respective topic methodologies.

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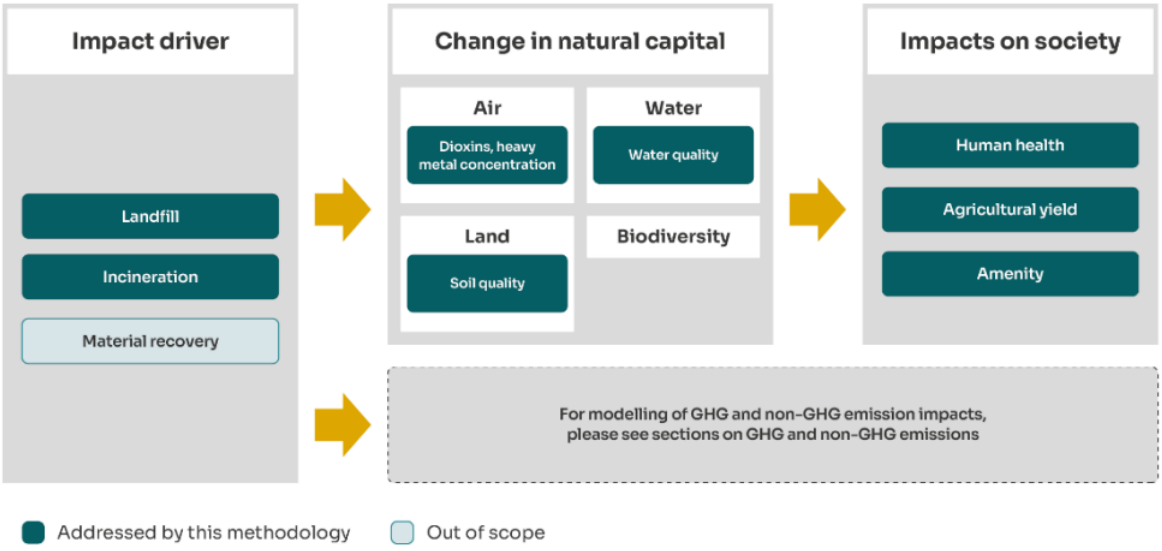
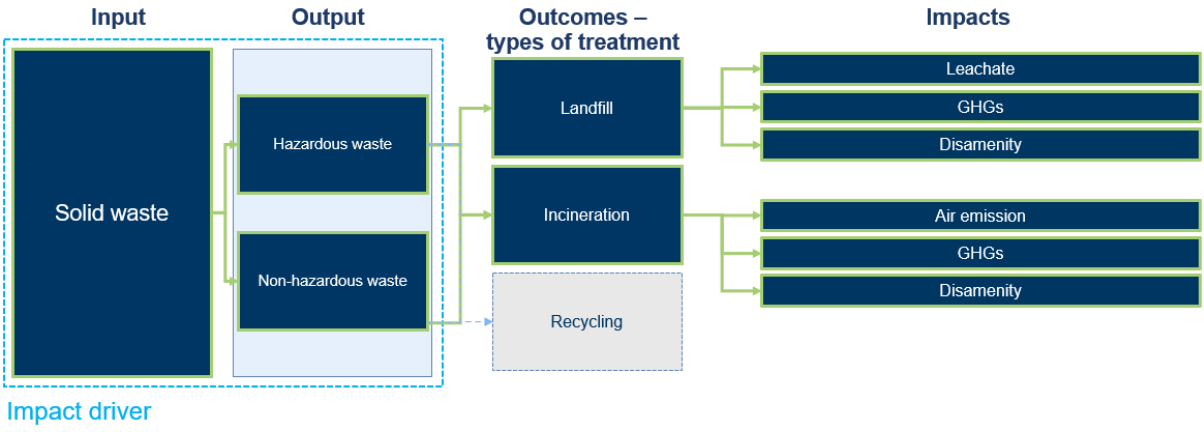


[Source: Waste Impact Pathway / Transparent]

2.3.4 WifOR Institute

WifOR Institute employs a comprehensive approach to assessing the environmental impacts of waste, utilising activity data from sources like EXIOBASE HYBRID and categorising waste into hazardous and non-hazardous subcategories. Their formula for monetized impact calculation is country and sector-specific, considering factors like GHG emissions, air quality, disamenity, and leachate, with valuation methods ranging from health impacts to WTP via hedonic pricing. Valuation data is drawn from sources such as EXIOPOL and PwC, with geographical differences weighted by population density. The approach also accounts for waste specifics, including disposal methods and recovery processes, ultimately aiming to quantify global damage and provide environmental prices for informed decision making.



[Source: Waste Impact Pathway / WifOR Institute]

2.3.5 GIST Impact

The evaluation framework and methodology outlined by GIST Impact consider various business activities as drivers of hazardous and non-hazardous waste generation, with end-treatment technologies like incineration and landfilling leading to environmental impacts. Calculation logic involves assessing externalities related to waste treatment and disposal, with emissions from different disposal methods such as incineration, landfilling, composting, recycling, and dumping analysed for their respective impacts. Data sources include

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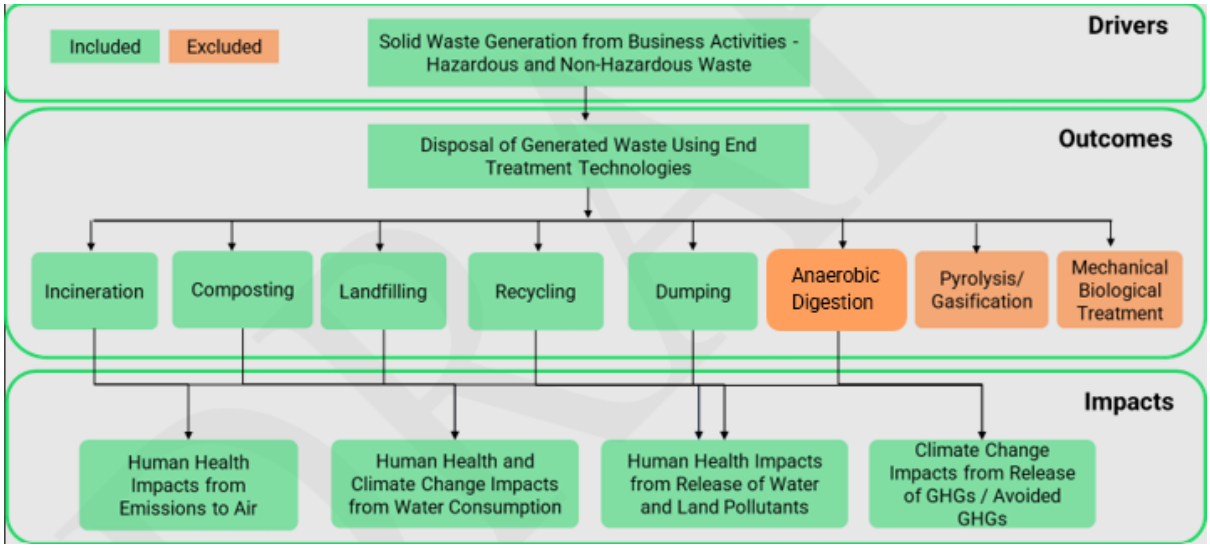
comprehensive reviews and studies on waste management and its environmental effects, as well as specific research on emissions and impacts from various waste treatment methods. The methodology aims to quantify the impacts of waste generation using tonnage disposed and value factors for different disposal methods, providing insights into the environmental consequences of waste management practices.



[Source: Waste Impact Pathway / GIST Impact]

2.3.6 Value Balancing Alliance

The approach presents a methodology for quantifying and valuing the societal cost of solid waste disposal, focusing on environmental impacts in monetary terms. It covers various aspects such as GHG emissions, disamenity, leachate release, and air pollution, providing specific calculation logic and value factors for each. The methodology utilises data from multiple sources and employs different models, including the societal cost of carbon, hedonic pricing, hazard rating systems, and dose-response functions, to estimate the monetary impacts associated with waste disposal.

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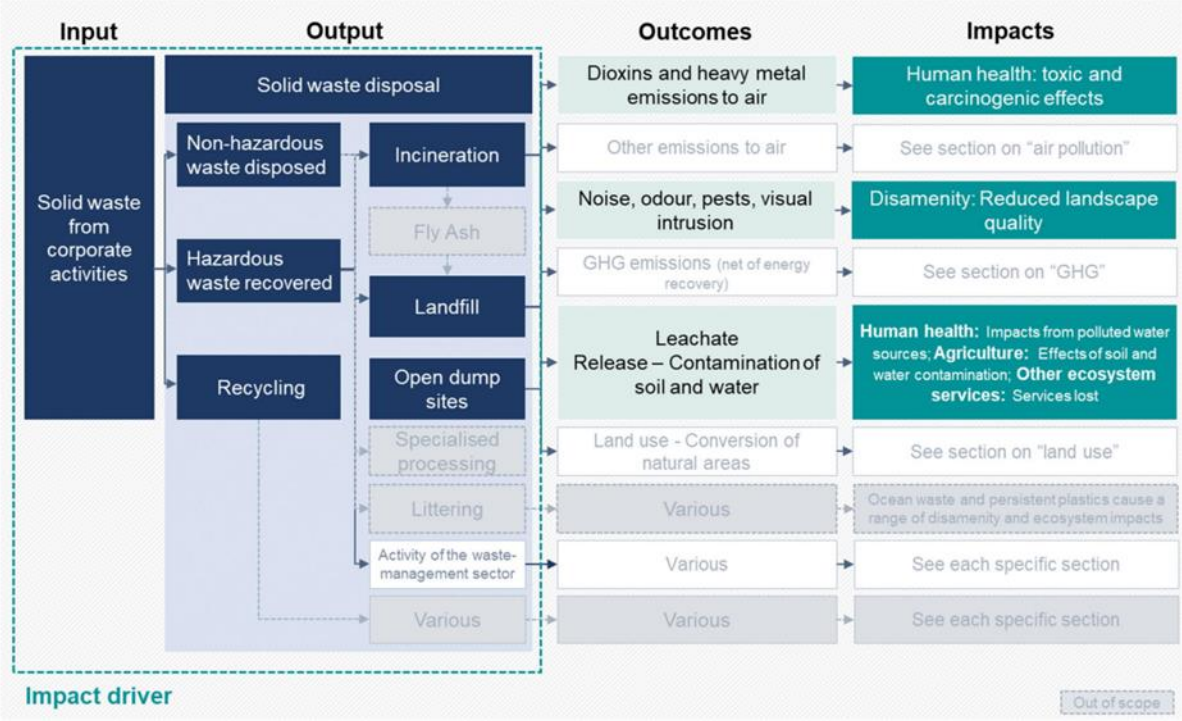

Figure 13: Simplified impact pathway waste

[Source: Waste Impact Pathway / VBA]

2.3.7 Analysis

The comparison highlights four distinct waste management methodologies: Transparent waste, VBA waste, GIST Impact, and WifOR Institute waste approaches. Each method assesses various waste disposal techniques and assigns monetary value to impacts including human health and GHG emissions. While some methodologies adjust for geographic and population factors, there is a notable gap in considering broader social and economic impacts. Moreover, future trends and data accessibility pose challenges, indicating areas for improvement in waste management assessment methodologies.

2.4 Water Consumption

2.4.1 Challenge

Water consumption, defined as water withdrawn from a source and not returned, poses significant societal challenges by affecting human health, agricultural productivity, and environmental sustainability. These consequences include increased reliance on contaminated water sources, heightened disease prevalence, diminished agricultural yields leading to malnutrition, and resource depletion. Addressing this challenge aligns with SDGs 6, 9, 11, and 12, which emphasise increasing water use efficiency, ensuring sustainable freshwater supply, enhancing skills for employment, promoting sustainable urban management, and advocating for responsible consumption and production. Leading international organisations, including the World Water Council, WB, World Economic Forum, IMF, UNDP, and WRI, highlight the critical need for coordinated action to achieve sustainable water management and equitable access to clean water resources globally.

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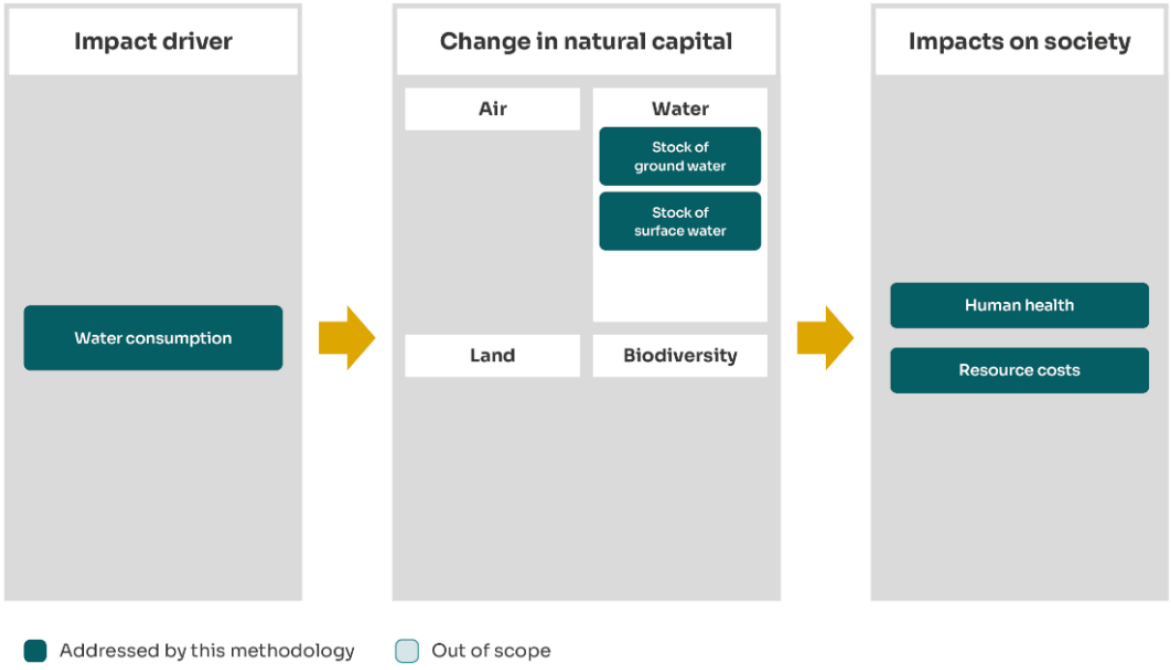
2.4.2 Activity Data

The quantification of water consumption impact drivers involves measuring the volume of withdrawn (blue) water not returned to the cycle, typically assessed in cubic meters per country, encompassing water utilised in products or rendered unfit for return due to contamination.

2.4.3 Transparent

The NCMA methodology to water consumption assessment involves quantifying the impact of water depletion by measuring the volume of withdrawn water not returned to the cycle, typically in cubic meters per country. Calculation logic includes determining water consumption by subtracting output water from input water, with considerations for local water scarcity. The value factor encompasses components such as human health and resource costs, with impacts quantified in monetary terms through stated or revealed preference approaches for human health and cost-based approaches for resource costs.



[Source: Water Consumption Impact Pathway / Transparent]

2.4.4 WifOR Institute

The WifOR Institute approach to water consumption valuation acknowledges the critical role of global water systems while highlighting the escalating consumption rates and disproportionate withdrawals that strain these systems. By 2025, predictions indicate that two-thirds of the world's population could face water shortages, leading to waterborne diseases and agricultural losses. The impact pathway demonstrates how commercial water use exacerbates domestic water scarcity, posing risks to human health and agricultural sustainability. WifOR Institute's valuation method focuses on economic costs such as reduced agricultural output and damages to human health measured in DALYs, considering geographical differences in water stress levels and utilising country-specific water scarcity factors for valuation.

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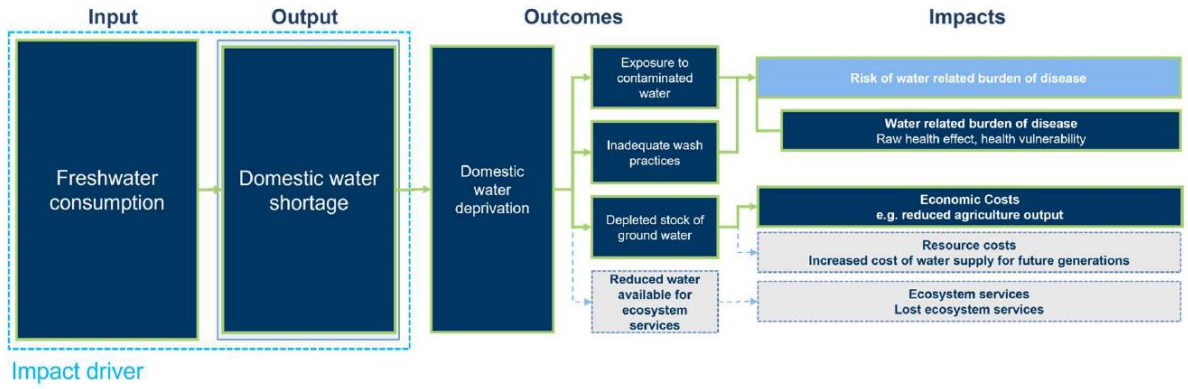
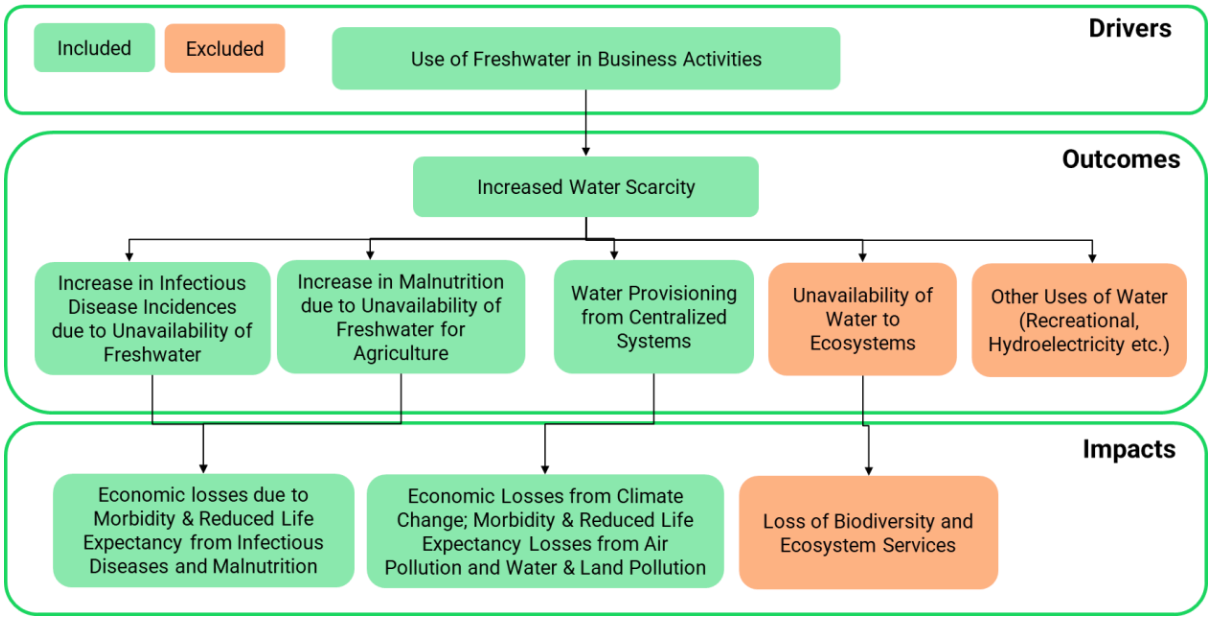


Figure 6: Impact Pathway of water consumption (source: own illustration)

[Source: Water Consumption Impact Pathway / WifOR Institute]

2.4.5 GIST Impact

The GIST Impact methodology evaluates the impacts of water consumption by considering three main components: water provisioning, malnutrition, and infectious disease incidence. Water provisioning evaluates the energy consumption and associated costs of transferring water to regions with higher scarcity levels. Malnutrition and infectious disease components assess the impacts on human health, measured in DALYs, resulting from water scarcity and consumption of unsafe water sources. These assessments draw from various scientific methodologies and models to quantify the overall impact of water consumption, providing valuable insights for sustainable management practices.



[Source: Water Consumption Impact Pathway / GIST Impact]

2.4.6 VBA

The VBA methodology assesses the impacts of corporate water consumption by considering three main components: malnutrition, infectious water-borne diseases, and groundwater depletion. These impacts are monetized using value factors derived from regression analyses and cost-based approaches. The methodology integrates various data sources and valuation

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techniques to estimate the societal costs associated with water consumption, providing valuable insights for companies aiming to minimise their negative impacts on water resources.

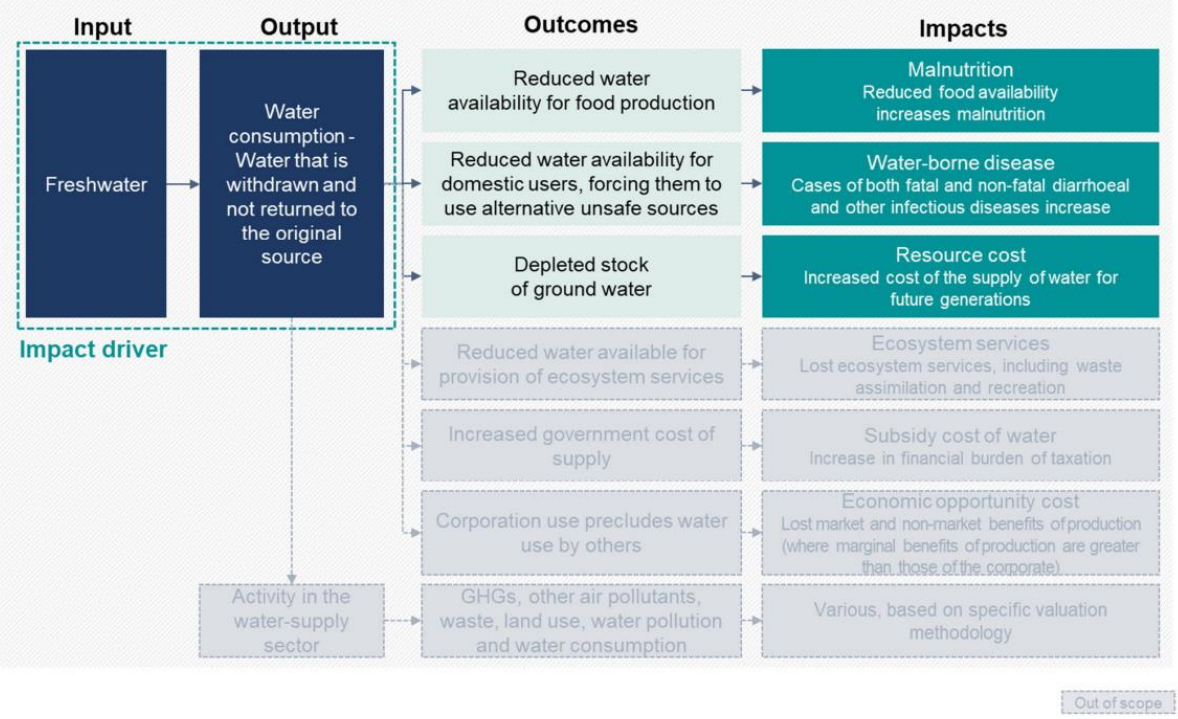

Figure 3: Simplified impact pathway water consumption

(i) Impact drivers: The volume and location of corporate water consumption
(ii) Reduced availability of water for other users, depletion of groundwater reserves at an unsustainable rate and the impact of the water supply sector.
(iii) Human health impacts, future costs to society of alternative water sources and impacts via GHGs, air pollution and waste from the water supply sector.

[Source: Water Consumption Impact Pathway / VBA]

2.4.7 Analysis

While all approaches consider multiple dimensions of impact, including human health and economic costs, they vary in comprehensiveness, methodology, and applicability. Adjustments and assumptions are made in each approach to account for factors like purchasing power parity and future costs, with varying levels of transparency regarding these adjustments.

2.5 Water Pollution

2.5.1 Challenges

Water pollution poses significant challenges to societies worldwide, with diverse pollutants impacting water sources and ecosystems. Understanding the societal impacts of water pollution is crucial, as it affects human health, recreational activities, property values, and commercial interests in fisheries. The SDGs, particularly SDG 6, emphasise the importance of addressing water pollution and ensuring access to safe drinking water and sanitation, highlighting the urgency of mitigation efforts. Leading international organisations such as the UNEP, WHO, and WB provide comprehensive insights into global water pollution challenges and propose solutions for sustainable water resource management. Despite these efforts, ongoing pollution threats persist, necessitating concerted action to safeguard water quality and ensure equitable access to clean water for all.

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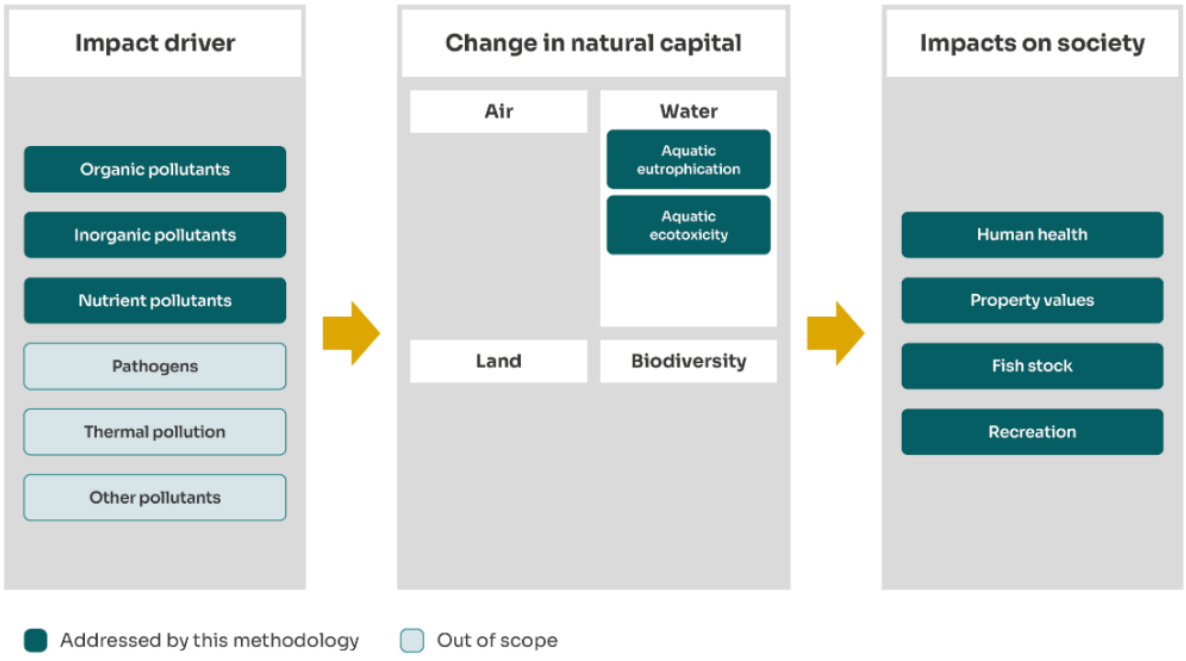
2.5.2 Activity Data

Activity data collection for own operations, upstream and downstream, involves both direct measurement and the use of emission factors to comprehensively assess environmental impact. This process includes identifying manufacturing processes with potential pollutant emissions, detailed data collection on materials used and water consumption, and quantifying pollutant releases per unit of activity using recognised emission factors. Regular review and updates of emission factors ensure accuracy, facilitating targeted reporting and supporting effective environmental management and regulatory compliance.

2.5.3 Transparent

The NCMA methodology emphasizes comprehensive data collection and analysis to quantify the impacts of various pollutants on human health and the environment It identifies key pollutant categories that should be considered, including organic pollutants, inorganic pollutants, and nutrient pollutants each with distinct adverse effects on water quality and ecosystem health. The calculation logic for monetizing the impacts of water pollution is based on the multiplication of pollutant quantity with corresponding value factors, which encompass human health, property values, fish stock, and recreational activities. Impacts on society are thereby modelled based on dose-response functions for human health impacts, and valued based on stated or revealed preference approaches for all impacts in scope.



[Source: Water Pollution Impact Pathway / Transparent]

2.5.4 WifOR Institute

The WifOR Institute approach highlights the contribution of economic activities to water pollution, particularly through the release of substances like nitrogen, phosphorus, heavy metals, and other pollutants into freshwater systems, posing risks to biodiversity and human health. Its valuation method aims to quantify the impacts on ecosystems by assessing biodiversity reduction, decreased fish production, and potential health hazards associated with these pollutants, using indicators such as economic damage, preservation costs for biodiversity loss, and DALYs for human health impacts. Geographical differences are considered based on water stress levels in regions or countries, with transfer mechanisms

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relying on water scarcity data from the WB, resulting in estimated global damage of USD 0.4 trillion in 2020.

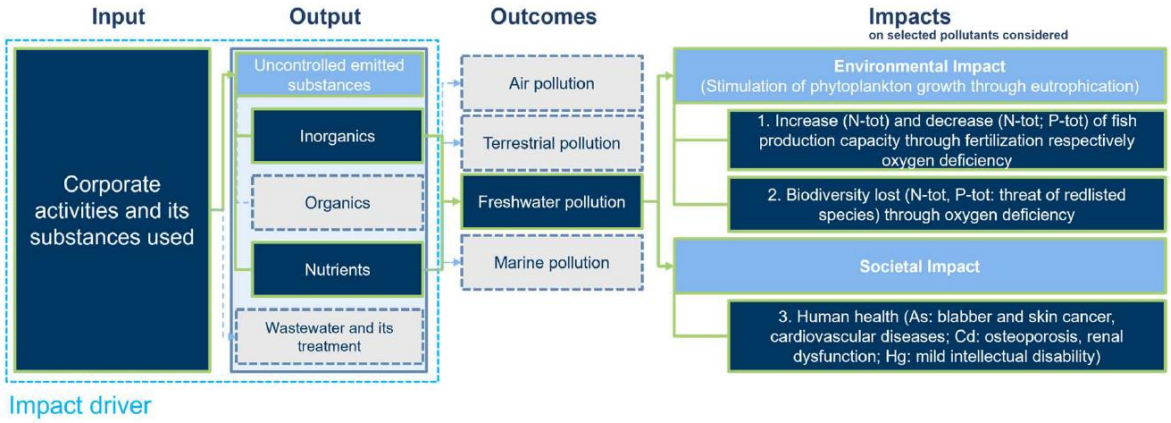
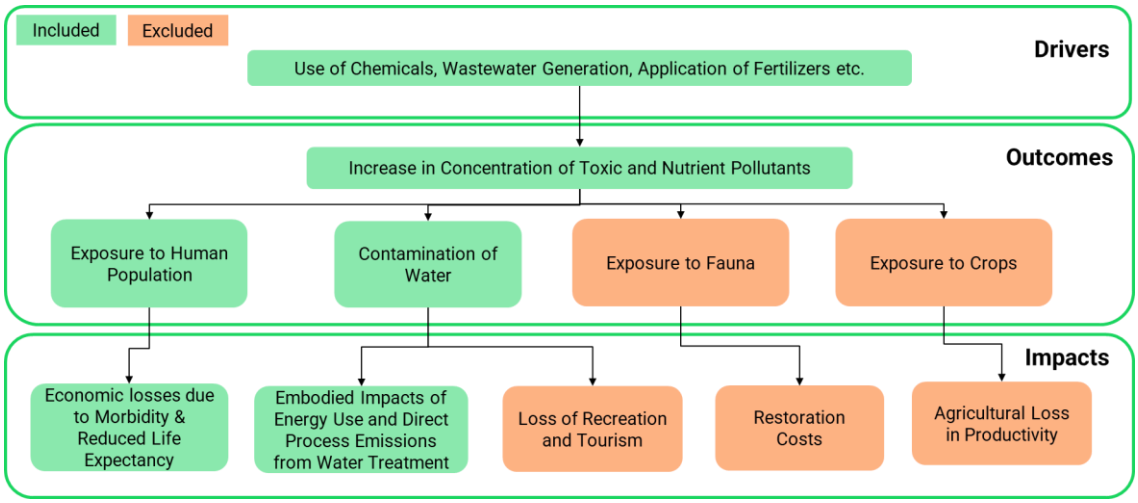


Figure 7: Simplified impact pathway of Water pollution (source: own illustration based on Steen (2020).[48]

[Source: Water Pollution Impact Pathway / WifOR Institute]

2.5.5 GIST Impact

The GIST Impact approach evaluates the effects of water and land pollution by considering drivers such as sewage generation and chemical use, leading to the release of toxic and nutrient pollutants. The framework calculates the impact cost by assessing pollutant removal or treatment costs and direct emissions during wastewater treatment for nutrient pollutants, while considering human health impacts, including cancer and non-cancer cases, for toxic pollutants. Data sources include USEtox for characterization factors and various references for pollutant quantities and treatment technologies. Ultimately, the impact due to water and land pollutants is determined by aggregating the impacts from both nutrient and toxic pollutants, quantified in terms of USD.



[Source: Water Pollution Impact Pathway / GIST Impact]

2.5.6 VBA

The VBA approach incorporates two distinct methodologies for assessing the economic costs associated with water pollution: one for toxic pollutants and another for nutrient pollutants. For toxic pollutants, the methodology utilises the USEtox database to quantify human health

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impacts in terms of DALYs and monetary valuation techniques based on the VSL. For nutrient pollutants, the approach involves assessing eutrophication potential and applying WTP estimates to derive damage values per kilogram of pollutant released. The valuation of both types of pollutants involves extensive data sources, including characterization factors, DALY values, and WTP estimates, while accounting for regional variations and socioeconomic factors such as GNI per capita and PPP.

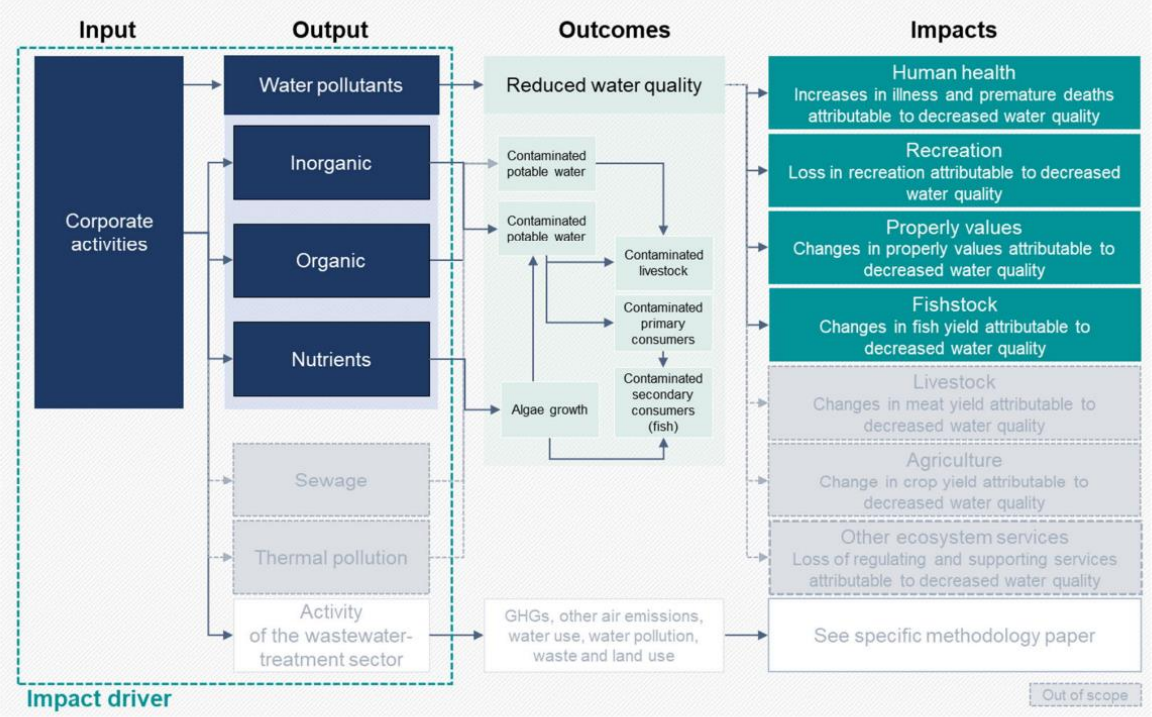

Figure 5: Simplified impact pathway water pollutants

i. Impacts are driven by the release of different types of chemicals and compounds into the water
ii. Changes in the state of natural capital (or outcomes): These are primarily identifiable as increased concentrations of pollutants and associated reductions in water quality. Secondary effects include the bioaccumulation of pollutants in the food web.
iii: Impacts on society are principally related to health but also include impacts on amenity values, recreation and the market economy.

[Source: Water Pollution Impact Pathway / VBA]

2.5.7 IWA

The Impact Weighted Account (IWA) initiative assesses the environmental impact of greenhouse gas emissions and related substances into water by combining Waterfund's Water Cost Index and EPS weighting factors. Through impact pathways like Water Production and Water Consumption, the initiative calculates the environmental impact by considering factors such as water production cost, distribution cost, net consumption, and AWARE factors, while applying a 3% discount rate.

2.5.8 EPS, Chalmers

The assessment evaluates the monetary impact of various pollutants, such as BOD, N-tot, P-tot, Cd, and As, on freshwater ecosystems, focusing on their effects on environmental goods like fish production capacity, human health, and biodiversity. It concludes that BOD emissions pose a moderate economic problem, suggesting the need for localised abatement strategies,

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while N-tot emissions primarily affect marine eutrophication, and P-tot emissions are significant only in specific contexts like wastewater treatment. Moreover, the impacts of pollutants like As on cardiovascular diseases and Cd on osteoporosis highlight their substantial health-related costs, although the prevalence of severe cases remains uncertain.

2.5.9 Analysis

Each approach considers multiple impact pathways, such as human health, property values, and biodiversity, providing a comprehensive understanding of the repercussions of water pollution. While they all utilise models and data sources to estimate impacts accurately, there is variability in transparency and specificity across approaches, affecting the assessment's reliability. Additionally, differences exist in the scope of impact assessment and the valuation techniques employed, with some approaches adopting more comprehensive methodologies than others. Adjustments for contextual factors like PPP and water scarcity vary across approaches, influencing the accuracy of estimations in different regions and contexts.

2.6 Land Use

2.6.1 Challenge

Assessing the impact of land use involves quantifying occupied hectares per type of occupation and by country, aligning reporting with sector-specific guidelines to address drivers of biodiversity loss. This assessment is crucial as ecosystems provide essential services such as climate stability, flood protection, and food production, but increasing land demand often leads to their degradation. SDGs 11, 13, and 15 emphasise the importance of sustainable land use practices to create resilient cities, combat climate change, and protect terrestrial ecosystems. International organisations like FAO, WRI, and the WB offer valuable insights and frameworks to promote responsible land management and address global environmental and developmental challenges.

2.6.2 Activity Data

In evaluating land use associated with production or operational activities, a meticulous approach combines direct measurement and emission factor utilisation. Initial steps involve identifying and categorising occupied land into distinct types according to methodologies, quantifying each type in terms of hectares, multiplying by corresponding emission factors to estimate overall land use impact. This comprehensive approach provides nuanced assessments tailored to industry-specific contexts, supporting informed decision making and environmental reporting aligned with sustainability objectives.

2.6.3 Transparent

The NCMA methodology to value land use impacts involves a comprehensive calculation logic where the monetized impact is determined by multiplying the area of land or seabed used or converted by a corresponding value factor. The value factor encompasses economic productivity, property values, recreation, and optionally, human health considerations, with changes in natural capital relative to a baseline being modelled. Impacts on society are quantified and valued monetarily using various techniques, with assumptions made regarding allocation of impacts, valuation methods, and ecosystem condition assessment. This approach ensures a thorough evaluation of land and seabed use, capturing its societal and environmental implications in monetary terms and providing a framework for informed decision-making aligned with sustainability objectives.

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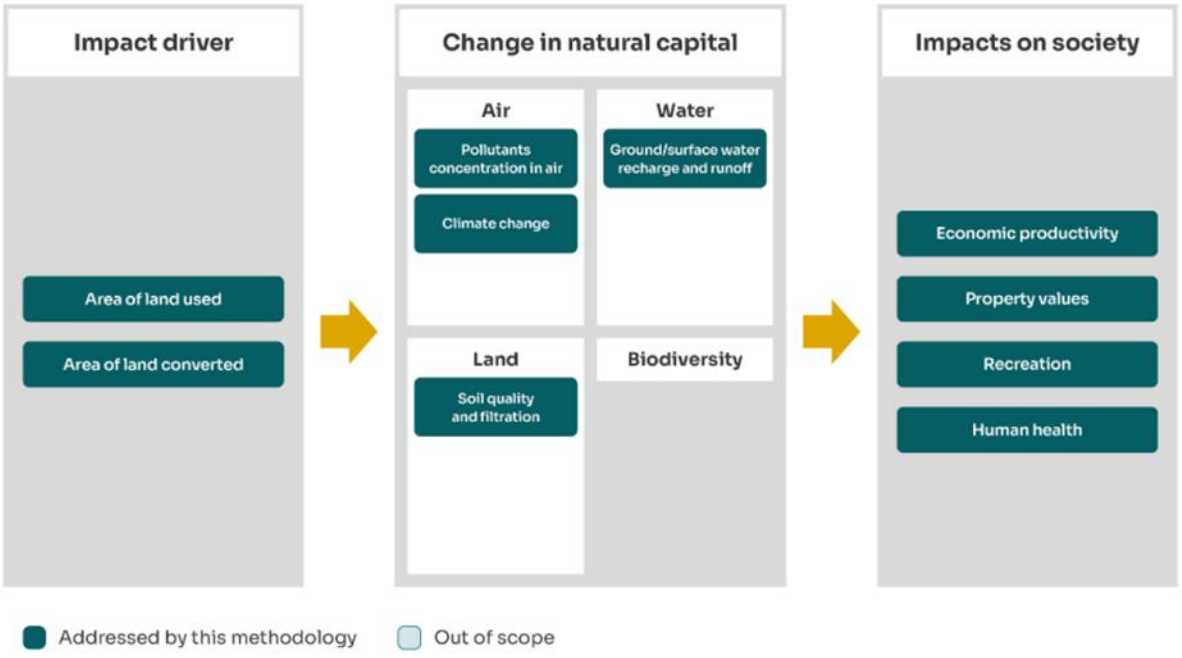
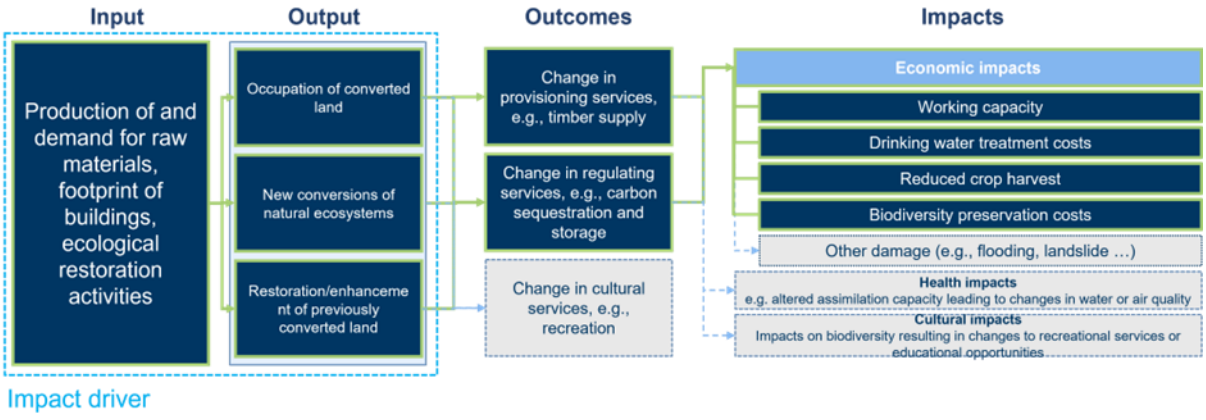


[Source: Land Use Impact Pathway / Transparent]

2.6.4 WifOR Institute

The WifOR Institute approach to land use impact assessment relies on various data sources such as EXIOBASE 3.8.1 and valuation methodologies tailored to specific subcategories, including agriculture, forestry, and paved areas. Activity data is sourced from EXIOBASE 3.8.1, and the formula for calculating monetized impact involves multiplying the area of land used by corresponding value factors, with country-specific adjustments. Valuation methods include assessing productivity loss, drinking water treatment costs, reduced crop harvest, and loss of biodiversity, with data sourced from EPS (2015), Steen (2016), Price and Heberling (2020), among others. Geographical differences are accounted for by calculating country-specific impact values using LANCA characterization factors, while the transfer mechanism values are denominated in USD without adjustment for PPP. The WifOR Institute approach provides insights into the global damage and environmental prices associated with land use activities and offers detailed methodologies for assessing the impacts across various subcategories.



[Source: Land Use Impact Pathway /WifOR Institute]

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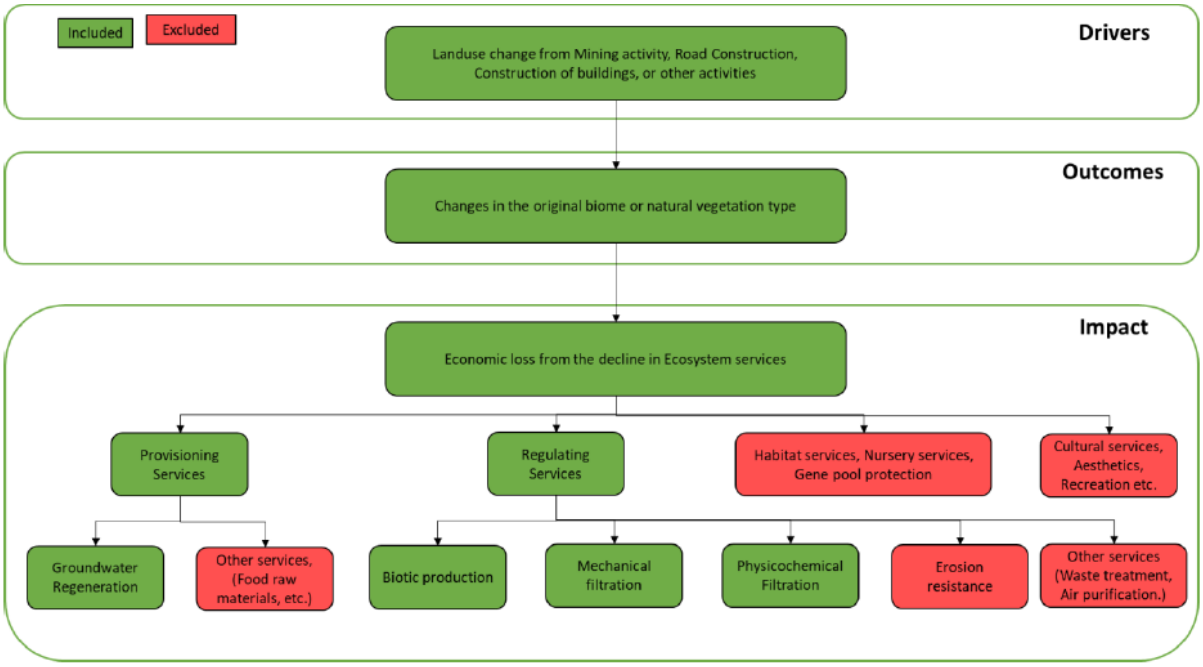
2.6.5 GIST Impact

The GIST Impact approach to evaluating land use change focuses on identifying drivers, outcomes, and impacts of such changes, including activities like construction and conversion of forest plantations. Valuation is based on impact drivers, converting biotic potential into economic terms using methods like the social cost of carbon or considering energy consumption for filtration. Data sources include studies on environmental and financial life cycle impact assessment, land cover data, carbon sequestration efficacy comparisons, climate surfaces, and guidelines on global land use impact assessment.



[Source: Land Use Impact Pathway /GIST Impact]

2.6.6 VBA

The VBA approach focuses on estimating the economic value of lost ecosystem services resulting from the conversion and occupation of natural land areas, leveraging data from sources like the TEEB Valuation Database. It utilises a calculation logic that involves summing activity data over countries and types of land use, multiplied by a value factor representing the lost ecosystem service value in USD/ha. Valuation techniques encompass various methods such as avoided cost, benefit transfer, and contingent valuation, with adjustments made based on regional socioeconomic factors and eco-region types affected.

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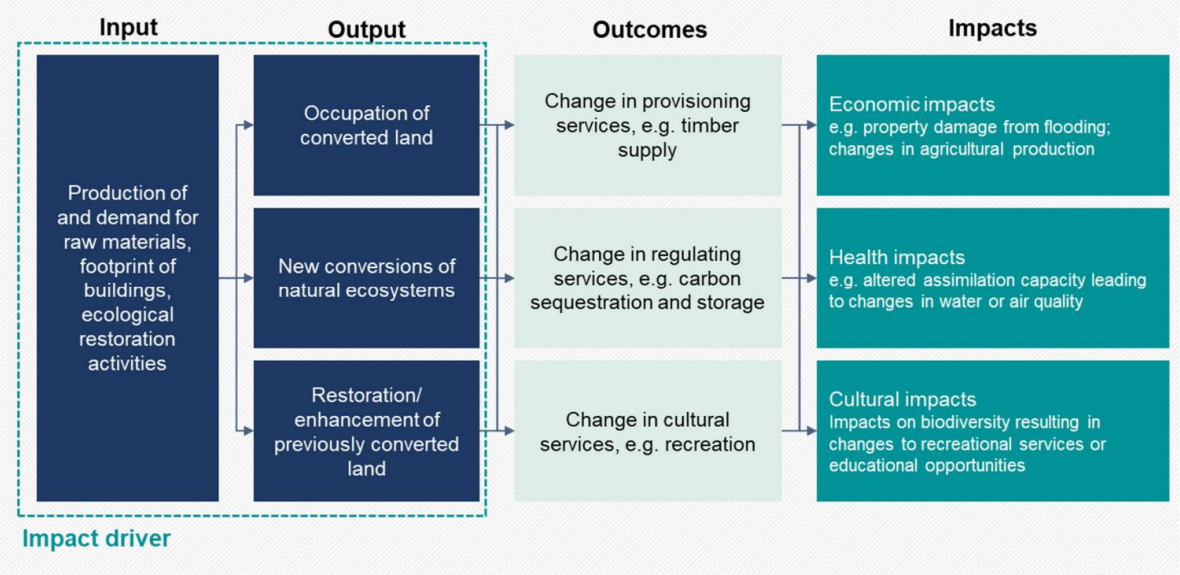

Figure 9: Simplified impact pathway land use

[Source: Land Use Impact Pathway /VBA]

2.6.7 EPS, Chalmers

The Chalmers approach evaluates the environmental impact of land use transformation, particularly focusing on cities with over 0.5 million inhabitants. It considers various factors such as heat stress, decreased working capacity, crop and wood production, drinking water production, and biodiversity loss. Data sources include studies by Bengt Steen, Weihe, Peng et al., Demographia World Urban Areas, Dunne et al., and the IUCN Redlist, among others, to provide comprehensive insights into the monetary valuation of environmental impacts associated with land use in urban areas.

2.6.8 Analysis

All approaches consider factors beyond economic costs, including health impacts and various aspects of land use such as recreation, cultural values, and ecosystem services. However, there is inconsistency in addressing health impacts, with some approaches explicitly considering them while others do not. Similarly, while some approaches mention the consideration of cultural values, it is not explicitly addressed by others. Furthermore, there's a lack of clarity on valuation techniques across distributors, and the allocation of impacts varies, potentially leading to inconsistencies in assessment results.

2.7 Biodiversity

2.7.1 Challenge

The challenges in biodiversity conservation and ecosystem management are multifaceted. They include the failure of traditional economic models to properly value nature's benefits, resulting in its unsustainable exploitation. Dependencies on nature's services are often poorly understood within corporate decision making, posing systemic risks to the financial system. Additionally, incentive structures currently favour activities that deplete biodiversity, lacking mechanisms to reward conservation efforts. Knowledge gaps in scientific understanding and data further hinder effective policymaking, exacerbating the unprecedented decline of nature, with accelerating rates of biodiversity loss driven by habitat destruction, climate change, and

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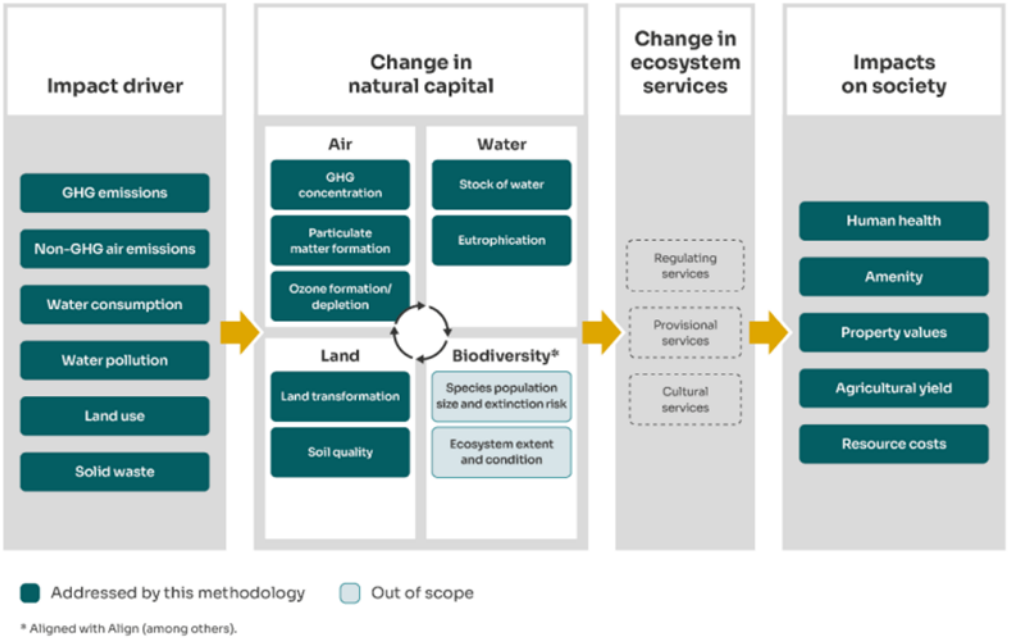
unsustainable resource use. Urgent transformational change across societal and economic systems is essential to address these pressing challenges.

2.7.2 Transparent

The scope of the NCMA methodology includes the principal natural capital assets of air, water, land and biodiversity, and the ecosystem services they provide. Because businesses measure the drivers that impact these assets and the people depending on them, the methodology is structured according to impact drivers as shown in the figure below. Impact drivers in blue boxes are addressed in detail in the NCMA methodology, grayed boxes, as well as ecosystem services are not explicitly modelled in the NCMA methodology.

(NCMA methodology, page 7)

Figure 2. Relation between impact drivers, impact pathways, and the value to society perspective



This is an illustration of impact pathways. All ecosystem services are underpinned by ecosystem assets, whereby changes in the assets lead to changes in the ecosystem services, which eventually impact societies.

[Source: Biodiversity Impact Pathway / Transparent]

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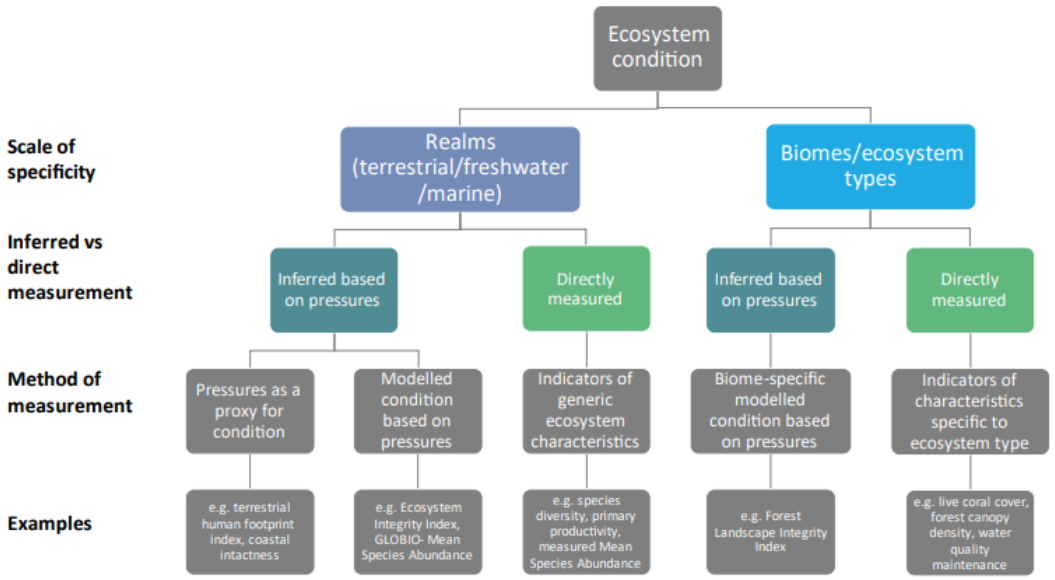
2.7.3 Align



[Source: Biodiversity Impact Pathway / Align]

2.7.4 WifOR Institute

The WifOR Institute approach to biodiversity valuation focuses on quantifying the environmental impact of human activities on threatened species. It utilises an additive multiplicative formula, where the monetized impact is calculated as the sum of biodiversity-threatening activities multiplied by value factors specific to each country. These value factors are determined based on the costs of biodiversity conservation, distributed across countries and sectors according to their contribution to species-threatening activities and the number of threatened species. The approach acknowledges geographical differences in threatened species distribution and provides valuation data from sources such as ESVD, Steen (2020), Deutz et al. (2020), and IUCN (2022), ultimately estimating global damage at USD 3.75 trillion in 2020 dollar terms.

2.7.5 GIST Impact

The GIST Impact biodiversity framework offers a comprehensive approach to assessing the impacts of business activities on biodiversity, covering both ecosystem services and species levels. It goes beyond direct drivers like land transformation to include indirect impact drivers such as greenhouse gas emissions and water pollution. The framework utilises Business LCIA to calculate impacts on ecosystem quality, considering a standard set of drivers at an asset or company level. Species-level biodiversity impacts are measured using metrics like the Potentially Disappeared Fraction of Species (PDF) and Mean Species Abundance (MSA), while considering both direct and indirect drivers. Data sources for the framework include various studies and reports addressing biodiversity loss and ecosystem degradation.

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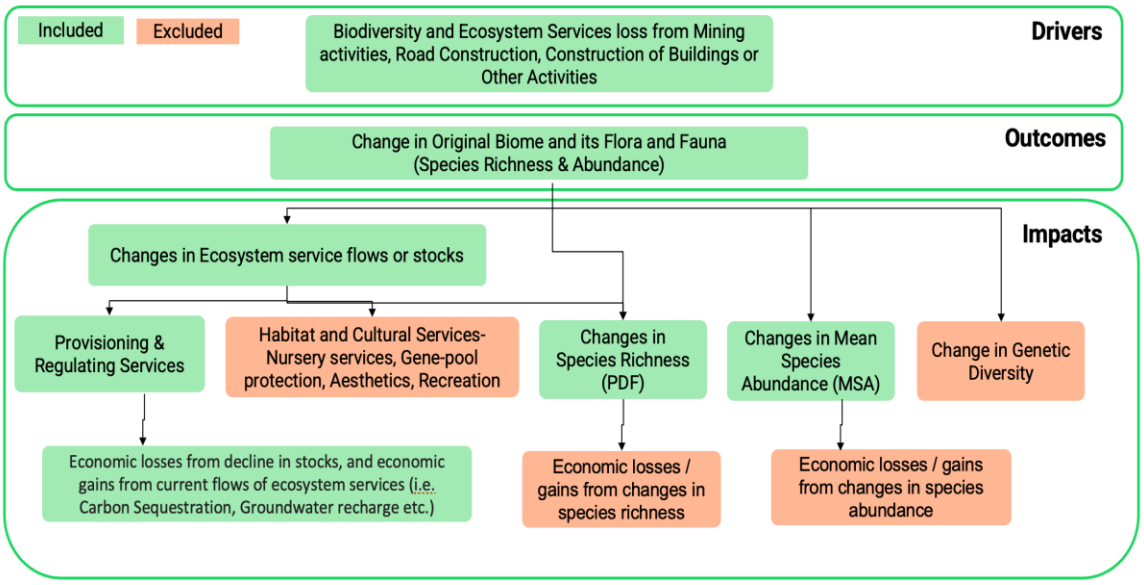

[Source: Biodiversity Impact Pathway / GIST Impact]

2.7.6 Analysis

WifOR Institute and GIST Impact both aim to assess human activity impacts on biodiversity, utilising different models and methodologies. While WifOR Institute employs an additive multiplicative model and focuses on economic valuation based on biodiversity conservation costs, GIST Impact utilises a comprehensive framework covering both direct and indirect drivers of biodiversity loss, emphasising impact quantification rather than economic valuation. Both frameworks consider activities like pollution and land use, drawing from various data sources to inform their assessments. However, WifOR Institute provides country-specific value factors for activities threatening biodiversity, while GIST Impact relies more on LCIA. Despite their common goal of understanding biodiversity impacts, both frameworks may have gaps in considering socioeconomic factors, dynamic ecosystem processes, and geographical coverage, potentially limiting their effectiveness in addressing localised biodiversity conservation needs.

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SOCIAL

2.8 Occupational Health and Safety

2.8.1 Challenge

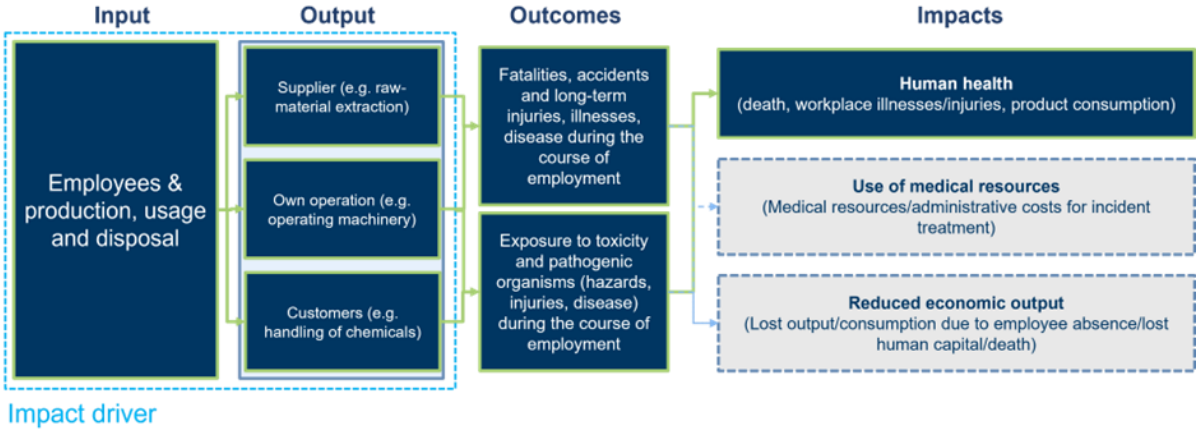
Assessing the impact of occupational health and safety involves examining work-related incidents and illnesses, categorising them by severity and analysing them on a country-specific basis. This assessment is crucial as it not only measures direct effects on employers, such as lowered productivity and increased costs, but also considers indirect impacts on employees' families, communities, and society at large. The evaluation aligns with SDGs 8, 9, and 11, emphasising the protection of labour rights, investment in infrastructure resilience, and reduction of adverse environmental impacts on cities. Leading international reports like the "Global Burden of Occupational Disease", Eurostat's "ESAPOD", ISSA's "Annual Survey", and ILO's "ILOOSH Statistical Update" provide valuable insights and data for evidence-based policymaking and initiatives aimed at improving workplace conditions worldwide.

2.8.2 Activity Data

In assessing occupational health and safety impacts, clear differentiation between work-related injuries and illnesses, along with quantification by absence duration, is crucial for understanding societal costs. Following guidelines from organisations like Safe Work Australia ensures consistency and accuracy in severity classification, enabling nuanced evaluations. Transparent documentation of methodology and assumptions supports reliable data extrapolation and enhances the accuracy of impact assessments.

2.8.3 WifOR Institute

The WifOR Institute approach to assessing occupational injuries and illnesses focuses on quantifying the societal impacts of fatal and non-fatal incidents occurring during employment. This includes calculating costs such as production and human capital losses, healthcare expenses, and adverse effects on well-being. Using data from sources like the ILO and Eurostat, WifOR Institute employs a multiplicative calculation logic to monetize the impacts, considering factors like DALYs for fatal incidents and disability weights for non-fatal injuries. The approach values each category of DALYs using an assumed impact of USD200,000 per case and assumes a global value transfer mechanism to estimate a staggering total global damage of USD 14.2 trillion.



[Source: OHS Impact Pathway / WifOR Institute]

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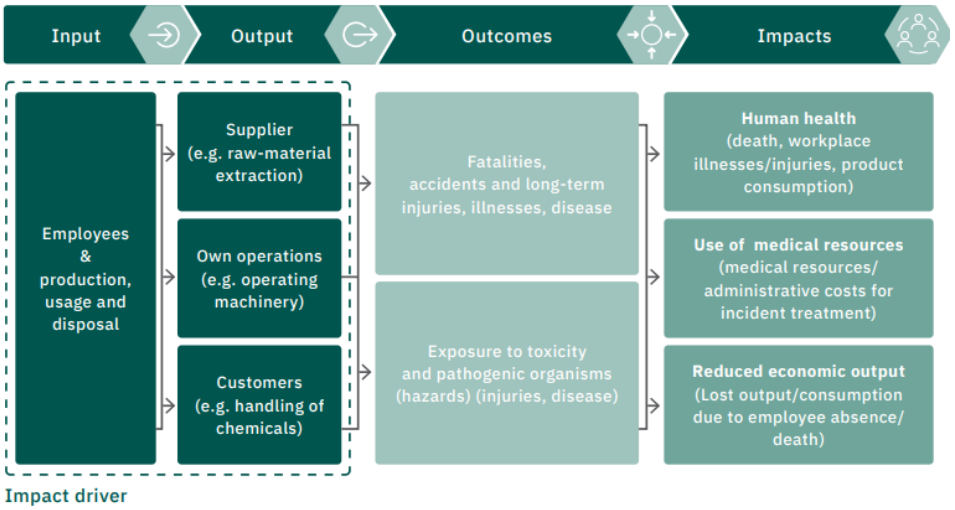
2.8.4 VBA

The VBA approach to assessing the impact of occupational health and safety incidents involves gathering data on incidents and illnesses occurring during employment, considering factors such as severity and duration of absence. The valuation is based on a study by Safe Work Australia, which calculates value factors by considering total costs to workers and the community. These costs are then extrapolated to respective countries using GDP per capita and adjusted for inflation. The approach focuses on indirect societal impacts, excluding direct effects on employers already reflected in financial results. Data should be supplied in a specified format, and adjustments are made based on additional statistical information databases such as IMF, WB, and OECD.



[Source: OHS Impact Pathway / VBA]

2.8.5 Analysis

The VBA and WifOR Institute approaches both aim to assess the societal impacts of OHS incidents, utilising data sources like Eurostat and global health studies. However, VBA focuses on deriving monetary valuation factors based on severity categories of incidents, while WifOR Institute utilises DALYs to value both fatal and non-fatal incidents. Additionally, VBA excludes direct effects on employers from their valuation scope, whereas WifOR Institute considers a broader range of factors including impacts on mental health and overall well-being. While both approaches contribute valuable insights, their differences lie in the scope of valuation factors, treatment of employer costs, and the monetization of impacts.

2.9 Training

2.9.1 Challenge

The challenge addressed by training and skills development spans various SDGs and Targets, ensuring equal access to education, promoting economic productivity, reducing inequalities, integrating sustainability practices, enhancing climate action education, and building capacity in developing countries. Key international documents from organisations like the ILO, OECD, WB, UNESCO, and European Centre for the Development of Vocational Training (Cedefop), along with standards set by the ISO, provide valuable insights and guidelines to shape policies and practices globally, emphasising the importance of investing in human capital and adapting to evolving workforce needs.

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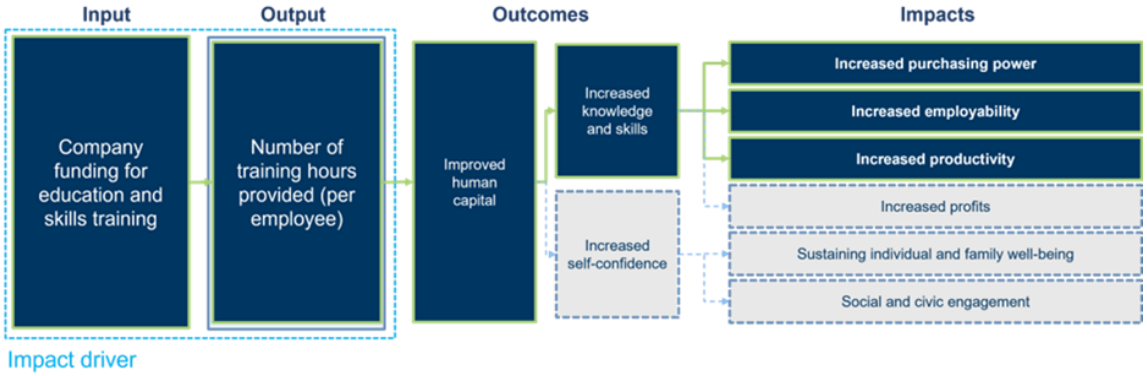
2.9.2 Activity Data

In assessing the impact of training using the VBA methodology, key activity data required includes the total number of training hours provided to direct employees, average wage, average age of employees, and turnover rate calculated based on FTE. Additional granular data at the individual level, such as training hours completed by each employee and their demographic information, is essential for a nuanced evaluation of the societal impact of training initiatives. These data points should be accessible through companies' human resource systems, including training platforms, HR management systems, and payroll systems.

2.9.3 WifOR Institute

The WifOR Institute approach for training assesses the societal value created by corporate training, estimating the economic productivity increase of trained individuals until retirement. It utilises data on returns to schooling, country-specific labour productivity, and remaining work life to calculate the net present value of future productivity gains from training. This comprehensive approach accounts for geographical differences and sources data from various reputable sources like Psacharopoulos & Patrinos (2018), OECD, ILO, and others to provide a thorough valuation of training impacts.



[Source: Training Impact Pathway / WifOR Institute]

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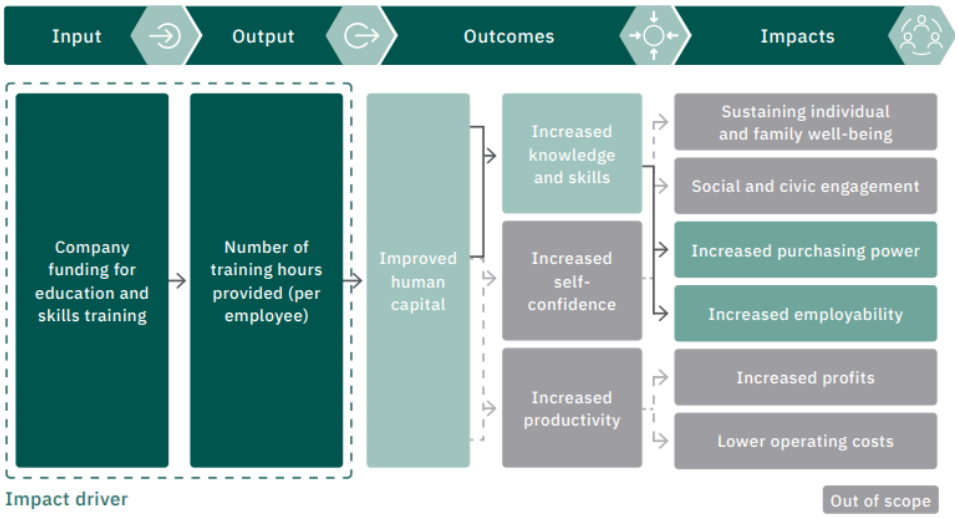
2.9.4 VBA

The VBA approach for training focuses on measuring the social impacts of increasing employees' skills and capabilities within a company's own operations. It utilises data sources such as returns to investment in education from Psacharopoulos and Patrinos (2004), OECD retirement age statistics, and Pension Watch. The methodology calculates the impact of employee education/training on a company's operations, considering factors like training coefficients, training hours, turnover rates, and average wages. However, it acknowledges the absence of consensus on measuring upstream and downstream impacts and emphasises using full-time equivalents for turnover rate calculations and proportional distribution of training costs if shared with others.



Impact Valuation Roundtable 2017 & C. Mainguet and A. Baye (2006), 3.C. Defining a framework of indicators to measure the social outcomes of learning, OECD

Figure 2: Simplified impact pathway training

[Source: Training Impact Pathway / VBA]

2.9.5 Analysis

Both VBA and WifOR Institute highlight the importance of training activities and recognise similar impacts such as increased purchasing power and employability. While VBA emphasises adjustments based on education and socioeconomic parameters, enriching the depth of their analysis, WifOR Institute focuses more on economic benefits like higher wages and productivity. Despite their differing approaches, both provide valuable insights into the societal implications of training initiatives, offering distinct but complementary perspectives on the subject. VBA's comprehensive analysis complements WifOR Institute's emphasis on economic outcomes, collectively contributing to a holistic understanding of the broader impacts of training programmes.

2.10 Wages

2.10.1 Challenge

The challenge of fair wages is crucial for ensuring workers can meet basic needs like housing, food, healthcare, and education. Wages below the living wage threshold have negative societal impacts, leading to health issues, increased stress, and social problems, while also contributing to economic inequality and instability. Addressing this challenge aligns with Sustainable Development Goal 8, aiming for full and productive employment, decent work for all, and equal pay for equal value. Leading international documents from organisations like

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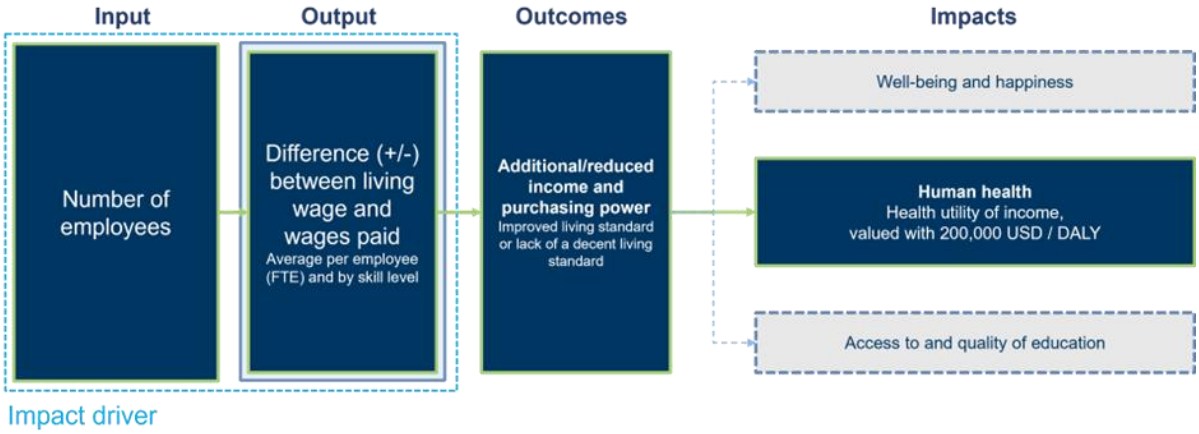
the UNDP, ILO, WB, ITUC, and WHO shed light on the importance of fair wages in advancing social progress, gender equality, and sustainable development, advocating for workers' rights and addressing wage disparities.

2.10.2 Activity Data

In assessing the impact of adequate wages using the methodologies, primary data collection focuses on base salaries paid securely to employees throughout the value chain, excluding bonuses and performance-based payments but including taxes and social contributions. It considers differentiation between average wages below and above the living wage threshold, using individual-level data or salary bands/ranges if necessary, and encompasses contractors and non-permanent staff. Upstream impacts are evaluated using EEIO databases like Exiobase, integrating emission factors and country-specific nuances for accurate assessment.

2.10.3 WifOR Institute

WifOR Institute's approach to wages focuses on evaluating their impact on health and life expectancy, using the fair wages indicator to assess employment quality. This method calculates DALYs gained or lost due to wage levels compared to living wages, applying a HUI factor. Different income groups, categorised based on wage levels relative to the living wage, are assigned varying percentages of HUI, reflecting the marginal declining utility of income. This approach allows for a comprehensive assessment of wage-related impacts on individual well-being, providing valuable insights into the societal implications of fair wages. Geographical differences are accounted for through country-specific living wages and different HUI factors, with regional averages used for missing countries, resulting in an estimated global damage of USD 11.5 trillion.



[Source: Wages Impact Pathway / WifOR Institute]

2.10.4 Valuing Impact

The Valuing Impact approach focuses on assessing the impact of income on health through the HUI methodology, aiming to understand the direct and indirect effects of income on health outcomes. It utilises internationally established data sources from organisations like the OECD, Eurostat, and the WageIndicator Foundation to gather comprehensive wage-related information and health indicators. By applying HUI factors as direct multipliers to income, adjusted for lifestyle factors, taxes, and health outcomes, the methodology quantifies the influence of income on human capital. This approach allows for a detailed analysis of income inequalities and their impact on well-being, facilitating evidence-based policymaking and research initiatives in the realm of health and socioeconomic development.

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2.10.5 VBA

The old VBA approach for wages focuses on assessing the impact of wages on human capital, particularly through the HUI methodology. It utilises HUI values from the Valuing Impacts database and OECD's VSL to quantify the influence of wages on health outcomes. The calculation logic involves formulas for wages both above and below the living wage, considering the well-being gains of additional income and country-specific factors such as resources per capita.

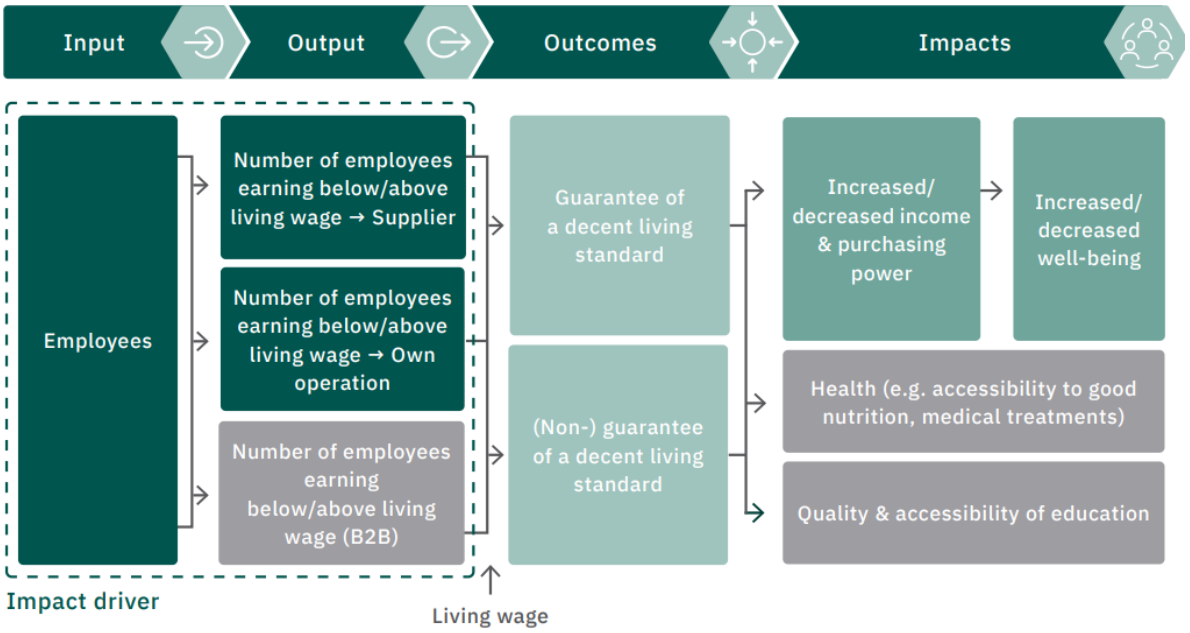

Figure 7: Simplified impact pathway Living Wages

[Source: Wages Impact Pathway / VBA]

2.10.6 IWA

The Impact Weighted Account (IWA) approach combines four impact dimensions – wage quality, diversity, opportunity across job categories, and location – to calculate the employment impact intensity for each firm. This intensity metric represents the impact per employee and is derived by scaling the total employment impact by the number of employees. The approach utilises various data sources, including Revelio Labs, MIT Living Wage Calculator, and official government sources, to gather primary data on workforce composition, location, and wages. Through detailed formulas and valuation techniques, IWA evaluates wage quality by considering living wage adjustments and marginal utility, assesses diversity by comparing actual and expected employee demographics, examines opportunity across job categories and seniorities, and quantifies location impact based on local unemployment statistics and incremental wages due to firm employment.

2.10.7 IFVI / VBA

The IFVI/VBA approach of adequate wages emphasises the concept of "adequate wages", aiming to ensure a basic yet decent standard of living for workers, aligning with the EU's ESRS. It focuses on two key well-being effects: the positive "remuneration impact" of wages on workers' well-being and the negative "living wage deficit impact" when workers earn less than the living wage. Data sources include the "World Happiness Report" for subjective well-being assessments and estimates derived from the UK Treasury for the WUI factor. The calculation

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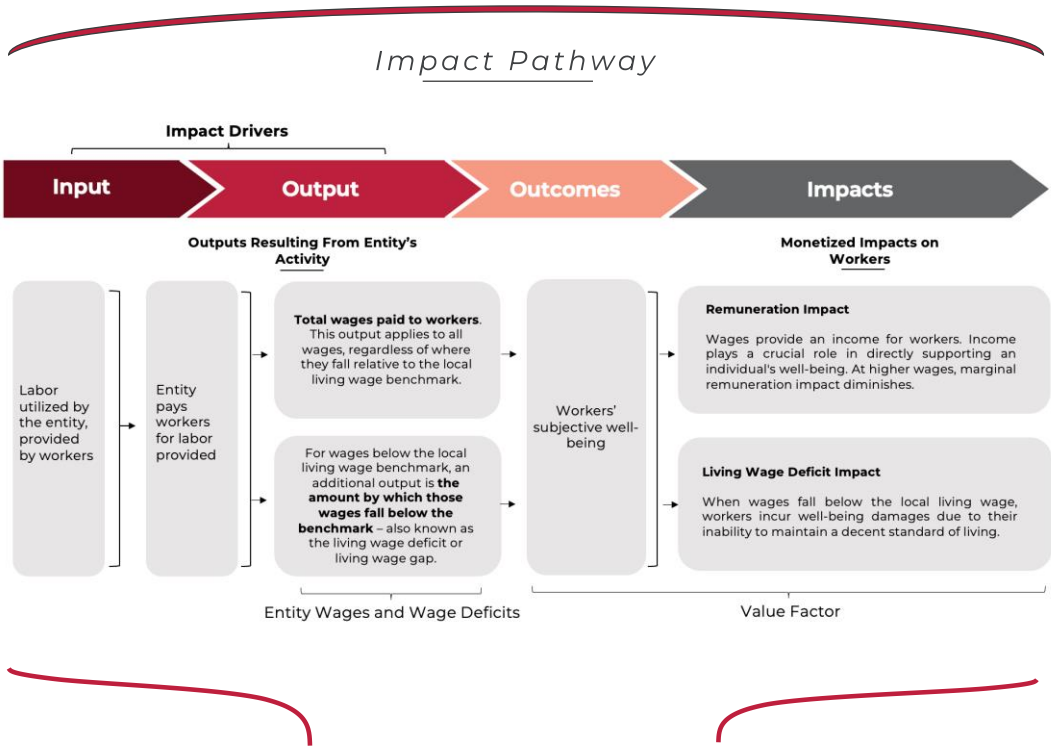
logic involves assessing the well-being gap about the income gap using equations that consider worker categories earning below the living wage, above the living wage but below the satiation threshold, and above the satiation threshold, with potential variations in the valuation formula for the latter category in the future.



[Source: Wages Impact Pathway / IFVI]

2.10.8 Analysis

The comparison between different fair wage evaluation methodologies highlights their shared focus on well-being assessment, drawing on metrics like HUI, human capital impact, and subjective well-being indicators. Each approach relies on diverse data sources, including reports from organisations like the WB and OECD, to comprehensively inform their assessments. Calculation logic varies, but all methodologies consider factors such as wage differentials, living wage thresholds, and location-specific variables to quantify social value creation or loss due to wage disparities. Equity and fairness in employment practices are emphasised across methodologies, aiming to address wage inequalities globally. Despite a global perspective, challenges such as data availability and quality, subjectivity in metrics, and geographical disparities remain, potentially limiting the accuracy and scope of assessments. Overall, these methodologies offer valuable insights with significant policy implications for promoting equitable economic development and improving overall societal welfare.

2.11 Child Labour

2.11.1 Challenge

Child labour presents a multifaceted challenge, defined by engagement in work beyond legal limits, often hazardous and impeding education. It not only deprives children of their rights and dignity but also perpetuates cycles of poverty and hinders societal well-being. Efforts to combat child labour align with SDGs 8.7 and 16.2, calling for global action and investment in education and social protection to eradicate this pervasive issue.

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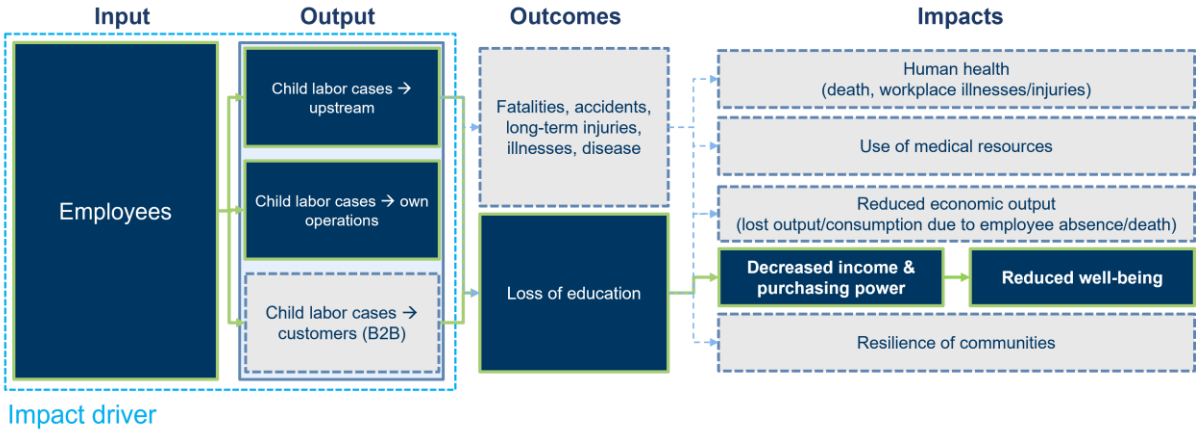
2.11.2 Activity Data

The methodologies offer two practical options for assessing child labour: direct measurement through on-site visits or adherence to regulations, and modelling based on low-skilled employees using UNICEF statistics at a country level. This involves distributing data across sectors based on global average distribution and applying child labour shares to low-skilled employees, with ILOSTAT serving as a resource to estimate the number of low-skilled workers, ensuring transparency and regular updates to reflect changes in child labour statistics. Through these methods, companies can comprehensively assess the societal impact of child labour, aligning with regulations and fostering continuous improvement efforts.

2.11.3 WifOR Institute

The WifOR Institute approach to child labour aims to quantify its economic impact by assessing the income and productivity forfeited due to lost education opportunities. This involves approximating the economic costs incurred by estimating the net present value of future losses across an individual's working life, using GDP per capita in PPP. Data sources include the WB, OECD, International Social Security Association, and Pension Watch, with valuation data sourced from organisations such as the ILO, UNICEF, and academic papers. The methodology uses returns to schooling to estimate productivity loss, considering the adult working life in each country and culminating in a global estimate of USD 1.1 trillion in damage.



[Source: Child Labour Impact Pathway / WifOR Institute]

2.11.4 VBA

The VBA approach to child labour aims to quantify its societal impacts, focusing on factors such as loss of education and potential illnesses and injuries. Data for child labour cases are sourced from UNICEF, with calculations based on the number of cases relative to the number of employees in sectors, assuming children perform only low-skill labour. The approach suggests tracking child labour cases in own operations while using UNICEF statistics for upstream activities. Metrics like loss of education are assessed by assuming one year of missed education per case and incorporating economic indicators such as GNI per capita for 20 years, adjusted for changes in well-being.

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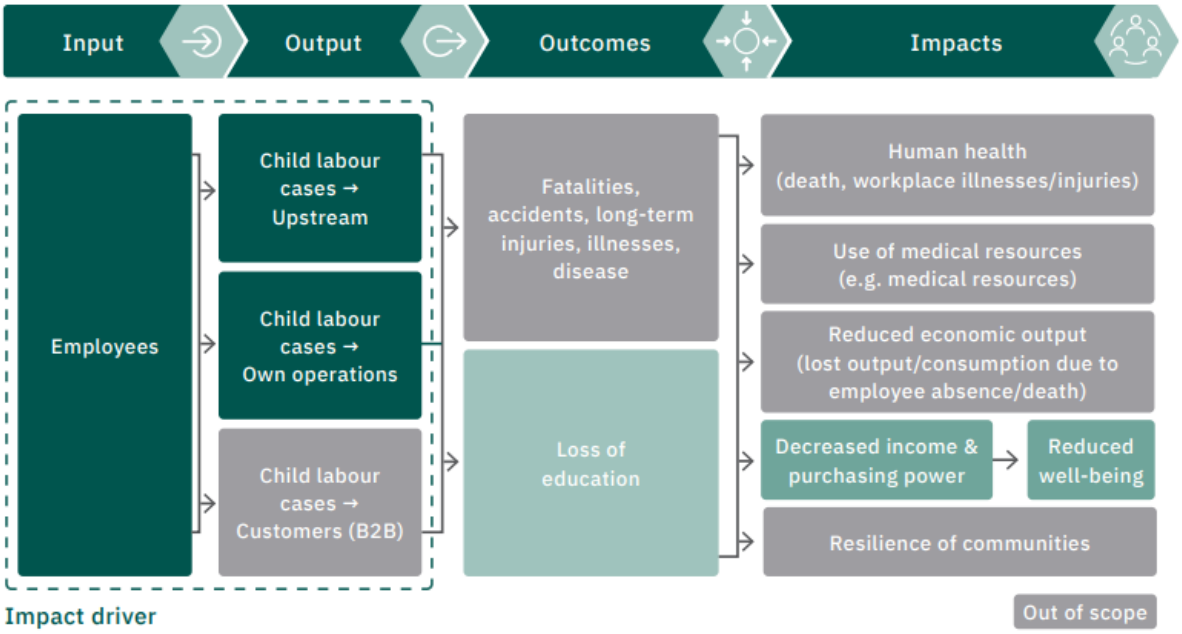

Figure 4: Simplified impact pathway Child Labour

[Source: Child Labour Impact Pathway / VBA]

2.11.5 Analysis

Both the VBA and WifOR Institute methodologies focus on quantifying the impacts of child labour, particularly regarding lost education and decreased income, using data from reputable sources like UNICEF and the WB. While both approaches highlight the importance of addressing child labour for societal and economic well-being, they exhibit gaps in fully capturing non-economic consequences and challenges in obtaining comprehensive data for upstream activities.

2.12 Forced Labour

2.12.1 Challenge

Forced labour is a severe violation of human rights, compelling individuals to work under exploitative conditions against their will. It not only restricts freedom and alternative work opportunities but also contributes to injuries, and illnesses, and perpetuates cycles of exploitation and inequality. Efforts to combat forced labour align with SDGs, emphasising Targets aimed at eradicating all forms of forced labour and human trafficking while promoting justice and equality for all (SDG 8, Targets 8.7. & 8.8; SDG 16, Targets 16.2 & 16.3).

2.12.2 Activity Data

Companies utilise two primary approaches to assess the negative impact of forced labour within methodologies: direct measurement and modelling based on low-skilled employees. Direct measurement involves on-site visits or adherence to codes of conduct while modelling estimates forced labour cases using statistical data on prevalence from the Global Slavery Index Initiative and the number of low-skilled employees from ILOSTAT. This modelling approach ensures transparency and documentation of sources, calculations, and assumptions, providing a comprehensive understanding of forced labour's societal impact, with regular updates recommended for accuracy and relevance.

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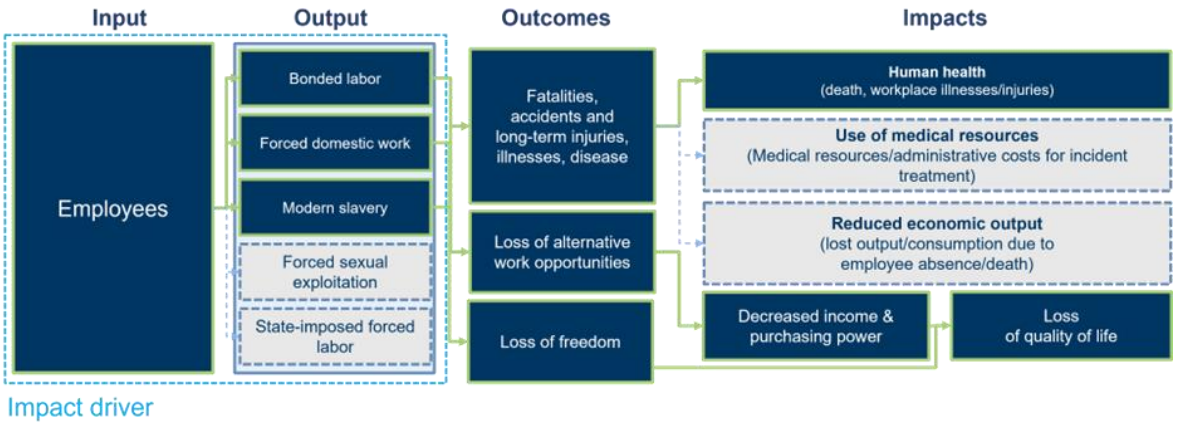
2.12.3 WifOR Institute

WifOR Institute's approach to understanding forced labour quantifies the combined impacts of mental health repercussions and financial exploitation endured by victims, aiming to delineate country and sector-specific impacts in terms of USD per victim. They value mental health impacts using DALYs and assess unduly withheld income by distinguishing between non-domestic forced labour sectors such as agriculture and other sectors, and domestic labour. Geographical differences are considered due to income disparities, with estimated global damage reaching USD 1.6 trillion, underscoring the significant economic and human costs of forced labour worldwide.



[Source: Forced Labour Impact Pathway / WifOR Institute]

2.12.4 VBA

The VBA indicator assesses the societal impacts of forced labour within own operations and upstream activities, focusing on the loss of life quality resulting from forced labour incidents. It values this impact assuming a 50% loss of DALY per incident, equivalent to a severe anxiety disorder, and assigns a universal value of USD 185,900 per DALY. However, the assessment currently excludes the effects of illnesses and injuries associated with forced labour due to insufficient data on their severity.

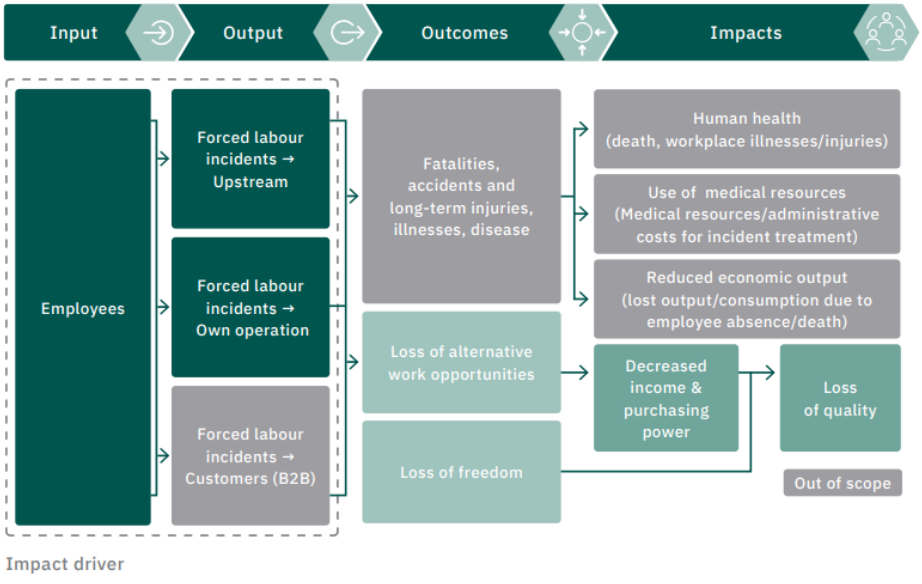


Figure 6: Simplified impact pathway Forced Labour

[Source: Forced Labour Impact Pathway / VBA]

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2.12.5 Analysis

The WifOR Institute and VBA methodologies both assess the societal impacts of forced labour, focusing on mental health repercussions and financial exploitation while excluding certain categories like sexual exploitation and state-imposed labour. They rely on reputable data sources such as the Walk Free Foundation and the Global Slavery Index Initiative to quantify forced labour incidents and understand their financial implications. However, WifOR Institute primarily quantifies mental health impacts and financial exploitation through simple calculation logic, while VBA values the loss of life quality per incident using DALYs and a universal monetary value per DALY, potentially overlooking nuances in valuation approaches. Despite both methodologies considering geographical differences, variations in estimation methods and data interpretation may result in discrepancies in the assessment of forced labour impacts across regions.

2.13 Human Capital

2.13.1 Challenge

The challenge of human capital encompasses issues such as living wages, inequality, and occupational health and safety, with implications varying by demography, sector, and region. Aligned with SDGs, initiatives aim to promote good health, decent work, and reduced inequality. Reports like the “Global Goals Report 2022” and the “World Inequality Report 2022” emphasise the urgent need for equitable access to resources and opportunities for human capital development. Furthermore, the “World Happiness Report 2023” highlights the multidimensional nature of human well-being beyond material wealth. To address these challenges, investments in education, health, and social protection are crucial for fostering sustainable and inclusive development globally.

2.13.2 Activity Data

The activity data requires the association of individuals with demographic characteristics, regions, sectors, and income.

2.13.3 GIST Impact

The GIST Impact approach to human capital valuation centres on assessing the economic value embodied in individuals, encompassing their knowledge, skills, and health. This framework emphasises the pivotal role of training in enhancing productivity and future wages, thereby enriching human capital. It adopts an income-based approach aligned with neoclassical economic theory, accounting for factors influencing human capital formation and its externalities, particularly focusing on employee health and safety impacts. Additionally, the approach diverges from previous models by adopting a gate-to-grave perspective, considering individuals’ economic life until retirement, and incorporates insights from research on diversity, equity, and inclusion, using gender and ethnicity-specific data to assess workforce dynamics.

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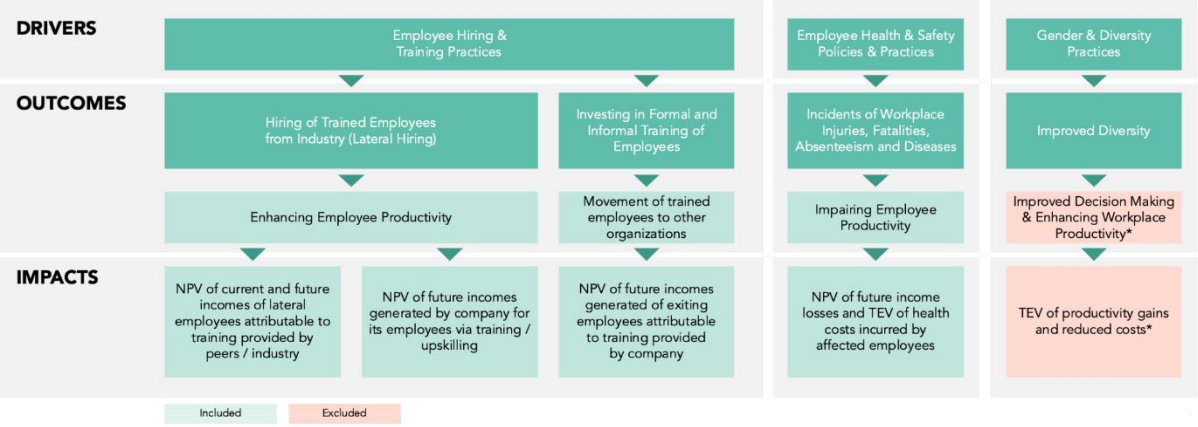

[Source: Human Capital Impact Pathway / GIST Impact]

2.13.4 IWA

The Impact Weighted Account (Human Capital) approach quantifies a firm's human capital impact by integrating four dimensions: wage quality, diversity, opportunity, and location. It utilises activity data from various sources, such as Revelio Labs and government statistics, to assess employment impact intensity per employee. Through detailed formulas and valuation techniques, it evaluates factors like wage quality adjustments, diversity impacts, and opportunity disparities across job categories and seniority levels, as well as the influence of firm location on employment outcomes. Overall, this approach provides a comprehensive framework for measuring and analysing the holistic impact of human capital within organisations.

2.13.5 Analysis

The comparison of human capital assessment frameworks, namely the IWA and GIST Impact frameworks, reveals their shared focus on evaluating businesses' impact on human capital. Both frameworks analyse metrics such as wage quality, diversity, opportunity, and location to understand how firms influence employee well-being and economic opportunity. However, while the IWA framework emphasises quantitative metrics and may overlook qualitative aspects like training, GIST Impact considers factors such as human capital creation and health but may lack granularity in quantifying impacts. Bridging these gaps could involve integrating qualitative aspects into the IWA framework and enhancing quantitative analysis in GIST Impact for a more comprehensive assessment of businesses' contributions to human capital.

2.14 Diversity, Equity, and Inclusion

2.14.1 Challenge

The challenges related to DEI encompass addressing disparities in pay, equal employment opportunities, and health outcomes based on factors such as gender, ethnicity, and socioeconomic status. Achieving gender equality and promoting diversity, equity, and inclusion across various sectors are essential goals requiring comprehensive strategies to end discrimination and ensure equal opportunities for all. Aligned with the SDGs (equality (SDG 5: Targets 5.1 & 5.5), reducing inequalities (SDG 10: Target 10.2), and ensuring decent work and economic growth for all (SDG 8: Targets 8.5 & 8.8)), efforts emphasise the need to combat discrimination against women, empower marginalised groups, and create inclusive work environments. Reports such as "The Global Gender Gap Report", "The Global Diversity Management Outlook", and "The Inclusive Growth and Development Report" provide valuable insights into DEI challenges, highlighting the importance of closing gender gaps, fostering

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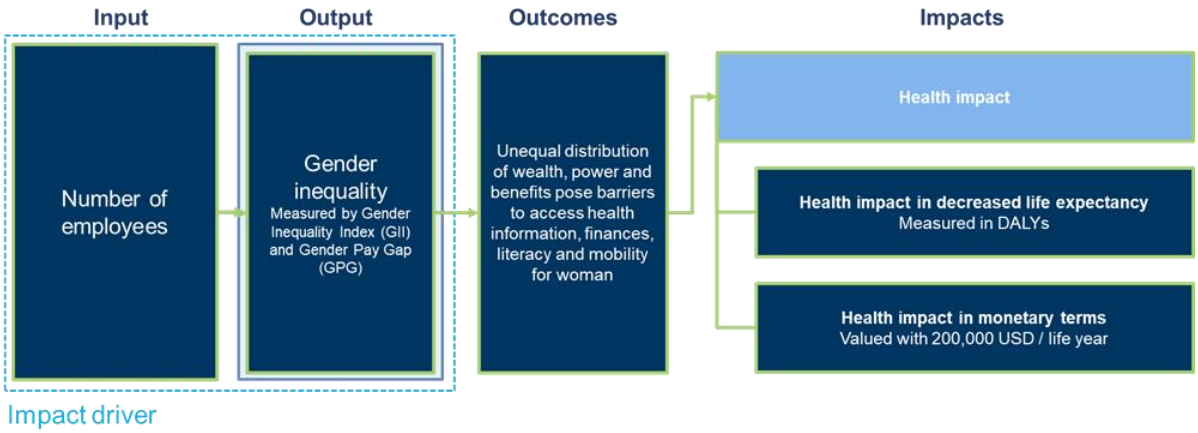
inclusive workplaces, and promoting equitable economic opportunities for shared prosperity globally. These challenges underscore the imperative of creating environments where everyone can thrive and contribute to sustainable development.

2.14.2 Activity Data

The activity data requires the association of individuals with demographic characteristics, regions, sectors, and income.

2.14.3 WifOR Institute

The WifOR Institute approach to DEI focuses on assessing the impact of gender pay disparities, which serve as a key indicator of gender inequality within societies. By quantifying the difference in earnings between men and women (known as the gender pay gap), the approach sheds light on systemic issues and barriers faced by women in achieving parity in societal status. Utilising data sources such as the WIOD, the ILO database, Eurostat, and the OECD, the approach analyses labour-related indicators to understand employment patterns and challenges. Through the calculation of the gender pay gap as a percentage difference in mean earnings, the approach provides a monetized impact, offering insights into the economic toll exacted by gender disparities on overall well-being.



[Source: DEI Impact Pathway /WifOR Institute]

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3 CHAPTERS

ENVIRONMENTAL

3.1 Greenhouse Gas (GHG) Emissions

3.1.1 Challenge

GHGs play a significant role in climate change, acting as atmospheric compounds that absorb and re-emit infrared radiation. This phenomenon, known as the greenhouse effect, results from human activities such as burning fuels and deforestation, contributing to elevated GHG concentrations. The warming effect caused by the absorption of infrared radiation leads to global warming and consequential climate change. This environmental shift impacts the world in various ways, including altered climate patterns, rising sea levels, and societal costs such as desertification and reduced agricultural yields. The resulting consequences extend to human health issues, including malnutrition and diseases. To delve into the intricacies of these processes, detailed methodology documents are available for reference, ensuring a comprehensive understanding of the relationship between human activities, GHG emissions, and their far-reaching impacts.

The IPCC Report of 2014 lists the following gases as problematic:

- Carbon dioxide (CO2)
- Methane (CH4)
- Nitrous oxide (N2O)
- Fluorinated gases (F-gases)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF6)

The IPCC report 2023 provides a more detailed assessment of the contributions of different greenhouse gases to global warming. It finds that CO2 is still the most important greenhouse gas, accounting for about 74% of the warming from human activities since 1750. However, it also finds that methane has become more important in recent years, accounting for about 13% of the warming since 1750. Nitrous oxide and fluorinated gases account for about 5% and 18% of the warming since 1750, respectively.

SDG 13 addresses this challenge by focusing on combating climate change and its impacts, emphasising targets such as halving greenhouse gas emissions globally by 2030, improving global infrastructure and resilience to climate change, mobilising financial resources for climate-related action, and enhancing capacity-building for climate resilience and effective climate change policies. These principles align with efforts to achieve the Paris Agreement's goals of limiting global warming to well below 2 degrees Celsius and pursuing efforts to limit it to 1.5 degrees Celsius above pre-industrial levels.

The IPCC has been instrumental in synthesising scientific evidence and providing comprehensive assessments of climate change, as seen in its reports such as the 2014 Synthesis Report and the more recent 2023 Synthesis Report. These reports compile contributions from Working Groups I, II, and III, offering insights into the latest scientific understanding of climate change impacts, adaptation and mitigation strategies. Additionally, the UNEP has published critical reports, like the Emissions Gap Report, which highlights the urgency of reducing GHG emissions to mitigate climate change. The IEA provides valuable

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data on CO2 emissions, offering insights into emission trends and their implications for climate action. Furthermore, organisations like GermanWatch and the Climate Action Tracker (CAT) contribute to the discourse on climate change by publishing reports such as the Climate Risk Index and assessments of countries' progress towards meeting climate targets. Together, these leading international documents play a crucial role in informing policymakers, stakeholders, and the public about the state of GHG emissions, climate impacts, and the urgency of climate action.

3.1.2 Activity Data

Collecting activity data from own operations is essential for accurately calculating emissions. This involves obtaining quantitative information from various internal departments, such as energy consumption from facilities and fuel usage from transportation. The collaboration extends to external stakeholders, particularly for Scope 3 emissions that encompass indirect impacts along the value chain. Producers must engage with suppliers, customers, and other relevant parties to gather activity data related to their products and services upstream and downstream. Concurrently, activity data must be converted into standardised CO2 equivalents by considering the global warming potential of each greenhouse gas over a specific time horizon, typically 100 years. This meticulous process ensures a comprehensive and standardised approach to greenhouse gas accounting, aligning with widely accepted industry standards.

Carbon dioxide (CO2)

- EDGAR (Emission Database for Global Atmospheric Research)
- GHG-Inventories.Org
- WRI's CAIT Climate Data Explorer
- Global Carbon Project
- Methane (CH4)

Methane

IPCC Tier 1 CH4 Emissions Database

- GRI Renewables GHG Database
- FAOSTAT Agri-Environmental Statistics
- UNEP/CH4
- Nitrous oxide (N2O)

Example

CO2 tonne = CH4 tonne * 28

Nitrous oxide

IPCC Tier 1 N2O Emissions Database

- OECD-FAO Agricultural Data
- UNEP/AGENDA 2000
- GRI Renewables GHG Database
- Fluorinated gases (F-gases)

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Example

CO2 tonne = N2O tonne * 310

Fluorinated gases (F-gases)

IPCC Tier 1 F-gas Emissions Database

- UNEP-TEAP (Technology and Economic Assessment Program)
- Eurostat GHG Emission Accounts
- USEPA Greenhouse Gas Inventory
- Hydrofluorocarbons (HFCs)

Example

CO2 tonne = F-gas tonne * GWP (100 years)

where GWP (100 years) is the global warming potential of the F-gas in question. For example, if you have 1 tonne of sulfur hexafluoride (SF6), which has a GWP of 23,900, then you would have 23,900 tonnes of CO2 equivalent.

- IPCC F-gas GWP values: The IPCC provides a table of GWP values for F-gases in its 2014 Fifth Assessment Report (AR5). The table includes GWP values for both the 20-year and 100-year time horizons.
- UNEP TEAP F-gas GWP values: The United Nations Environment Programme's Technology and Economic Assessment Program (UNEP-TEAP) also provides a table of GWP values for F-gases. The table includes GWP values for both the 20-year and 100-year time horizons.
- USEPA Greenhouse Gas Inventory F-gas GWP values: The US Environmental Protection Agency (EPA) also provides a table of GWP values for F-gases. The table includes GWP values for the 100-year time horizon.
- German: Umweltbundesamt (Federal Environment Agency): https://www.umweltbundesamt.de/daten/klima/treibhausgas-emissionen-in-deutschland/emissionen-fluorierter-treibhausgase-f-gase
- European Union: Joint Research Centre (JRC): https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022PC0150
- Swiss: Bundesamt für Umwelt (BAFU): http://www.bafu.admin.ch/
- Chinese: Ministry of Ecology and Environment (MEE): https://english.mee.gov.cn/
- Hong Kong: Environmental Protection Department (EPD): https://www.epd.gov.hk/epd/english/top.html
- Japanese: Ministry of the Environment (MOE): https://www.env.go.jp/en/
- Korean: Ministry of Environment (MOE): https://me.go.kr/eng/web/main.do
- Saudi Arabian: Ministry of Environment, Water and Agriculture (MEWA): https://www.mewa.gov.sa/en/Pages/default.aspx

Hydrofluorocarbons (HFCs)

IPCC Tier 1 HFC Emissions Database

- UNEP-TEAP (Technology and Economic Assessment Program)
- UNEP/AGENDA 2000
- USEPA Greenhouse Gas Inventory

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- Perfluorocarbons (PFCs)

Example

CO2 tonne = HFC tonne * GWP (100 years)

where GWP (100 years) is the global warming potential of the HFC in question. For example, if you have 1 tonne of HFC-134a, which has a GWP of 14,800, then you would have 14,800 tonnes of CO2 equivalent.

- IPCC HFC GWP values: The IPCC provides a table of GWP values for HFCs in its 2014 Fifth Assessment Report (AR5). The table includes GWP values for both the 20-year and 100-year time horizons.
- UNEP TEAP HFC GWP values: The United Nations Environment Programme's Technology and Economic Assessment Program (UNEP-TEAP) also provides a table of GWP values for HFCs. The table includes GWP values for both the 20-year and 100-year time horizons.
- USEPA Greenhouse Gas Inventory HFC GWP values: The US Environmental Protection Agency (EPA) also provides a table of GWP values for HFCs. The table includes GWP values for the 100-year time horizon.
- German: Umweltbundesamt (Federal Environment Agency): https://www.umweltbundesamt.de/publikationen/hydrofluorocarbon-emission-reduction-a-crucial
- European Union: Joint Research Centre (JRC): https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022PC0150
- Swiss: Bundesamt für Umwelt (BAFU): http://www.bafu.admin.ch/
- Chinese: Ministry of Ecology and Environment (MEE): https://english.mee.gov.cn/
- Hong Kong: Environmental Protection Department (EPD): https://www.epd.gov.hk/epd/english/top.html
- Japanese: Ministry of the Environment (MOE): https://www.env.go.jp/en/
- Korean: Ministry of Environment (MOE): https://me.go.kr/eng/web/main.do
- Saudi Arabian: Ministry of Environment, Water and Agriculture (MEWA): https://www.mewa.gov.sa/en/Pages/default.aspx

Perfluorocarbons (PFCs)

IPCC Tier 1 PFC Emissions Database

- UNEP-TEAP (Technology and Economic Assessment Program)
- UNEP/AGENDA 2000
- USEPA Greenhouse Gas Inventory
- Sulfur hexafluoride (SF6)

Example

CO2 equivalent = mass (PFC) * GWP (PFC)

Perfluorocarbon-14 (CF4)	CF4	7,380
Perfluorocarbon-12 (CF2Cl2)	CF2Cl2	9,240

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Perfluorocarbon-16 (C2F6) C2F6 14,800

Sulfur hexafluoride (SF6)

IPCC Tier 1 SF6 Emissions Database

- UNEP-TEAP (Technology and Economic Assessment Program)
- UNEP/AGENDA 2000
- USEPA Greenhouse Gas Inventory

Example

CO2 equivalent (SF6) = Mass (SF6) * GWP (SF6)

Sulfur hexafluoride (SF6) SF6 23,900

3.1.3 Database

GEO GHG Emission Database:	This database provides data on GHG emissions from a variety of sources, including energy, industry, agriculture, forestry, and land use change. The database includes data from over 190 countries.
GEO GHG Emission Database:	https://unepgrid.ch/platforms
Aqueduct:	https://www.wri.org/research/aqueduct-30-updated-decision-relevant-global-water-risk-indicators
NDC Registry:	https://unfccc.int/NDCREG
GGREAD:	https://www.ipcc-nggip.iges.or.jp/

3.1.4 Transparent

3.1.4.1 Introduction

The Earth's atmosphere shields us from harmful radiation, provides us with air to breathe, and traps enough heat from the sun to enable the planet to support complex forms of life. Scientists have long been aware of this essential "greenhouse effect". However, in recent decades, they have become increasingly concerned about changes in the composition of the Earth's atmosphere and the potential of these changes to increase the amount of heat trapped. The data now conclusively show that the Earth is warming and has been for some time. Scientists are confident that the net effect of human activities – and the resulting increase in atmospheric GHG concentration – has contributed to this warming. This is discussed in detail in the Intergovernmental Panel on Climate Change (IPCC 2013, 2018) reports. Emissions of CO2, other GHGs, aerosols, and ozone precursors affect the radiation absorption properties of the atmosphere. This has both short-term and long-term effects. Even in the absence of humans, Earth has a naturally occurring carbon cycle in which carbon is exchanged between different living organisms and the environment through natural processes. Some processes (e.g. photosynthesis) remove GHGs from the atmosphere, while others (e.g. respiration or decomposition in the soil) emit carbon into the atmosphere. Since the industrial revolution, human activity has modified the carbon cycle by adding sources (e.g. burning fossil fuels) and removing sinks (e.g. changes in land use, especially deforestation). This has led to an increasing concentration of GHGs in the atmosphere, which increases the greenhouse effect. This, in turn, changes the Earth's climate.

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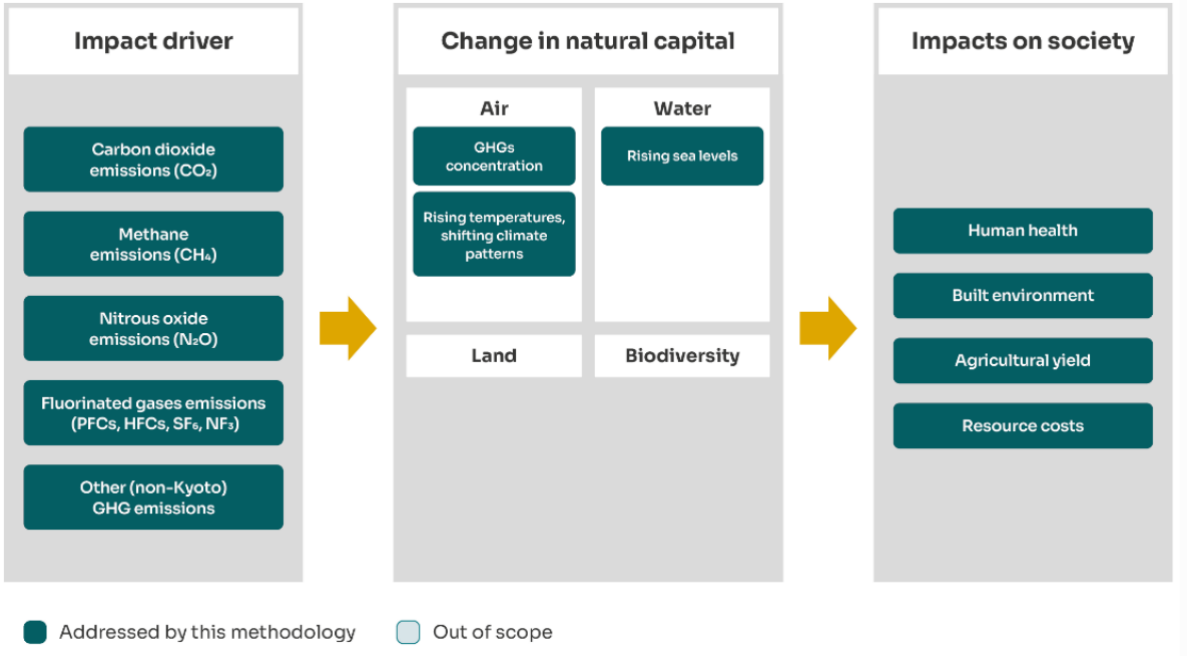
(Transparent Natural Capital Management Accounting methodology (NCMA), page 23)



[Source: GHG Impact Pathway / Transparent]

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- Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.), "An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development", Cambridge University Press, Cambridge, UK & New York, 2018.

3.1.4.2 Data Sources

No explicit value factor is recommended. Potential SCC estimates in Annex III of NCMA General Guidance (see page 62):

- Resources for the Future (RFF): "Comprehensive evidence implies a higher social cost of CO2"
- Interagency Working Group on Social Cost of Greenhouse Gases, United States Government: "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990"
- Project Drawdown: "Solutions cost per metric ton"
- CDP: "Putting a price on carbon, The state of internal carbon pricing by corporates globally"

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For marginal abatement costs, the following information is provided in Annex II of NCMA General Guidance (see page 62): “marginal abatement costs that are computed from a cost-effectiveness analysis. This analysis computes the costs of carbon as its shadow price when reaching a predefined climate goal and can thus incorporate science-based targets (e.g., 1.5° goal (IPCC 2018, NGFS 2022 climate scenarios).”

- Rennert, K., Errickson, F., Prest, B.C. et al, “Comprehensive evidence implies a higher social cost of CO2”, Nature, vol. 610, pp. 687-692, 2022.
- Interagency Working Group on Social Cost of Greenhouse Gases, United States Government, “Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide”, 2021.
- Project Drawdown, “Solutions Cost Per Metric Ton”, [Online]. Available: https://drawdown.org/solutions/solutions-table-cost-per-tonne. [Accessed 5 December 2022]
- CDP, “Putting a price on carbon”, April 2021. [Online]. Available: https://www.cdp.net/en/research/global-reports/putting-a-price-on-carbon. [Accessed 5 December 2022].
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- Network for Greening the Financial System: NGFS Scenarios for central banks and supervisors. Available: https://www.ngfs.net/sites/default/files/medias/documents/ngfs_climate_scenarios_for_central_banks_and_supervisors_.pdf.pdf [September 2022]

3.1.4.3 Calculation Logic

Formula

Monetized impact = Emissions in CO2 equivalent x social costs of carbon

Alternatively,

Monetized impact = Emissions in CO2 equivalent x marginal abatement costs

Required Activity Data:

Emissions in CO2 equivalent

Valuation method: damage cost or marginal abatement costs. No distinct source provided that should be used. Use of social cost of carbon estimate for emissions irrespective of their location.

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3.1.5 WifOR Institute (Environmental Prices)

3.1.5.1 Introduction

Greenhouse gas emissions contribute to global warming, creating a greenhouse effect in the Earth's atmosphere, leading to climate change effects such as increased extreme weather events, rising sea levels, and reduced water resources. Recalling the IPCC reports, the primary gases – CO2, CH4, and N2O – are evaluated based on their GWP relative to CO2 over a 100-year period. Costs associated with climate change, as advised by the UBA, are assessed in terms of damage, encompassing various impacts like lost agricultural yields, reduced recreational benefits, and compromised quality of life due to chronic health issues. While some economic losses are quantified directly, translating societal impacts, such as health damages, into monetary terms like medical treatment costs, remains essential for comprehensive assessment.

3.1.5.2 Data Source

- WIOD, EXIOBASE 3.8.1, EDGAR v8.0, Eurostat Air Emission Accounts, OECD Air Emission Accounts, IPCC's Fifth Assessment Report A5

3.1.5.3 Subcategories

Co2, CH4, N2O

3.1.5.4 Formula

- Sum of activity data per country/sector: Co2 equivalent = Co2 x 28*CH4 x 265*N2O in 100-year GWP
- Simple multiplicative: Monetized impact = Sum of activity data x value factor (social cost of carbon)
- Global Value

3.1.5.5 Impact Pathway

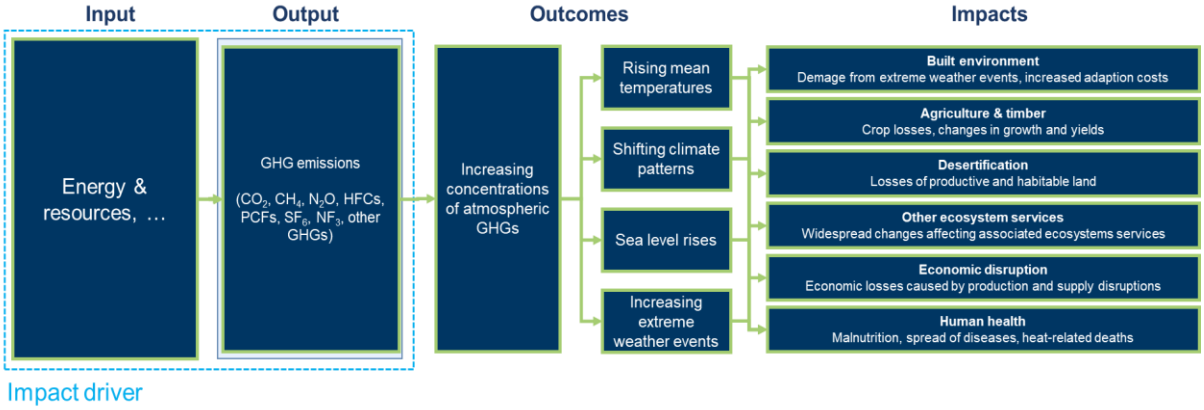

Figure: Impact Pathway of GHG emissions (source: VBA/WifOR Institute illustration)

3.1.5.6 Valuation Method (hui, GDP loss, …)

1. Built Environment (e.g. increased adaption costs) →Economic Damage
2. Agriculture and Timber (e.g. crop loss) → Economic Damage
3. Desertification (e.g. loss of productive land) → Economic Damage
4. Other Ecosystem Services (e.g. acidification of oceans) → Economic Damage, Well-being
5. Economic Disruption (e.g. due to reduction of production) → Economic Damage
6. Human Health (e.g. heat-related death) → HUI/DALY

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3.1.5.7 Sources of Valuation Data:

German Federal Environmental Agency (UBA)

The underlying air quality modelling data is based on the IAM model FUND.

3.1.5.8 Geographical Differences

- None, we only look at the global values.

3.1.5.9 Transfer Mechanism

Global Value in USD. No adjustment for PPP.

3.1.5.10 GHG-specific

IAM model: FUND

Pure time discount rate: 1%

Tipping point treatment: Not included.

3.1.5.11 Global Damage

USD 11.5 Trillion (2020)

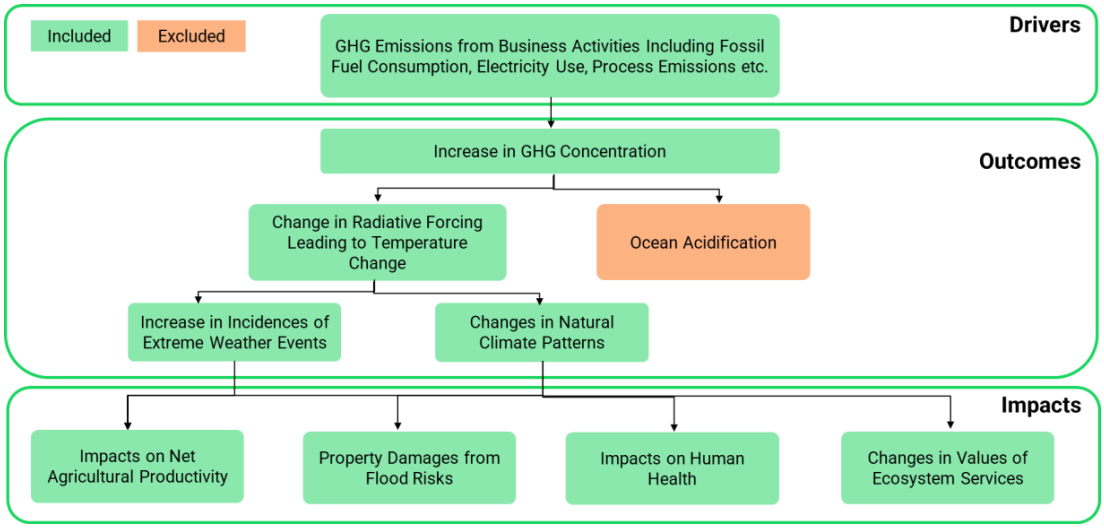
3.1.5.12 Environmental Prices

WifOR Institute: https://www.wifor.com/en/impact-valuation-factors/

3.1.6 GIST Impact

3.1.6.1 Evaluation Framework and Methodology

An overview of the framework adopted for the valuation of GHGs is shown below.



[Source: GIST Impact]

The Social Cost of Carbon (SCC) approach has been adopted by GIST Impact for economic valuation. The SCC approach considers the damage costs due to global warming and its associated impacts. The method has been preferred because it accounts for the amount of investment required to reduce future damage caused by the present levels of GHG emissions. SCC also accounts for the incremental concentration of GHG in the atmosphere (as the residence time of few GHGs in the atmosphere is quite long) and therefore provides a different value for every year. Further, SCC accounts for a global cost of damage, which is important because impacts caused by GHG emissions, such as climate change, are not a local phenomenon but a global level issue. Thus, SCC allows the large-scale (global) externalities

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of GHG emissions to be incorporated into the decision-making and policy development activities of countries across the globe.

The framework for the evaluation of greenhouse gas emissions is based on the social cost of carbon approach as adopted by USEPA. Within this framework, multiple activities that are carried out across the value chain of a company can be "drivers" for GHG emissions. Some of the most important activities include the use of fossil fuels, the use of electricity district heating, steam, transportation of goods within company premises and outside, use of products and services of the company by users during product lifetime, etc. The release of GHGs in the atmosphere, due to these drivers (across different scopes of the value chain – e.g. Scope 1, 2, and 3), leads to an increase in the concentration of these gases. This can also be termed as a biophysical change in the environment (i.e. the "outcome").

The next step includes modelling for projecting the outcomes and estimating long-term impacts, as detailed in the approach adopted by USEPA. The USEPA approach uses IAMs, namely FUND, DICE, and PAGE[5] for carrying out these steps. Although the three models vary significantly from each other based on the considered parameters and assumptions, the input variables were chosen based on extensive research to get consistent outputs from all three models. The final outputs of SC-CO_2 are based on different discounting scenarios of 2.5%, 3%, and 5%. The value at each discount rate represents the average costs of damage obtained from all three models.

GIST Impact uses the individual Social Cost for CO_2, CH_4, and N_2O, as reported at a 3% discounting rate. For other GHGs (HFCs, PFCs, SF_6, NF_3, etc.), aggregated CO_2 equivalents were calculated, and the Social Cost of CO_2 was applied as separate Social costs are not available.

3.1.6.2 Calculation Logic

The cost of GHG release or benefit due to avoided GHG release is then calculated based on released quantities in a year and the associated social cost of GHG.

Benefits/Cost (in USD) = Emissions quantity released / avoided in a particular year (tonne) * Social cost of GHG for that year (USD/tonne)

3.1.6.3 Data Sources [6]

- Griffiths, C., Kopits E., Marten, A., Moore, C., Newbold, S., Wolverton, A., (2012). The social cost of carbon: Valuing carbon reductions in policy analysis In *Fiscal policy to mitigate climate change*. International Monetary Fund.
- Rennert K., Kingdon C., (2019). The social cost of carbon 101: A review of the social cost of carbon, from a basic definition to the history of its use in policy analysis Washington, DC: Resources for the Future. The Climate Decade: Changing Attitudes on Three Continents, 30.
- Rennert K., Prest B. C., Pizer W. A., Newell, R. G., Anthoff D., Kingdon C., Errickson F., (2021). The Social Cost of Carbon: Advances in Long Term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates. Brookings Papers on Economic Activity.

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5 FUND-Climate Framework for Uncertainty, Negotiation and Distribution, DICE-Dynamic Integrated Climate-Economy Model, PAGE-Policy Analysis of the Greenhouse Effect.

6 The reference list is intentionally limited for confidentiality reasons.

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- Interagency Working Group (2021). Technical support document social cost of carbon, methane, and nitrous oxide interim estimates under executive order 13990 Tech. rep., White House. URL https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf
- Carleton, T., Greenstone, M., (2021). Updating the United States government's social cost of carbon. University of Chicago, Becker Friedman Institute for Economics Working Paper, (2021-04).
- USEPA (2021). Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. Interagency Working Group on Social Cost of Greenhouse Gases, United States Government.
- Tol, R. S., (2019). A social cost of carbon for (almost) every country. Energy Economics 83, 555-566.

3.1.7 Upright Project

3.1.7.1 Activity Data Sources

Upright generates GHG emission data for companies by using its own proprietary net impact model. The modelling includes the following steps:

- Use a global emission figure: Hannah Ritchie, Pablo Rosado and Max Roser (2020) - “Greenhouse gas emissions” Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/greenhouse-gas-emissions' [Online Resource]
- Estimate share of the emissions caused by the private sector by utilising information on sector and country emissions, combined with the information about public/private companies per sector and country
- Allocate the emissions to products and services produced by the private sector, and ultimately to company entities by utilising the Upright net impact model: https://docs.uprightplatform.com/methodology/net-impact/overview-of-the-upright-net-impact-model

By using the above top-down approach, it is possible to prevent double-counting between companies, meaning that the sum of emissions caused by all companies globally as well as the social costs resulting from them sum up to a global figure. This can be especially useful when thinking about the “true profitability of a company” (how much this company would need to pay to compensate for the externalities it causes) and externality-based taxation.

3.1.7.2 Calculation Logic

Monetary Impact = Sum of CO2 equivalents activity data * social costs of carbon (global)

The monetization factor of USD 417 per tonne CO2 used by Upright for CO2 equivalents emissions is based on the study by Ricke, Drouet, Caldeira, et al., titled “Country-level social cost of carbon”, published in Nature Climate Change in 2018. Despite the abundance of new research on the SCC since then, Upright has not found a compelling reason to update this figure. This decision is supported by several factors:

1. The USD 417 per tonne CO2 figure falls within the margins of error or variations accounted for in newer mainstream research on SCC.
2. Newer studies often reflect minor changes in assumptions, such as discount rates, and the USD 417 figure remains well within these variations.

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3. Upright reviewed various authoritative sources when making decisions on the social cost of carbon, including IPCC reports, OECD publications on Effective Carbon Rates and Cost-Benefit Analysis, and multiple academic papers on SCC from renowned scholars.

Among the studies considered were works by Carleton, Tamma, Greenstone, Pindyck, Tol, Smith, Braathen, Kikstra, the US Interagency Working Group (IWG) Technical Support Document, Prest, Rennert, Newell, Wingenroth, and the comprehensive evidence presented in Rennert, Errickson, Prest, et al.'s 2022 Nature publication.

These sources collectively supported Upright's decision to maintain the USD 417 per tonne CO2 as the monetization factor for CO2 equivalents emissions. While newer research exists, the overall consensus and compatibility with the previously established figure have led Upright to retain this value for its calculations related to carbon emissions.

3.1.7.3 Subcategories

Greenhouse gases included in the calculation: carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, and ozone.

All these different categories are converted to CO2 equivalents.

3.1.7.4 Impact Pathways

Preferable, at least the following impacts should be taken into account when defining the social cost of carbon: effects on human health (DALY), effects on agriculture (economic damage), the decline in ecosystem services (economic damage, DALY), damage to the built environment (economic damage), the decline in labour productivity (economic damage).

As Upright does not have its own estimates for the social cost of carbon, we have relied on SCC studies that aim to take these factors into account as widely as possible (see below list).

3.1.7.5 Data Sources for Social Cost of Carbon

Upright's reliance on this particular study reflects a meticulous consideration of esteemed and influential data sources within the climate science and economics domain.

- Ricke, Drouet, Caldeira et al. (2018): The primary reference for establishing the USD 417 per tonne CO2 value, serving as a foundational study in understanding the country-level social cost of carbon.
- IPCC Sixth Assessment Report: An authoritative report providing comprehensive insights into the current state of climate science, impacts, and mitigation strategies.
- OECD Publications:
    - Effective Carbon Rates 2021: This OECD report sheds light on carbon pricing and its effectiveness in mitigating carbon emissions. [missing]
    - Cost-Benefit Analysis and the Environment: Further Developments and Policy Use 2018: An OECD publication exploring the application of cost-benefit analysis in environmental policy. [missing]
- Carleton, Tamma, Greenstone (2021): A University of Chicago working paper focused on updating the United States Government's Social Cost of Carbon, offering insights into newer methodologies and assessments.

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- Pindyck (2019): The Journal of Environmental Economics and Management paper revisits the social cost of carbon, contributing to the ongoing discourse on SCC estimation.
- Tol (2019): Energy Economics publication discussing the social cost of carbon for various countries, adding nuanced perspectives to the valuation process.
- Smith, Braathen (2015): An OECD Environment Working Paper providing an overview of monetary carbon values and their relevance in policy appraisal.
- Kikstra et al. (2021): An Environmental Research Letters article exploring the social cost of carbon dioxide concerning climate-economy feedback and temperature variability, contributing to newer understandings of SCC estimation.
- US Interagency Working Group (IWG) Technical Support Document: A document that likely presents official assessments and calculations related to the social cost of carbon, methane, and nitrous oxide in the United States.
- Prest, Rennert, Newell, Wingenroth (2022): The "Social Cost of Carbon Explorer" publication, provides a contemporary examination and assessment of the social cost of carbon. [missing]
- Rennert, Errickson, Prest et al. (2022): A Nature publication presenting comprehensive evidence suggesting a higher social cost of CO2, potentially impacting the ongoing discussion on SCC valuation. [missing]

3.1.7.6 Calculation Logic

Monetary impact = Sum of CO2 equivalents activity data * social costs of carbon (global)

The monetization factor of USD 417 per tonne CO2 used by Upright for CO2 equivalents emissions is based on the study by Ricke, Drouet, Caldeira, et al., titled “Country-level social cost of carbon”, published in Nature Climate Change in 2018. Despite the abundance of new research on the SCC since then, Upright has not found a compelling reason to update this figure. This decision is supported by several factors:

1. The USD 417 per tonne CO2 figure falls within the margins of error or variations accounted for in newer mainstream research on SCC.
2. Newer studies often reflect minor changes in assumptions, such as discount rates, and the USD 417 figure remains well within these variations.
3. Upright reviewed various authoritative sources when making decisions on the social cost of carbon, including IPCC reports, OECD publications on Effective Carbon Rates and Cost-Benefit Analysis, and multiple academic papers on SCC from renowned scholars.
4. In general, the precautionary principle supports maintaining a bias towards estimates on the higher end of the ranges of estimates. On average, the beliefs of climate scientists imply a much higher SCC (around USD 300 or more) than do the beliefs of economists (see: Pindyck, 2019).

Among the studies considered were works by Carleton, Tamma, Greenstone, Pindyck, Tol, Smith, Braathen, Kikstra, the US Interagency Working Group (IWG) Technical Support Document, Prest, Rennert, Newell, Wingenroth, and the comprehensive evidence presented in Rennert, Errickson, Prest, et al.'s 2022 Nature publication.

These sources collectively supported Upright's decision to maintain the USD 417 per tonne CO2 as the monetization factor for CO2 equivalents emissions. While newer research

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exists, the overall consensus and compatibility with the previously established figure have led Upright to retain this value for its calculations related to carbon emissions.

3.1.7.7 Geographical Differences

Geographical differences are not yet taken into account when monetizing GHG emissions.

3.1.8 VBA / IFVI

3.1.8.1 Introduction

GHGs are components of the atmosphere that absorb and emit infrared radiation effectively trapping and emitting heat towards the surface of Earth. Due to human-related activities, including activities from corporate entities, the concentration of CO2 (a significant GHG) has risen. Most of the GHG emissions have come directly from burning fossil fuels. The increased concentration of GHGs in the atmosphere alters the physical environment by increasing temperatures, altering precipitation patterns, raising sea level, acidifying oceans, and intensifying the severity and frequency of extreme climate events (e.g. droughts, wildfires, hurricanes, floods), as outlined by the IPCC. Each of these changes to the environment directly affects society by increasing human mortality and displacement, deteriorating food supplies, flooding coastal areas, and damaging infrastructure, to name a few.

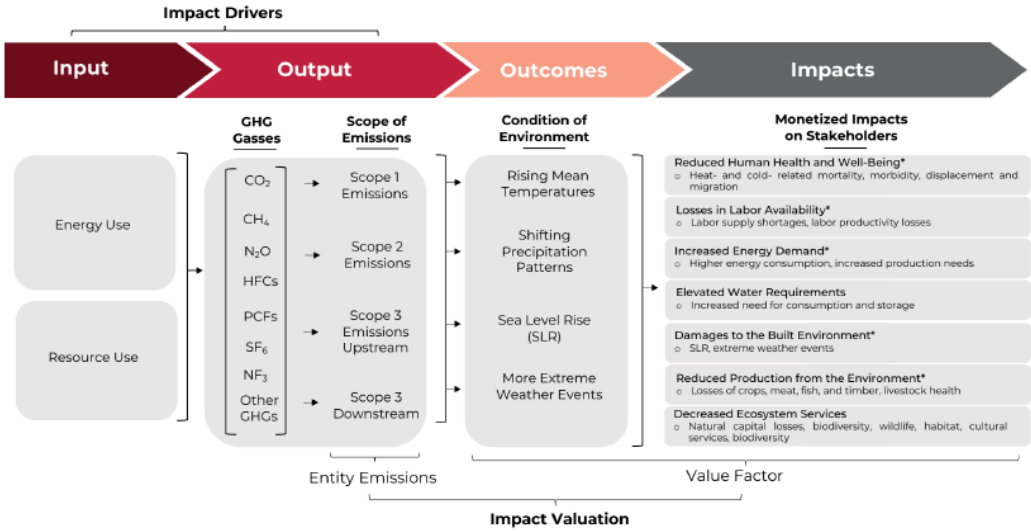

Figure: Simplified impact pathway for GHG emissions

3.1.8.2 Data Sources

The SCC models include four modules which determine the final value factor (socioeconomic/emissions module, climate module, damage module, and discounting module). An overview of the individual modules of the modelling is available in Figure 2.10-B.

General information on the SCC models:

1. DSCIM: Climate Impact Lab (2022): Documentation for Data-driven Spatial Climate Impact Model (DSCIM). https://impactlab.org/research/dscim-user-manual-version-092022-epa/.
2. GIVE: Rennert et al. (2022): Comprehensive evidence implies a higher social cost of CO2. https://www.nature.com/articles/s41586-022-05224-9. (see also: https://www.rff.org/publications/data-tools/scc-explorer/)

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3.1.8.3 Calculation Logic

General calculation logic:

$$Monetary\ value\ of\ GHG\ emissions_{total} = \sum (GHG\ emission\ Scope\ 1, 2, and\ 3)\ x\ VF\ (SCC)$$

Value factor (VF) for GHG emissions (2023): USD 236/metric tonne of CO2 equivalents.

Activity Data (impact driver – GHG emissions):

Total GHG emissions of an entity should be measured, including Scope 1, 2, and 3. All three scopes as measured according to the GHG Protocol are fully attributable to the entity as the GHG Protocol allocates emissions to entities.

To normalise the potential impacts of different GHGs, all GHGs should be converted to CO2 equivalents using GWP. GWP values reflect the warming period over a 100-year time horizon and should come from the most recent assessment from the IPCC report 2023. All GHG emissions data should be in units of metric tonnes of CO2 equivalents.

Valuation of GHG emissions (Social Cost of Carbon – SCC):

Impacts from GHG emissions which are considered in the valuation include:

- Human health and well-being (mortality)
- Increased energy demand
- Damage to the built environment
- Reduced production from the environment (agricultural production)
- Loss in available labour

To determine the value factor, the SCC approach is used. The SCC is calculated using an IAM that considers outcomes and impacts on society of each metric tonne of CO2 equivalents emitted. By considering socioeconomic futures, GHG emissions (outputs) are linked to changes in the physical environment (outcomes) and subsequent monetized damages (impacts). In the last step, future damages are discounted to present value. The output from an SCC model is a cost, in currency, of each metric tonne of CO2 equivalents emitted which is then used as the value factor.

Two models are used to determine the GHG value factor: The Greenhouse Gas Impact Value Estimator (GIVE) and the Data-driven Spatial Climate Impact Model (DSCIM). The value factor developed from each model is averaged to produce a single value factor. This approach maximises the distinctive and complementary strengths of each model.

Valuation of impacts follows a damage cost approach. A global value factor is used since climate change is a global phenomenon, which does not materialise at the source of the emissions.

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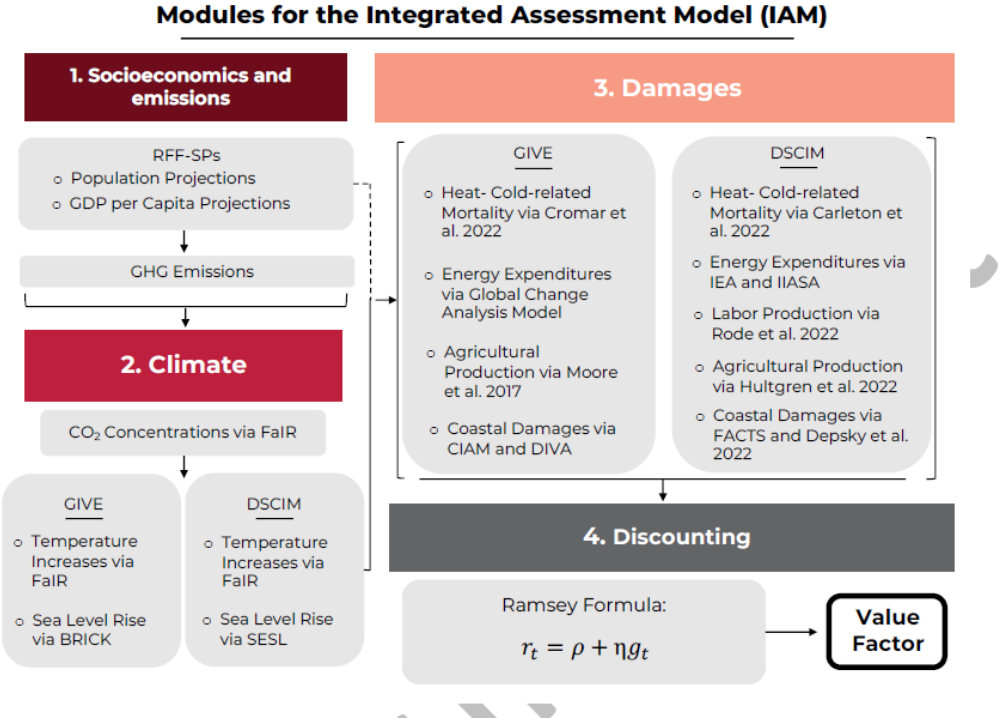

Figure 2.10-B: Modules of the IAM

Assumptions and other considerations:

The value factor uses a dynamic discount rate (Ramsey formula) calibrated to meet a near-term discount rate of 2%; modelling of future impacts due to GHG emissions until the year 2300.

Sources are listed by each of the four modules:

Socioeconomic/emissions module:

- Rennert et al. 2022, The Social Cost of Carbon: Advances in Long-Term Probabilistic Projections of
- Population, GDP, Emissions, and Discount Rates.

Climate module:

- The Finite Amplitude Impulse Response (FaIR) model can be accessed via: https://docs.fairmodel.net/en/latest/
- Wong et al. (2017): BRICK v0.2, a simple, accessible, and transparent model framework for climate and regional sea level projections.
- Climate Impact Lab (2022): Data-driven Spatial Climate Impact Model User Manual, Version 092022-EPA.

Damage module:

- Cromar et al. (2022): Global health impacts for economic models of climate change: A systematic review and meta-analysis.
- Clarke et al. (2018): Effects of long-term climate change on global building energy expenditures.

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- Edmonds et al. (2004): Stabilization of CO2 in a B2 world: insights on the roles of carbon capture and disposal, hydrogen, and transportation technologies.
- Moore et al. (2017): New science of climate change impacts on agriculture implies higher social cost of carbon.
- Diaz (2016): Estimating global damages from sea level rise with the Coastal Impact and Adaption Model (CIAM).
- Vafeidis et al. (2008): A new global coastal database for impact and vulnerability analysis to sea level rise.
- Carleton et al. (2022): Valuing the global mortality consequences of climate change accounting or adaptation costs and benefits.
- Rode et al. (2021): Estimating a social cost of carbon for global energy consumption, Nature.
- IEA: https://www.iea.org/data-and-statistics/data-product/world-energybalances#data-sets Scenario explorer database can be accessed via IIASA (2022): https://data.ece.iiasa.ac.at/ar6/#/login?redirect=%2Fworkspaces
- Hultgren et al. (2022): Estimating global impacts to agriculture from climate change accounting
- for adaptation. Depsky et al. (2022): DSCIM-Coastal v1.0: An Open-Source Modelling Platform for Global Impacts of Sea Level Rise.

Discounting module:

- Carleton & Greenstone (2022): A guide to updating the US government's social cost of carbon.
- Rennert et al. (2022): Comprehensive evidence implies a higher social cost of CO2.

3.1.9 CE Delft (Environmental Prices)

3.1.9.1 Data Sources

- National Emission Register (NER) from RIVM
- Global Greenhouse Gas Emissions Database (GGGI) from PBL
- Emissions Database for Global Atmospheric Research (EDGAR) from JRC
- National Emission Register (NER) from RIVM
- National Environmental Overview Data (NOG) from RIVM
- Climate Monitor Netherlands from PBL

3.1.9.2 Calculation Logic

Monetary impact = Sum of CO2 equivalents activity data * Social Costs of Carbon (Netherlands)

CE Delft follows the ReCiPe (Relevance, Endpoint, and Impact assessment Point) method.

The calculation of GHG emissions within the ReCiPe 2016 model typically involves several steps. First, it considers the emissions of different greenhouse gases such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), among others. Each of these gases is assigned a GWP factor, which reflects its relative potency in causing climate change over a specified timeframe compared to CO2.

Once the emissions of these gases are identified, they are converted into a common unit known as CO2 equivalents to allow for a standardised comparison of their impacts. This conversion involves multiplying the amount of each greenhouse gas emitted by its respective

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GWP factor. For instance, methane has a higher GWP than CO2, so a certain amount of methane emitted will be converted into a higher CO2 equivalents value.

These CO2 equivalents values are then aggregated across different gases and emission sources to provide an overall assessment of the total greenhouse gas emissions associated with a particular activity, process, product, or system. The result offers insight into the potential climate change impact of the assessed entity based on its GHG emissions.

The ReCiPe 2016 model goes further by considering other environmental impact categories beyond GHG emissions, providing a comprehensive evaluation of environmental impacts across multiple dimensions. This holistic approach allows decision makers to better understand and compare the overall environmental footprint of different processes or products, aiding in making more informed and sustainable choices.

EEA 2021 methodology has made the following improvements over the NEEDS using the rationale of the NEEDS project that is ultimately based on QALY and DALY analysis. These improvements relate to spatial resolution, concentration response functions, atmospheric chemical modelling, and integration of damage costs.

Midpoints:

- GWP: the most well-known GHG indicator, which measures the potential of a greenhouse gas to trap heat in the atmosphere.
- Tropospheric ozone formation potential (ODP): measures the potential of a substance to contribute to the formation of tropospheric ozone, which is a form of air pollution that can damage human health and ecosystems.
- Methane lifetime (ML): measures the average lifetime of methane in the atmosphere before it is broken down.
- Water vapour lifetime (WL): measures the average lifetime of water vapour in the atmosphere before it precipitates out as rain or snow.
- Nitrous oxide lifetime (N2O): measures the average lifetime of nitrous oxide in the atmosphere before it is broken down.

3.1.9.3 Environmental Prices

Chemical	Lower	Middle	Upper
CO2	€50	€130	€160
CFC-11	€283	€725	€926
PM2.5	€ 73,3	€121	€169
PM10	€ 41,4	€ 69,3	€ 97,9
PM0,1	€296	€438	€660
NO	€ 18,3	€ 29,9	€ 44,1
SO2	€ 33,7	€57.50	€ 83,1
NH3	€ 30,4	€ 49,3	€ 67,9
NMVOS	€ 1,76	€ 2,73	€ 3,82
CH4	€ 1,81	€ 4,70	€ 5,78
As	€6.99	€10.34	€15.58
Cd	€115.74	€171.13	€257.81
Cr-VI	€1.83	€2.74	€4.20
Pb	€19.66	€29.08	€43.81

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Hg	€10.17	€15.33	€23.82
Ni	€103	€190	€386
1,3 Butadiene	€ 1,08	€ 1,66	€ 2,43
Benzeen	€0.24	€0.37	€543
Benzo(a)pyrene	€3.86	€5.70	€8.59
Dioxines	€ 34.071.638	€ 50.367.398	€ 75.847.243
Formaldehyde	€330	€520	€744

[Source: CE Delft, Environmetnal Prices, 2023, Table, pp. 31-32, (in EUR / kg)]

Chemical	Lower (€)	Central (€)	Upper (€)
Carbon dioxide (CO_2)	0.022	0.057	0.094
Chlorofluorocarbons (CFC11)	130	306	504
Fine particulates (PM2.5)	27.7	38.7	59.5
Coarse particulates (PM_{10})	19	26.6	41
Nitrogen oxides (NO_x)	9.97	14.8	22.1
Sulphur dioxide (SO_2)	8.3	11.5	17.9
Ammonia (NH_3)	10	17.5	25.2
Volatile organic compounds (NMVOC)	0.84	1.15	1.84
Carbon monoxide (CO)	0.0383	0.0526	0.0918
Methane (CH_4)	0.673	1.74	2.91
Cadmium (Cd)	371	589	869
Arsenic (As)	586	862	963
Lead (Pb)	3631	5367	5761
Mercury (Hg)	24680	34490	52920
Formaldehyde (CH_2O)	9	12.3	19

[Source: CE Delft, Environmental Prices, Table 2016, p. 33-EUR / kg emission in 2016]

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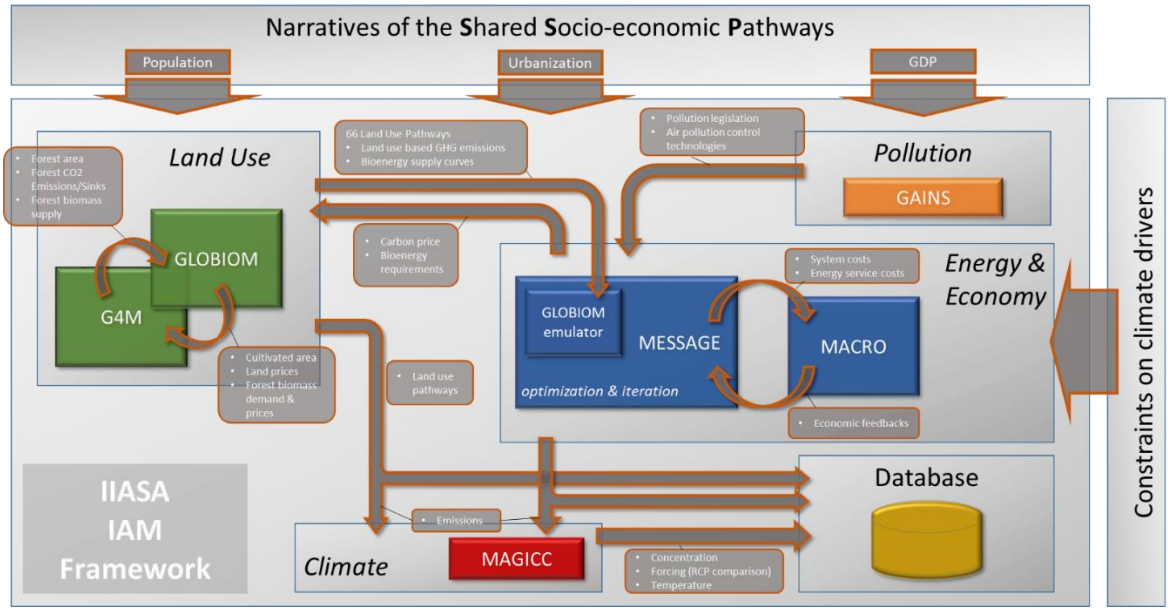
3.1.10 NGFS MESSAGEix-GLOBIOM 1.1-M-R12 (Environmental Prices)

3.1.10.1 Key Drivers



[Source: MESSAGEix-GLOBIUM, github]

3.1.10.2 Valuation Technique

The MESSAGEix-GLOBIOM IAM is a comprehensive tool for analysing energy systems, land use, and climate change. It includes a detailed representation of energy supply technologies, end-use sectors, population and GDP, macro-economy, land use, water, carbon dioxide, non-CO2 greenhouse gases, air pollution, emissions from land, and climate. The model is used to develop scenarios of future energy and climate change that reflect a range of possible societal developments. It can also be used to evaluate the impacts of different mitigation and adaptation policies.

- Energy systems: The model can be used to assess the impacts of different energy technologies, such as renewable energy, nuclear energy, and fossil fuels, on energy supply, emissions, and costs.
- Land use: The model can be used to assess the impacts of different land use practices, such as deforestation, afforestation, and agricultural intensification, on land use, emissions, and food production.
- Climate change: The model can be used to assess the impacts of different greenhouse gas emissions scenarios on global temperature, sea level rise, and extreme weather events.
- Population and GDP: The model can be used to assess the impacts of different population and GDP scenarios on energy demand, emissions, and economic growth.
- Macro-economy: The model can be used to assess the impacts of different energy and climate policies on the macro-economy, including GDP, employment, and inflation.
- Water: The model can be used to assess the impacts of different water management practices on water availability, water demand, and water quality.
- Carbon dioxide: The model can be used to assess the impacts of different CO2 mitigation strategies on emissions, costs, and energy security.

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- Non-CO2 greenhouse gases: The model can be used to assess the impacts of different non-CO2 mitigation strategies on emissions, costs, and air quality.
- Air pollution: The model can be used to assess the impacts of different air pollution control strategies on emissions, health, and ecosystems.
- Emissions from land: The model can be used to assess the impacts of different land use management practices on emissions, soil carbon, and biodiversity.
- Climate: The model can be used to assess the impacts of different climate change scenarios on global temperature, sea level rise, and extreme weather events.

[Source: https://docs.messageix.org/projects/global/en/latest/overview/index.html]

The MESSAGEix-GLOBIOM IAM was first mentioned in the IPCC Fifth Assessment Report (AR5) in 2013. It was used to develop a set of scenarios for future energy and climate change. The model has been used in some subsequent IPCC reports, including the Sixth Assessment Report (AR6), which was released in 2021.

The MESSAGEix-GLOBIOM model uses the following SSPs:

- SSP1: Sustainability – Taking the green road: This scenario describes a world in which there is strong and consistent global cooperation on environmental issues, leading to rapid development and deployment of sustainable technologies.
- SSP2: Middle of the road: This scenario describes a world in which there is moderate environmental concern and a gradual transition to sustainability, with some countries and regions progressing faster than others.
- SSP3: Regional Rivalry – A rocky road: This scenario describes a world in which there is low international cooperation on environmental issues and a focus on national or regional security.

[IPCC Fifth Assessment Report (AR5) (2013); IPCC Special Report on Global Warming of 1.5°C (SR1.5) (2018); IPCC Sixth Assessment Report (AR6) (2021); The IEA World Energy Outlook (IEA, 2022); The NGFS Net Zero Roadmap (NGFS, 2021); The Global Energy Transition Outlook (IEA, 2021)]

3.1.10.3 Global Carbon Prices

MESSAGEix-GLOBIOM 1.1-M-R12 (World)

Scenario	Unit	2020	2025	2030	2035	2050
Below 2?C	US$2010/t CO2	$0,79	$9,60	$43,59	$61,00	$116,92
Current Policies	US$2010/t CO2	$0,79	$3,28	$2,39	$4,36	$10,40
Delayed transition	US$2010/t CO2	$0,79	$3,28	$2,39	$82,94	$166,97
Fragmented World	US$2010/t CO2	$0,79	$3,28	$2,39	$23,64	$129,13
Low demand	US$2010/t CO2	$0,79	$9,60	$218,54	$267,79	$549,94
Nationally Determined Contributions (NDCs)	US$2010/t CO2	$0,79	$9,60	$20,21	$26,31	$44,29
Net Zero 2050	US$2010/t CO2	$0,79	$9,60	$679,39	$659,16	$1.259,84

[Source: IIASA https://data.ene.iiasa.ac.at/]

Scenario A: Current Policies

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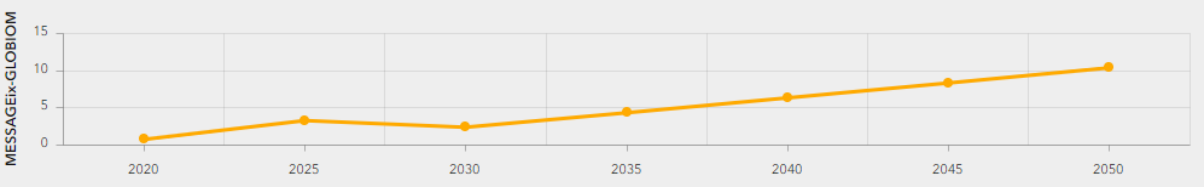
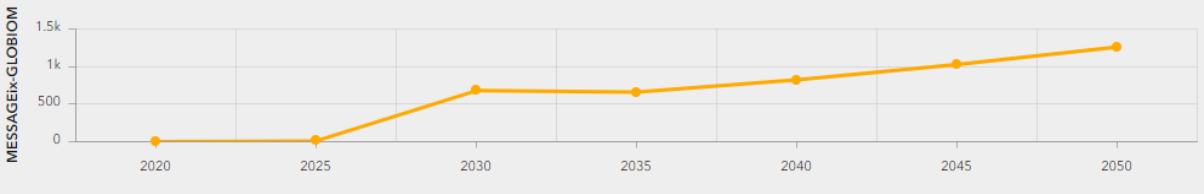


[Source: https://climatedata.imf.org/pages/ngfs]

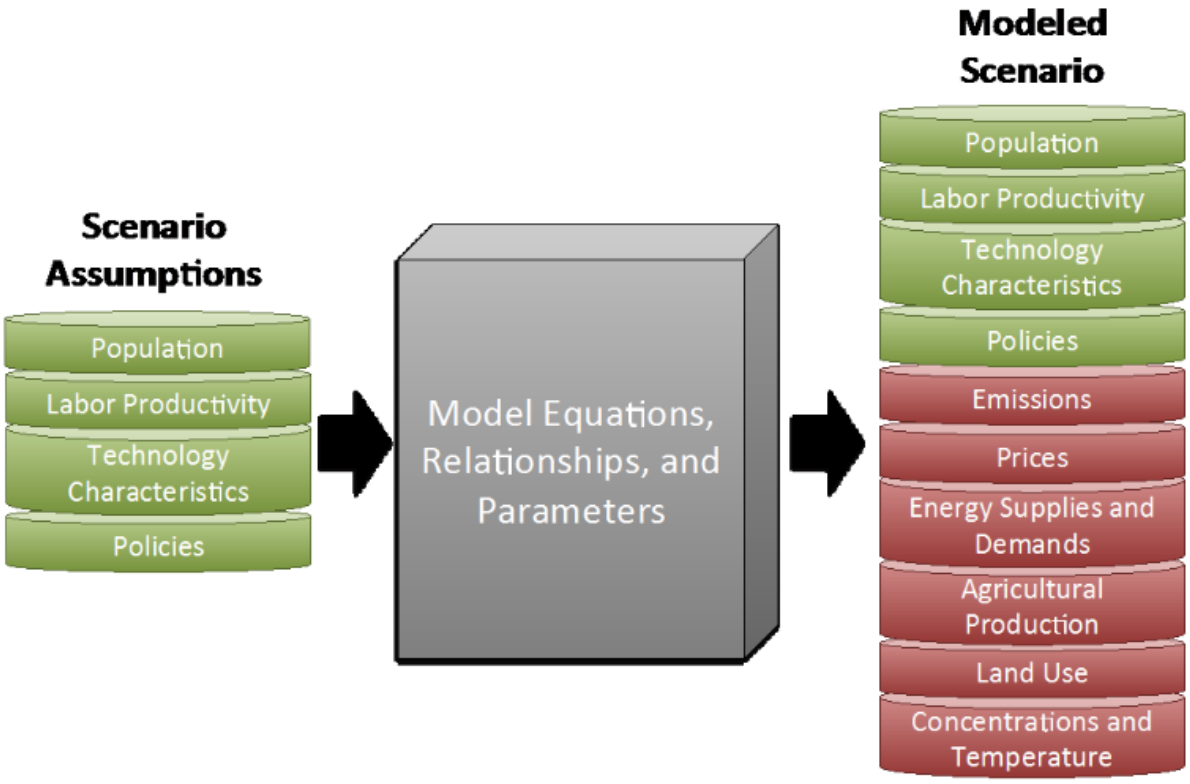
Scenario B: Net Zero 2050



[Source: https://climatedata.imf.org/pages/ngfs]

3.1.11 NGFS GCAM 6.0. (Environmental Prices)

3.1.11.1 Key Drivers



[Source: https://jgcri.github.io/gcam-doc/overview.html]

3.1.11.2 Valuation Technique

The Macro-economy module in GCAM utilises population and labour productivity assumptions to generate regional gross domestic product and populations, setting the scale of economic activity in the model.

The Energy Systems module in GCAM offers a detailed representation of energy supply sources, transformation modes, and energy service demands across various sectors,

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reporting both demands for and supplies of energy forms, as well as emissions of greenhouse gases and other short-lived species.

Agriculture and Land Systems in GCAM provide information on land use, land cover, carbon stocks, and emissions, driven by population size, income levels, and commodity prices, with the module reporting demands for agricultural and other commodities, land, and emissions of greenhouse gases.

The Water Systems module in GCAM offers information on water withdrawals and consumption for energy, agriculture, and municipal uses, helping to quantify the demand for water resources across different sectors.

The Physical Earth System in GCAM employs “Hector”, a physical Earth system emulator, to model the composition of the atmosphere based on emissions from other modules, providing insights into ocean acidity and climate within the global context.

[Source: https://jgcri.github.io/gcam-doc/overview.html]

The NGFS GCAM 6.0 model uses three Shared Socioeconomic Pathways (SSPs) from the IPCC:

- SSP1-1.9: This is the most ambitious pathway, in which global warming is limited to well below 2 degrees Celsius above pre-industrial levels, preferably to 1.5 degrees Celsius. This pathway is characterised by strong and sustained global cooperation on climate action, rapid technological change, and significant shifts in consumption patterns.
- SSP2-4.5: This pathway is in the middle of the range of possible pathways, in which global warming is likely to exceed 2 degrees Celsius but is stabilised at around 2.6 degrees Celsius by the end of the century. This pathway is characterised by moderate global cooperation on climate action, some technological advancements, and gradual changes in consumption patterns.
- SSP5-8.5: This is the most pessimistic pathway, in which global warming exceeds 3 degrees Celsius and continues to rise throughout the 21st century. This pathway is characterised by weak global cooperation on climate action, limited technological advancements, and continued reliance on fossil fuels.

[IPCC Fifth Assessment Report (AR5) (2013); IPCC Special Report on Global Warming of 1.5°C (SR1.5) (2018); IPCC Sixth Assessment Report (AR6) (2021); The IEA World Energy Outlook (IEA, 2022); The NGFS Net Zero Roadmap (NGFS, 2021); The Global Energy Transition Outlook (IEA, 2021)].

Since the IPCC AR5 2014 GCAM emerged as a model to simulate carbon prices [see most recent IPCC AR 6 Annex https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Annex-III.pdf]. NGFS GCAM 6.0 is an extension of the GCAM 6.0 model, which is a global energy system model, that includes additional modules for water, agriculture, land use, and the economy. The model covers transition risks aligned to country-specific transition pathways [https://www.ngfs.net/sites/default/files/media/2023/11/07/ngfs_user_guide_for_ngfs_scenarios_data_access.pdf].

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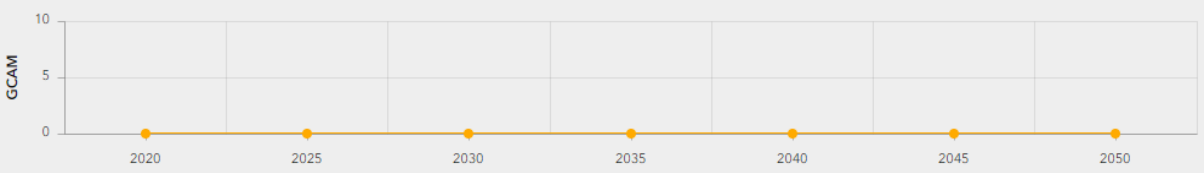
3.1.11.3 Global Carbon Price

GCAM 6.0. World

SCENARIO	UNIT	2025	2030	2035	2050
BELOW 2?C (VERSION: 1)	US$2010/t CO2	$ 5,74	$ 66,84	$ 121,53	$ 384,53
CURRENT POLICIES (VERSION: 1)	US$2010/t CO2	$ -	$ -	$ -	$ -
DELAYED TRANSITION (VERSION: 1)	US$2010/t CO2	$ -	$ -	$ 71,98	$ 575,78
FRAGMENTED WORLD (VERSION: 1)	US$2010/t CO2	$ -	$ -	$ 29,97	$ 143,27
LOW DEMAND (VERSION: 1)	US$2010/t CO2	$ -	$ 60,44	$ 145,70	$ 824,28
NATIONALLY DETERMINED CONTRIBUTIONS (NDCS) (VERSION: 1)	US$2010/t CO2	$ -	$ 20,80	$ 23,05	$ 51,61
NET ZERO 2050 (VERSION: 1)	US$2010/t CO2	$ 15,65	$ 128,64	$ 237,14	$1.153,07

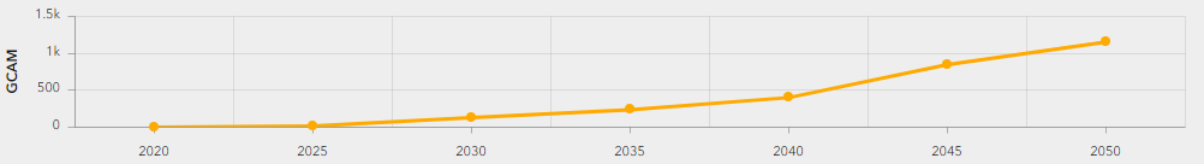
[Source: https://data.ene.iiasa.ac.at/ngfs]

Scenario A: Current Policies



[Source: https://climatedata.imf.org/pages/ngfs]

Scenario B: Net Zero 2050



[Source: https://climatedata.imf.org/pages/ngfs]

3.1.11.4 Region-specific Carbon Price

Carbon pricing is available for different regions.

GCAM 6.0. OECD & EU (R5)

SCENARIO	UNIT	2025	2030	2035	2050
BELOW 2?C (VERSION: 1)	US$2010/t CO2	$ 5,68	$ 64,06	$ 113,40	$ 447,23
CURRENT POLICIES (VERSION: 1)	US$2010/t CO2	$ -	$ -	$ -	$ -
DELAYED TRANSITION (VERSION: 1)	US$2010/t CO2	$ 0,00	$ -	$ 70,54	$ 966,94
FRAGMENTED WORLD (VERSION: 1)	US$2010/t CO2	$ -	$ -	$ 42,02	$ 258,68
LOW DEMAND (VERSION: 1)	US$2010/t CO2	$ -	$ 36,20	$ 123,27	$ 867,68
NATIONALLY DETERMINED CONTRIBUTIONS (NDCS) (VERSION: 1)	US$2010/t CO2	$ 1,35	$ 55,47	$ 41,87	$ 64,58
NET ZERO 2050 (VERSION: 1)	US$2010/t CO2	$ 23,47	$ 127,47	$ 242,28	$1.241,86

[Source: https://data.ene.iiasa.ac.at/ngfs]

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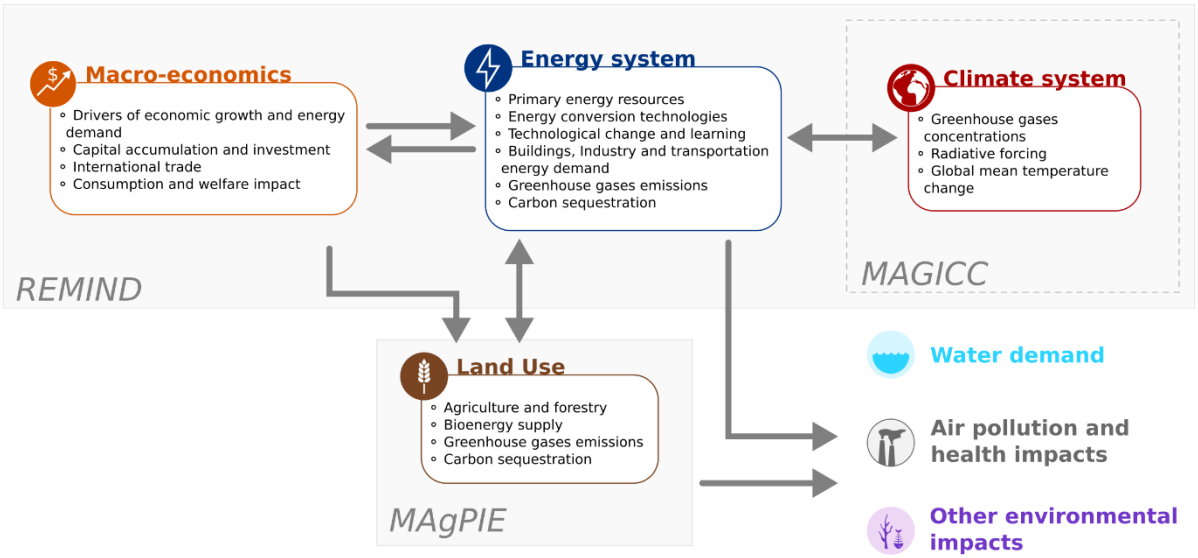
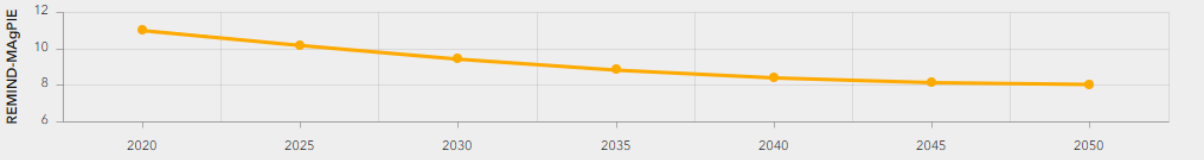
3.1.12 NGFS REMIND-MAgPIE

REMIND (REgional Model of Investment and Development) is an IAM designed to forecast the future trajectories of global economies, focusing particularly on energy sector development and climate implications. By incorporating population dynamics, technological advancements, policy frameworks, and climate considerations, REMIND seeks to identify the most welfare-optimal investment mix across economic and energy sectors in various regions. Additionally, it considers regional trade patterns concerning goods, energy resources, and emissions allowances, encompassing all human-induced greenhouse gas emissions.



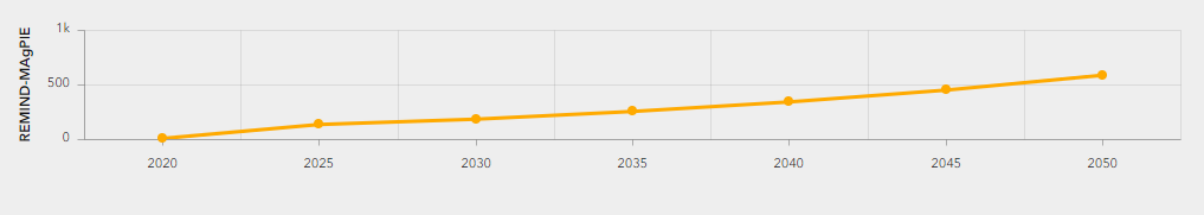
[Source: https://www.pik-potsdam.de/en/institute/departments/transformation-pathways/models/remind]

Scenario A: Current Policies



[Source: https://climatedata.imf.org/pages/ngfs]

Scenario B: Net Zero 2050



[Source: https://climatedata.imf.org/pages/ngfs]

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3.1.13 EPS IVL (Environmental Prices)

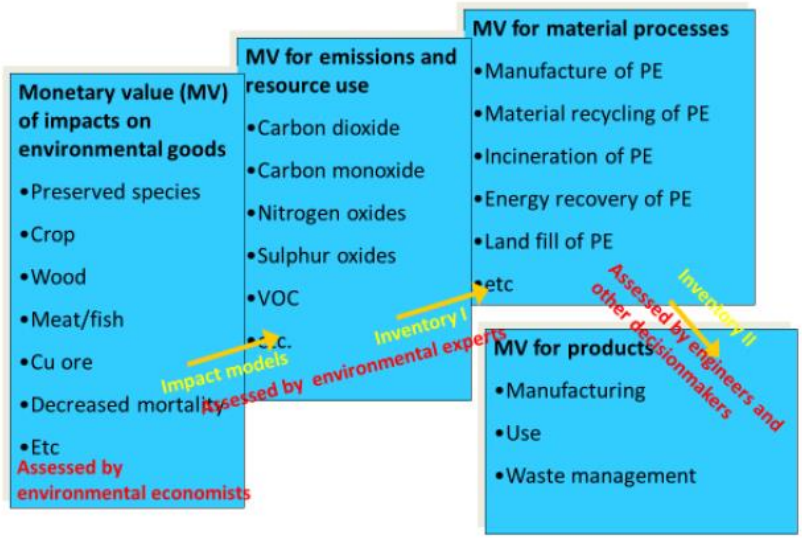

Figure 1 EPS architecture.

Source: [Swedish Life Cycle Center et al, EPS weighting factors - version 2020d, November 2020]

Valuation Technique

Aligned to ISO 14008:2009 Environmental Management - Monetary valuation of environmental impacts and related environmental aspects, the valuation technique follows the hierarchy of monetary valuation methods, from cost avoidance methods to monetization based on damage costs.

- Cost avoidance
- Damage
- Midpoint level

Emission	Receiving media	Unit	Monetary impact value, €	Notes
Carbon dioxide, CO2	Air	kg	2.88E-01	
Carbon monoxide, CO	Air	kg	1.08E+00	
Nitrogen oxides, NOx	Air	kg, as NO2	-2.64E+01	
Nitrous oxide, N2O	Air	kg	7.67E+01	
Ammonia, NH3	Air	kg	-4.34E+01	
Sulphur oxides, Sox	Air	kg	-8.45E+00	
Hydrogen Fluoride	Air	kg	-6.64E+00	
Hydrogen Chloride	Air	kg	-6.80E+00	
Hydrogen Sulphide	Air	kg	-1.97E+01	
PM2.5	Air	kg	2.32E+02	
PAH in particles	Air	kg	4.83E+00	in addition to PM2.5

[Source: Swedish Life Cycle Center et al, EPS weighting factors - version 2020d, November 2020]

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3.1.14 EPS, Chalmers

Carbon dioxide, a vital gas in the carbon cycle, is mainly emitted through combustion and biological processes. Its long residence time in the atmosphere means emissions from anywhere globally in 2015 have significant impacts. These impacts, estimated from 2015 to 2100 based on IPCC scenarios, include contributions to climate change, ocean acidification, and carbon dioxide fertilisation. CO2 emissions affect death rates due to cardiovascular diseases, crop production, poverty, and contribute to rising sea levels and extreme weather events, leading to land loss, flooding, and infrastructure damage. The emissions whose impacts are valued here refer to CO2 emissions anywhere in the world in the year 2015 at any source strength.

Impact pathways and environmental goods affected by carbon dioxide emissions

Environmental Indicator	Impact Indicator	Unit	Pathway
Human Health	YLL	person-years	Heat Stress
Human Health	YLL	person-years	Cold Moderation
Human Health	YLL	person-years	Undernutrition
Human Health	YLL	person-years	Flooding
Human Health	YLL	person-years	Diarrhoeal Diseases
Human Health	Undernutrition	person-years	Food Supply
Human Health	Working Capacity Loss	person-hours	Heat Stress
Human Health	Diarrhoea	person-years	Drinking Water
Crop	Production Capacity	Kg	Climate Change
Crop	Production Capacity	Kg	Sea Level Rise
Meat	Production Capacity	Kg	Drought
Fish	Production Capacity	Kg	Ocean Acidification
Wood	Production Capacity	m^3	Climate Change
Drinking Water	Production Capacity	m^3	Climate Change
Biodiversity	Share of Threat to Redlisted Species	Dimensionless	Habitat Change

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 54]

- YLL via Heat Stress and Cold Moderation:
  - Problem: Extreme heat effects on mortality rates, particularly in urban areas.
  - Impact Factor: 2.65×10^{-8} YLL/kg CO2 for heat stress and -4.16×10^{-9} YLL/kg CO2 for cold moderation.
  - Uncertainty: Factors contributing to uncertainty include the linearity of the dose-response function, humidity, and population growth projections.
- YLL via Undernutrition:
  - Problem: Undernutrition, particularly among children under five, is a significant cause of mortality globally.
  - Impact Factor: 1.74×10^{-6} YLL/kg CO2.
  - Uncertainty: Uncertainty stems from the correlation between increased mortality and severe stunting, as well as alternative estimation methods based on crop production decline.
- YLL via Flooding:
  - Problem: Mortality impacts related to flooding events, particularly in developing countries and coastal areas, citing projections indicating increased vulnerability to flooding due to climate change, with estimates of affected populations and associated mortality.

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- Impact Factor: 1.66×10^{-10} YLL/kg CO2.
- Uncertainty: High uncertainty, but due to the small impact factor, it's unlikely to significantly affect overall estimations.

- YLL via Diarrhoeal Diseases:
  - Problem: Climate change is projected to impact the incidence of diarrhoeal diseases, particularly in tropical and subtropical regions.
  - Impact Factor: 1.21×10^{-7} YLL/kg CO2.
  - Uncertainty: Socioeconomic development, climate scenarios, and sensitivity of different populations contribute to uncertainty.
- Undernutrition via Decreasing Food Supply:
  - Problem: Climate change is expected to impact food security, potentially leading to increased undernourishment. The text discusses estimates of increased mortality due to climate-induced changes in food supply, particularly among children under five.
  - Impact Factor: 1.72×10^{-6} person-years/kg CO2.
  - Uncertainty: Depends on socioeconomic development and choice of reference scenario, with a factor of 4 considered.
- Decreased Working Capacity from Heat Stress:
  - Impact Factor: 4.53×10^{-3} person-hours/kg CO2.
  - Uncertainty: Varies due to different estimates of productivity loss and sensitivity to changing work conditions.
- Diarrhoea via Climate Change and Degraded Water Quality:
  - Impact Factor: 2.69×10^{-10} person-years/kg CO2.
  - Uncertainty: Similar to YLL from diarrhoeal diseases, with a factor of 3 considered.
- Decreased Crop Production Capacity via Increased Droughts:
  - Impact Factor: 1.01×10^{-2} kg crop/kg CO2.
  - Uncertainty: Related to unknown degrees of adaptation, climate scenarios, and crop sensitivity.

When comparing monetary impact values, YLL from undernutrition and person-years loss of working capacity contribute to 91% of the total value. YLL from diarrhoeal diseases and undernutrition due to decreasing food supply contribute another 6%. Surprisingly, the contribution from flooding is low, possibly because damage to buildings and infrastructure is not included.

CO

- YLL via Climate Change (CO):
  - Carbon monoxide (CO) has a GWP that varies based on emission location and the inclusion of aerosol formation mechanisms in modelling.
  - The total environmental impact factor for all CO pathways to YLL is calculated as 6.59E–06 YLL/kg CO with an uncertainty factor of 1.6.
- YLL via Exposure to Ozone (CO):
  - CO contributes to increased ground level ozone, which has an impact on human health.
  - The total contribution from 1 kg of extra CO emitted is calculated as 3.32E–07 YLL/kg CO.

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    - Using European POCP data for global conditions introduces significant uncertainties, with an estimated uncertainty factor of 2.
- Decreased Crop Productivity Caused by Ozone (CO):
    - The environmental impact factor for decreased crop productivity caused by ozone exposure is estimated as 5.28E–03 kg crop/kg CO.
    - The uncertainty in this impact factor is estimated to be the same as for the environmental impact factor for YLL from ozone, i.e. a factor of 2.

Climate change impacts comprise 94% of the environmental damage cost of CO; as for CO2, it is undernutrition and decreased working capacity that are the major causes. Ozone creation and aggravation of angina pectoris contribute with 3% each.

NOx

- Excess Mortality from Secondary Particles (YLL via Exposure to Secondary Particles):
    - Environmental Impact Factor: 1.96E–06 YLL/kg NOx.
    - This factor accounts for the contribution of NOx emissions to excess mortality associated with secondary particles like nitrates and sulphates.
- Climate Change (YLL via Climate Change):
    - Environmental Impact Factor: -1.79E–04 YLL/kg NOx.
    - NOx contributes to both warming and cooling effects on climate. The net impact, considering the GWP 100, is negative.
- Excess Mortality via Exposure to Ozone (YLL via Exposure to Ozone):
    - Environmental Impact Factor: 6.97E–06 YLL/kg NOx.
    - NOx contributes to the formation of ground-level ozone, which affects human health and mortality.
- Respiratory and Cardiovascular Diseases Caused by Secondary Particles:
    - Environmental Impact Factor: 4.80E–07 YLD/kg NOx.
    - This factor accounts for the contribution of NOx emissions to respiratory and cardiovascular diseases caused by secondary particles.
- Undernutrition via Climate Change:
    - Environmental Impact Factor: -1.63E–04 person-years/kg NOx.
    - NOx emissions contribute to climate change, which can indirectly impact food production and nutrition.
- Decreased Working Capacity Caused by Climate Change:
    - Environmental Impact Factor: -4.30E–01 person-hours/kg NOx.
    - Climate change, influenced by NOx emissions, can affect working capacity due to extreme weather events and heat stress.
- Diarrhoeal Diseases Caused by Climate Change and Degraded Water Quality:
    - Environmental Impact Factor: -2.56E–08 person-years/kg NOx.
    - Climate change, influenced by NOx emissions, can affect water quality and contribute to diarrhoeal diseases.

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Dinitrogen oxide (N2O)

Summary of environmental impact factors and monetary impact values of 1 kg of NOx emissions

Environmental Indicator	Impact	Unit	Pathway	Impact Factor ($/unit) \$	Impact Value (/kgNOx)
Human Health	YLL	person-years	Secondary Particles	2.10E-01	2.14E-01
Human Health	YLL	person-years	Climate Change	-1.92E+01	-1.92E+01
Human Health	YLL	person-years	Oxidant Formation	7.46E-01	7.46E-01
Human Health	YLD	person-years	Secondary Particles	5.14E-02	5.14E-02
Human Health	Undernutrition	person-years	Climate Change	-1.05E+00	-1.05E+00
Human Health	Working capacity loss	person-hours	Climate Change	-1.29E+01	-1.29E+01
Human Health	Diarrhoea	person-years	Climate Change	-2.88E-04	-2.88E-04
Crop	Production	kg	Oxidant Formation	3.47E-02	1.00E-01
Crop	Production	kg	Climate Change	-4.22E-01	-4.22E-01
Meat	Production	kg	Climate Change	-9.14E-02	-9.14E-02
Fish	Production	kg	Eutrophication, Dead Zones	1.16E-03	1.16E-03
Fish	Production	kg	N-nutrification of Ocean	-5.83E-04	-5.83E-04

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 82]

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Summary of environmental impact factors and monetary impact values of 1 kg of NOx emissions

fish	production capacity	kg	acidification	7.88E–04	upper limit	2.42	1.91E–03
wood	production capacity	m^3	oxidant formation	0		72	0
wood	production capacity	m^3	N-fertilization	–4.28E–04	2	72	–3.08E–02
wood	production capacity	m^3	climate change	0	6.55E–04	72	0
drinking water	production capacity	m^3	climate change	–8.61E–02	upper limit	1.87	–1.61E–01
biodiversity	share of threat to redlisted species	dimensionless	climate change	–1.61E–14	4	7.61E+10	–1.23E–03
biodiversity	share of threat to redlisted species	dimensionless	eutrofication	1.37E–14	2	7.61E+10	1.04E–03
biodiversity	share of threat to redlisted species	dimensionless	acidification	1.70E–16	2	7.61E+10	1.29E–05
						sum	–3.28E+01

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 83]

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N2O

- Impact factors and monetary impact values for 1 kg of N2O emission
- YLL via Climate Change:
  - Problem: Nitrous oxide contributes to climate change, leading to years of life lost (YLL).
  - Impact Factor: 4.99×10^{-4} YLL/kg N2O
  - Uncertainty: Factor of 2
- YLL via Stratospheric Ozone Depletion:
  - Problem: N2O also contributes to ozone depletion in the stratosphere, which can indirectly impact human health through increased skin cancer rates.
  - Impact Factor: 3.04×10^{-6} YLL/kg N2O
  - Uncertainty: Factor of 4
- Increased Undernutrition via Climate Change:
  - Problem: Climate change induced by N2O emissions can lead to disruptions in food production and availability, contributing to undernutrition.
  - Impact Factor: 4.57×10^{-4} person-years/kg N2O
  - Uncertainty: Factor of 4
- Decreased Working Capacity via Climate Change:
  - Problem: Climate change impacts from N2O emissions can reduce overall working capacity due to heat stress, decreased labour productivity, and other related factors.
  - Impact Factor: 1.2 person-hours/kg N2O
  - Uncertainty: Factor of 4
- Increased Diarrhoea via Climate Change and Polluted Drinking Water:
  - Problem: Climate change, influenced by N2O emissions, can exacerbate factors leading to diarrhoeal diseases, especially in regions with poor water quality.
  - Impact Factor: 7.12×10^{-8} person-years/kg N2O
  - Uncertainty: Factor of 3
- Decreased Crop Production Capacity via Climate Change:
  - Problem: N2O emissions contribute to climate change, which can adversely affect crop yields and agricultural productivity.
  - Impact Factor: 4.08 kg crop/kg N2O
  - Uncertainty: Factor of 3
- Decreased Meat Production Capacity via Climate Change:
  - Problem: Climate change impacts from N2O emissions can also affect livestock production, leading to decreased meat production capacity.
  - Impact Factor: 9.85×10^{-2} kg meat/kg N2O
  - Uncertainty: Factor of 3
- Decreased Fish Production Capacity via Climate Change:
  - Problem: Climate change driven by N2O emissions can disrupt aquatic ecosystems and reduce fish populations, impacting fish production capacity.
  - Impact Factor: 7.75×10^{-3} kg fish/kg N2O
  - Uncertainty: Factor of 2
- Impact on Wood Production Capacity via Climate Change:
  - Problem: While N2O emissions contribute to climate change, the impact on wood production capacity is assumed to be negligible.

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- Impact Factor: 0 m3 wood/kg N2O
- Uncertainty: ± 1.83 x 10^{-3} m3 wood/kg N2O

- Decreased Drinking Water Production Capacity via Climate Change:
  - Problem: Climate change can also affect water availability and quality, leading to decreased drinking water production capacity.
  - Impact Factor: 2.40 x 10^{-1} m3 drinking water/kg N2O
  - Uncertainty: Factor of 3
- Decreased Biodiversity via Climate Change:
  - Problem: N2O emissions contribute to climate change, which can pose threats to biodiversity.
  - Impact Factor: 4.48 x 10^{-14} shares of present threat to biodiversity/kg N2O
  - Uncertainty: Factor of 4

NH3

Pathways by which NH3 impacts on environmental goods

Environmental Good	Impact Indicator	Unit	Pathway
Human Health	YLL	person-years	Secondary aerosols
Human Health	YLL	person-years	Climate Change
Human Health	YLD	person-years	Secondary Aerosols
Human Health	Undernutrition	person-years	Climate Change
Human Health	Working Capacity Loss	person-years	Climate Change
Human Health	Diarrhoea	person-years	Climate Change
Crop	Production Capacity	kg	Climate Change
Crop	Production Capacity	kg	Sea Level Rise
Meat	Production Capacity	kg	Drought
Fish	Production Capacity	kg	Ocean Acidification
Fish	Production Capacity	kg	Eutrophication
Fish	Production Capacity	kg	Fertiliser Input
Wood	Production Capacity	m^3	Climate Change
Drinking Water	Production Capacity	m^3	Climate Change
Biodiversity	Share of Threat to Redlisted Species	dimensionless	Habitat Change
Biodiversity	Share of Threat to Redlisted Species	dimensionless	Acidification
Biodiversity	Share of Threat to Redlisted Species	dimensionless	Eutrophication

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 90]

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NH3

- Human Health Impact via Secondary Aerosols (YLL):
  - Problem: NH3 emissions contribute to excess mortality through the formation of secondary aerosols, impacting human health locally to regionally.
  - Environmental Impact Factor: 3.82 x 10^{-6} YLL/kg NH3
  - Uncertainty: Assumed between 6 and 100% with 95% probability
- Human Health Impact via Climate Change (YLL):
  - Problem: NH3 emissions affect human health by contributing to climate change, leading to potential adverse effects on mortality.
  - Environmental Impact Factor: -2.84 x 10^{-4} YLL/kg NH3
  - Uncertainty: Estimated to be a factor of 2.7
- Years Lived with Disability (YLD) through Cardiovascular Diseases Caused by Secondary Aerosols:
  - Problem: NH3 emissions contribute to cardiovascular diseases through the formation of secondary aerosols, resulting in years lived with disability.
  - Environmental Impact Factor: 9.36 x 10^{-7} YLD/kg NH3
  - Uncertainty: Assumed to be a factor of 2
- Undernutrition via Climate Change:
  - Problem: NH3 emissions impact undernutrition indirectly by contributing to climate change, which can affect food security and nutritional availability.
  - Environmental Impact Factor: -2.60 x 10^{-4} person-years/kg NH3
  - Uncertainty: Estimated to be a factor of 2.1 in a log-normal distribution
- Decreased Working Capacity via Climate Change:
  - Problem: NH3 emissions contribute to climate change, which can lead to decreased working capacity due to various environmental and health factors.
  - Environmental Impact Factor: -6.84 x 10^{-1} person-hours/kg NH3
  - Uncertainty: Estimated to be a factor of 2.1 in a log-normal distribution
- Increased Diarrhoea via Climate Change and Polluted Drinking Water:
  - Problem: NH3 emissions contribute to climate change and polluted drinking water, potentially increasing the incidence of diarrhoeal diseases.
  - Environmental Impact Factor: -4.06 x 10^{-8} person-years/kg NH3
  - Uncertainty: Assumed to be a factor of 3
- Decreased Crop Production Capacity via Climate Change:
  - Problem: NH3 emissions impact crop production capacity by contributing to climate change, affecting temperature, precipitation, and soil conditions.
  - Environmental Impact Factor: -2.33 kg crop/kg NH3
  - Uncertainty: Estimated to be a factor of 3
- Decreased Production Capacity for Meat via Climate Change:
  - Problem: NH3 emissions affect meat production capacity indirectly through climate change, which can influence factors like grazing conditions and feed availability.
  - Environmental Impact Factor: -5.62 x 10^{-2} kg meat/kg NH3
  - Uncertainty: Estimated to be a factor of 3
- Decreased Fish Production Capacity Caused by Acidification:
  - Problem: NH3 emissions contribute to acidification, impacting aquatic ecosystems and reducing fish production capacity in affected areas.

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- Environmental Impact Factor: 6.48 x 10^{-4} kg fish/kg NH3
- Uncertainty: Estimated to be less than the estimate

- Decreased Fish Production Capacity from Eutrophication:
  - Problem: NH3 emissions contribute to eutrophication, leading to oxygen depletion in aquatic ecosystems and negatively affecting fish production capacity.
  - Environmental Impact Factor: 1.24 x 10^{-3} kg fish/kg NH3
  - Uncertainty: Estimated to be a factor of 3
- Increased Wood Production Capacity via N Fertilisation:
  - Problem: NH3 emissions can increase wood production capacity by serving as a nitrogen fertiliser for forests, particularly in nitrogen-limited ecosystems.
  - Environmental Impact Factor: -1.16 x 10^{-3} m3 wood/kg NH3
  - Uncertainty: Estimated to be a factor of 2
- Decreased Drinking Water Production Capacity via Climate Change:
  - Problem: NH3 emissions contribute to climate change, which can impact drinking water availability and quality through changes in precipitation patterns and water sources.
  - Environmental Impact Factor: -1.37 x 10^{-1} m3/kg NH3
  - Uncertainty: High, but towards less negative values
- Decreased Biodiversity via Acidification:
  - Problem: NH3 emissions contribute to acidification, negatively impacting biodiversity in affected ecosystems, particularly aquatic habitats sensitive to changes in pH levels.
  - Environmental Impact Factor: 3.08 x 10^{-15} shares of biodiversity/kg NH3
  - Uncertainty: Estimated to be a factor of 1.5
- Decreased Biodiversity via Climate Change:
  - Problem: NH3 emissions contribute to climate change, which poses various threats to biodiversity, including habitat loss, species extinction, and ecosystem disruption.
  - Environmental Impact Factor: -2.55 x 10^{-14} shares of biodiversity/kg NH3
  - Uncertainty: Estimated to be a factor of 4
- Decreased Biodiversity Caused by Eutrophication:
  - Problem: NH3 emissions contribute to eutrophication, leading to nutrient imbalances in ecosystems and negatively affecting biodiversity, particularly in aquatic environments.
  - Environmental Impact Factor: 3.54 x 10^{-14} shares of biodiversity/kg NH3
  - Uncertainty: Estimated to be a factor of 2

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Summary of environmental impact factors and monetary impact values of NH3 emissions

Environmental good	Impact indicator	Unit	Pathway	Environmental impact factor	Uncertainty	Indicator value ($/unit)	Impact value ($/kg NH_3)
human health	YLL	personyears	seconday aerosols	3.82E–06	2	107067	4.09E–01
human health	YLL	personyears	climate change	–2.84E–04	2.8	107067	3.04E+01
human health	YLD	personyears	seconday aerosols	9.36E–07	2	107067	1.00E–01
human health	undernutrition	personyears	climate change	–2.60E–04	2.1	6424	–1.67E+00
human health	working capacity	personyears	climate change	–6.84E–01	2.1	30	–2.05E+01
human health	diarrhea	personyears	climate change	–4.06E–08	3	11242	–4.57E–04
crop	production capacity	kg	climate change	–2.33	3	0.289	–6.73E–01
meat	production capacity	kg	climate change	–5.62E–02	3	2.59	–1.45E–01
fish	production capacity	kg	acidification	6.48E–04	upper limit	2.42	1.57E–03
fish	production capacity	kg	eutrophication	1.24E–03	3	2.42	3.00E–03
fish	production capacity	kg	fertilizing	–2.41E–04	4	2.42	–5.83E–04
wood	production capacity	m^3	fertilizing	–1.16E–03	2	72	–8.35E–02
drinking water	production capacity	m^3	climate change	–1.37E–01	upper limit	1.87	–2.56E–01
biodiversity	share of threat to redlisted species	dimensionless	acidification	3.08E–15	1.5	7.61E+10	2.34E–04
biodiversity	share of threat to redlisted species	dimensionless	climate change	–2.55E–14	4	7.61E+10	–1.94E–03
biodiversity	share of threat to redlisted species	dimensionless	eutrophication	3.54E–14	2	7.61E+10	2.69E–03
						sum	–5.32E+01

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 97]

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SO2

Environmental Good	Impact Indicator	Unit	Pathway
Human Health	YLL	person-years	Direct Exposure
Human Health	YLL	person-years	Secondary Particles
Human Health	YLL	person-years	Climate Change
Human Health	YLD	person-years	Direct Exposure
Human Health	YLD	person-years	Secondary Particles
Human Health	Undernutrition	person-years	Climate Change
Human Health	Working Capacity	person-hours	Climate Change
Human Health	Diarrhoea	person-years	Climate Change
Crop	Production Capacity	kg	Climate Change
Meat	Production Capacity	kg	Climate Change
Fish	Production Capacity	kg	Acidification
Wood	Production Capacity	m^3	Climate Change
Drinking Water	Production Capacity	m^3	Climate Change
Biodiversity	Share of Threat to Redlisted Species	dimensionless	Climate Change
Biodiversity	Share of Threat to Redlisted Species	dimensionless	Acidification
All	CO2 Emission	kg	Corrosion

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 98]

SO2

- Impacts on Years of Life Lost (YLL) via Direct Exposure:
  - Environmental Impact Factor: YLLs due to 1 kg SO2 emissions: 9.55E-06 YLL.
  - Uncertainties: Population exposure uncertainty; assumed within double and half the values (factor of 2).
- Impacts on YLL via Exposure to Secondary Particles:
  - Environmental Impact factor: YLL/kg SOx: 5.96E–06.
  - Uncertainties: Exposure and dose-response function uncertainty; factor of 3.
- Impacts on YLL via Climate Change:
  - Factor: GWP100 for sulfate particles: -40.
  - Transformation of SO2 into sulfate particles: About half of emitted SO2.
  - Environmental Impact Indicator: YLL/kg SO2 via climate change: –5.64E–05.
  - Uncertainties: Regional variation in GWP100 for SO2; factor of 2.
  - Overall Uncertainty Factor: 2.7.
- Impacts on Years Lived with Disability (YLD) via Direct Exposure:
  - Factor: Dose-response for respiratory hospital admissions due to SO2 exposure; +0.5% per 10 µg/m3.
  - Global YLD from respiratory diseases: Approximately 50 million.
  - Environmental Impact Indicator: YLD/kg SO2: 7.50E–06.
  - Uncertainties: Population exposure uncertainty; assumed within double and half the values (factor of 2).
- Impacts on YLD via Exposure to Secondary Particles and Respiratory Diseases:
  - Factor: Contribution of sulfates to YLD from PM2.5: 25%.
  - Global YLD from PM2.5 (2015): Approximately 3.9 million.
  - Environmental Impact Indicator: YLD/kg SOx: 1.46E–06.

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    - Uncertainties: Extent of impact uncertainty; factor of 1.4.
    - Contribution Estimate Uncertainty: Factor of 2.
    - Overall Uncertainty Factor: 2.2.
- Impacts on Undernutrition via Climate Change:
    - Factor: Environmental impact factor for undernutrition: –6.9E–05 person-years/kg SO2.
    - Uncertainties: Overall uncertainty factor: 2.1 in a log-normal distribution.
- Impacts on Working Capacity via Climate Change:
    - Factor: Environmental impact factor for working capacity: –1.81E–01 person-hours/kg SO2.
    - Uncertainties: Overall uncertainty factor: Factor of 2.1.
- Impacts on Diarrhoeal Diseases via Climate Change:
    - Environmental Impact Factor for SO2: −1.1E-8 person-years/kg SO2
    - Uncertainty Factor: 3.7
- Impacts on Crop Production Capacity via Climate Change:
    - Environmental Impact Factor for SO2: −6.16E-1 kg crop/kg SO2
    - Uncertainty Factor: 3.7
- Impacts on Meat Production Capacity via Climate Change:
    - Environmental Impact Factor for SO2: −1.49E-2 kg meat/kg SO2
    - Uncertainty Factor: 3.7
- Impacts on Fish Production Capacity via Acidification:
    - Environmental Impact Factor: 1.6E-3 kg fish/kg SOx
    - Uncertainty: Large, but assumed to be less than the estimate
- Impacts on Wood Production Capacity via Climate Change:
    - Environmental Impact Factor for SO2: 0 ± 2.76E-4 m³ wood/kg SO2
- Impacts on Drinking Water Production Capacity via Climate Change:
    - Environmental Impact Factor for SO2: −3.62E-2 m³ drinking water/kg SO2
    - Uncertainty Factor: 3.7
- Impacts on Biodiversity via Climate Change:
    - Environmental Impact Factor: −6.76E−15 shares of present impact on biodiversity
    - Uncertainty Factor: 4.7
- Impacts on Biodiversity via Acidification:
    - Environmental Impact Factor: 2.83E−15 shares of present impact on biodiversity
    - Uncertainty Factor: 1.5
    - Indirect Impacts on CO2 Emissions via Corrosion:
    - Environmental Impact Factor: 7.68E-3 kg CO2/kg SO2
    - Uncertainty Factor: 3

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Summary of environmental impact factors and monetary impact values of SOx emissions

Environmental good	Impact indicator	Unit	Pathway	Environmental impact factor	Uncer-tainty	Indicator value ($/unit)	Impact value ($/kg SO_x)
human health	YLL	personyears	direct exposure	9.55E–06	2	107,067	1.02E+00
human health	YLL	personyears	secondary particles	5.96E–06	3	107,067	6.38E–01
human health	YLL	personyears	climate change	–5.64E–05	2.7	107,067	–6.04E+00
human health	YLD	personyears	direct exposure	7.50E–06	2	10,707	8.03E–02
human health	YLD	personyears	secondary particles	1.46E–06	2.2	10,707	1.56E–02
human health	undernutrition	personyears	climate change	–6.90E–05	2.1	6,424	–4.43E–01
human health	working capacity	personhours	climate change	–1.81E–01	2.1	30	–5.43E+00
human health	diarrhea	personyears	climate change	–1.10E–08	3.7	11,242	–1.24E–04
crop	production capcity	kg	climate change	–6.16E–01	3.7	0.289	–1.78E–01
meat	production capcity	kg	climate change	–1.49E–02	3.7	2.59	–3.86E–02
fish	production capcity	kg	acidification	1.60E–03	upper limit	2.42	3.87E–03
wood	production capcity	m^3	climate change	0	± 2.76E–04	72	0
drinking water	production capcity	m^3	climate change	–3.62E–02	3.7	1.87	–6.77E–02
biodiversity	share of threat to redlisted species	dimensionless	climate change	–6.76E–15	4.7	7.61E+10	–5.14E–04
biodiversity	share of threat to redlisted species	dimensionless	acidification	2.83E–15	1.5	7.61E+10	2.15E–04
all	CO_2 emission	kg	corrosion	7.68E–03	3	3.76E–01	2.89E–03
						sum	–1.04E+01

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 104]

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Summary of environmental impact factors and monetary impact values of CO2 emissions

Environmental good	Impact indicator	Unit	Pathway	Environmental impact factor	Uncertainty	Indicator value, ($/unit)	Impact value ($/kg CO_2)
human health	YLL	personyears	heat stress	2.65E–08	1.6	107,067	2.84E–03
human health	YLL	personyears	cold moderation	–4.16E–09	1.6	107,067	–4.45E–04
human health	YLL	personyears	undernutrition	1.74E–06	2	107,067	1.86E–01
human health	YLL	personyears	flooding	1.66E–10	3	107,067	1.78E–05
human health	YLL	personyears	diarrhoeal diseases	1.21E–07	3	107,067	1.29E–02
human health	undernutrition	personyears	food supply	1.72E–06	4	6,424	1.11E–02
human health	working capacity loss	personhours	heat stress	4.53E–03	2	30	1.36E–01
human health	diarrhea	personyears	drinking water	2.69E-10	3	11,242	3.02E–06
crop	production capacity	kg	climate change	1.01E–02	3	0.289	2.93E–03
crop	production capacity	kg	rise of sea level	4.12E–03	3	0.289	1.19E–03
meat	production capacity	kg	draught	3.72E–04	3	2.59	9.63E–04
fish	production capacity	kg	ocean acidification	2.92E–05	2	2.42	7.08E–05
wood	production capacity	m^3	climate change	0.00E+00	6.90E–06	72	0.00E+00
drinking water	production capacity	m^3	climate change	9.06E–04	3	1.87	1.69E–03
biodiversity	share of threat to redlisted species	dimensionless	habitat change	1.69E–16	4	7.61E+10	1.29E–05
						Sum	3.56E–01

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 66]

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Environmental Good	Impact Indicator	Unit	Pathway
Human Health	YLL	person-years	Climate Change
Human Health	YLL	person-years	Oxidant Formation
Human Health	Aggravation of Angina Pectoris	person-years	Direct Exposure
Human Health	Undernutrition	person-years	Climate Change
Human Health	Working Capacity Loss	person-hours	Climate Change
Human Health	Diarrhoea	person-years	Climate Change
Crop	Production Capacity	kg	Climate Change
Crop	Production Capacity	kg	Oxidant Formation
Meat	Production Capacity	kg	Climate Change
Fish	Production Capacity	kg	Climate Change
Wood	Production Capacity	m^3	Climate Change
Drinking Water	Production Capacity	m^3	Climate Change
Biodiversity	Share of Threat to Redlisted Species	dimensionless	Climate Change

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 67]

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3.1.15 Analysis

NGFS (MESSAGEix-GLOBIOM): Evaluates GHGs based on GWP, focusing on energy and land use systems. Considers emissions and land use impacts, valuing them in terms of energy security, air pollution, and resource depletion.

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NGFS (GCAM): Utilises diverse data to simulate energy, land use, and climate interactions. The GCAM model assesses impacts on energy, water, agriculture, land use, economy, and climate, employing economic modelling and cost-benefit analysis.

NGFS (Remind-MagPie): Uses country-specific data to model energy, land use changes, and economic activities. It assesses impacts on energy, land use, economy, and climate, employing IAMs and economic valuation techniques.

GIST Impact: Estimates GHG impacts using various scientific literature and databases, assessing their costs and benefits across sectors like agriculture, property damages, human health, and ecosystem services. It employs IAMs and damage functions to calculate the social cost of carbon and damage costs.

WifOR Institute: Evaluates GHG emissions' monetary value based on their impacts on human health, the built environment, production, labour availability, and increased energy demand. Utilises the IAM model to calculate the social cost of carbon and assess economic damages.

Focus on GWP: All the models and methodologies discussed emphasise the assessment of GHGs based on their global warming potential. They evaluate not only carbon dioxide (CO2), but also other potent GHGs such as methane (CH4), nitrous oxide (N2O), and various fluorinated gases. This focus reflects the recognition of the diverse contributions of different gases to climate change.

Integration of Energy and Land Use Systems: Many of the models, such as NGFS (MESSAGEix-GLOBIOM) and NGFS (Remind-MagPie), integrate energy and land use systems in their assessments. This integration acknowledges the interconnectedness of these systems and their combined influence on GHG emissions and climate change.

Utilisation of IAMs (IAMs): Several methodologies, including NGFS (MESSAGEix-GLOBIOM), NGFS (Remind-MagPie), and GIST Impact, employ IAMs (IAMs). IAMs facilitate the comprehensive analysis of the interactions between the economy, energy systems, land use, and climate, allowing for a holistic understanding of the impacts of GHG emissions.

Economic Valuation Techniques: A common thread among the methodologies is the use of economic valuation techniques to assess the costs and benefits associated with GHG emissions. This includes estimating the social cost of carbon and evaluating economic damage across sectors such as agriculture, health, infrastructure, and ecosystems. By quantifying these economic impacts, decision makers can better understand the consequences of GHG emissions and formulate effective policy responses.

Multisectoral Approach: The models and methodologies discussed adopt a multisectoral approach to assessing the impacts of GHG emissions. They consider various sectors, including energy, land use, agriculture, water resources, human health, and the economy. This comprehensive perspective enables a more nuanced understanding of the diverse effects of GHG emissions across different aspects of society.

Uncertainties in Parameters and Assumptions: Many of these models rely on numerous parameters and assumptions, which introduce uncertainties into their predictions. Uncertainties arise from factors such as future technological advancements, changes in socioeconomic trends, and natural variability in climate systems. Addressing these uncertainties requires robust sensitivity analyses and probabilistic modelling techniques.

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Regional and Sectoral Variability: Existing models often provide aggregated or global-level assessments of GHG emissions and their impacts, which may mask regional and sectoral variability. It enhances the spatial and sectoral resolution of models to capture localised effects and support tailored mitigation and adaptation strategies at regional levels.

Incomplete Representation of Feedback Mechanisms: Feedback mechanisms between the climate system and human activities are not always fully incorporated into existing models.

Limited Consideration of Nonlinear Dynamics in Value Factors: Many climate models used assume linear relationships between emissions and their impacts, overlooking potential nonlinear dynamics and threshold effects. Nonlinearities could lead to abrupt changes in climate systems or ecosystems, amplifying the risks associated with GHG emissions. Future models should strive to incorporate nonlinear dynamics and tipping points into their frameworks.

Data Constraints and Data Quality: The reliability and availability of data pose significant challenges for model development and validation. Data constraints may arise from limited observations, inconsistencies in data sources, or insufficient coverage of certain variables. Improving data quality and filling data gaps, especially in regions with sparse monitoring networks, is critical for enhancing the robustness of modelling efforts.

Limited Integration of Social and Behavioural Factors: While many models incorporate economic factors, they often overlook social and behavioural dimensions that influence GHG emissions and responses to climate change. Factors such as consumer behaviour, cultural norms, and institutional dynamics can significantly affect mitigation and adaptation strategies but are not fully integrated into existing models.

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3.2 Air pollution

3.2.1 Challenge

Air pollution, stemming from industrial activities, introduces pollutants like fine particulate matter (PM2.5), coarse particulate matter (PM10), nitrogen oxides (NOx), sulphur oxides (SO2), volatile organic compounds (VOCs), and ammonia (NH3) into the atmosphere. These pollutants have local impacts, influencing human health, visibility, and agricultural yields. Unlike greenhouse gases, which have global effects, air pollutants contribute to location-specific environmental challenges like smog and acid rain. This section delves into the societal consequences of air pollution, shedding light on the localised and quantifiable outcomes associated with these pollutants.

SDG 3 reflects this challenge in emphasising reducing deaths and illnesses from hazardous chemicals and pollution (Target 3.9) and decreasing premature mortality from noncommunicable diseases (Target 3.10), aligning with efforts to improve health and well-being. SDG 11 focuses on reducing the adverse environmental impact of cities, including air quality (Target 11.6), while SDG 13 highlights improving global cooperation to address climate change, including air pollution mitigation (Target 13.2) and enhancing education and awareness on climate-related issues (Target 13.3). These principles underscore the importance of tackling air pollution to promote human health and sustainable development.

Leading international organisations such as the WHO, Environmental Protection Agency (EPA), and IPCC have produced a wealth of information on the global impact of air pollution. WHO's Global Air Quality Report for 2022 underscores the pervasive nature of air pollution, with PM2.5 emerging as a particularly concerning pollutant. The Global Burden of Disease (GBD) studies highlight the staggering toll of air pollution on human health, estimating millions of premature deaths annually. EPA's National Ambient Air Quality Standards provide regulatory frameworks to limit harmful pollutants like PM2.5, while reports like the National Air Quality Trends Report and the National Air Toxics Assessment offer insights into air quality trends and the health risks associated with various pollutants in the United States. IPCC's Sixth Assessment Report and Special Report on Global Warming of 1.5°C emphasise the urgent need to address air pollution to mitigate climate change and safeguard human health. The 2022 IPCC Climate Change and Health Synthesis Report further underscores the interconnection between air pollution and climate change, and their detrimental effects on human health, emphasising the pressing need for global action to curb air pollution and its impacts.

3.2.2 Activity Data

Collecting activity data from own operations requires direct measurement and the use of emission factors. Direct measurement involves deploying air quality monitoring equipment within a facility to obtain real-time data on pollutant concentrations. This method provides precise, site-specific information, facilitating the identification of emission sources and offering immediate insights into environmental impacts. However, it requires specialised equipment and expertise, incurring associated costs. On the other hand, the use of emission factors relies on standardised values to estimate emissions based on materials or processes. While practical and widely accepted, this may introduce uncertainty compared to direct measurements. A recommended approach involves integrating both methods for a comprehensive understanding, leveraging the strengths of each. This combined strategy allows for continuous improvement by incorporating the latest research findings and regulatory updates, ensuring a reliable and evolving air quality assessment process. The choice between

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these methods should consider resource availability, pollutant specificity, and desired evaluation precision.

3.2.3 Database

UNEP Air Quality Monitoring Platform: This platform provides real-time air quality data from thousands of initiatives around the world. The platform includes data on PM2.5, PM10, ozone, and other air pollutants.

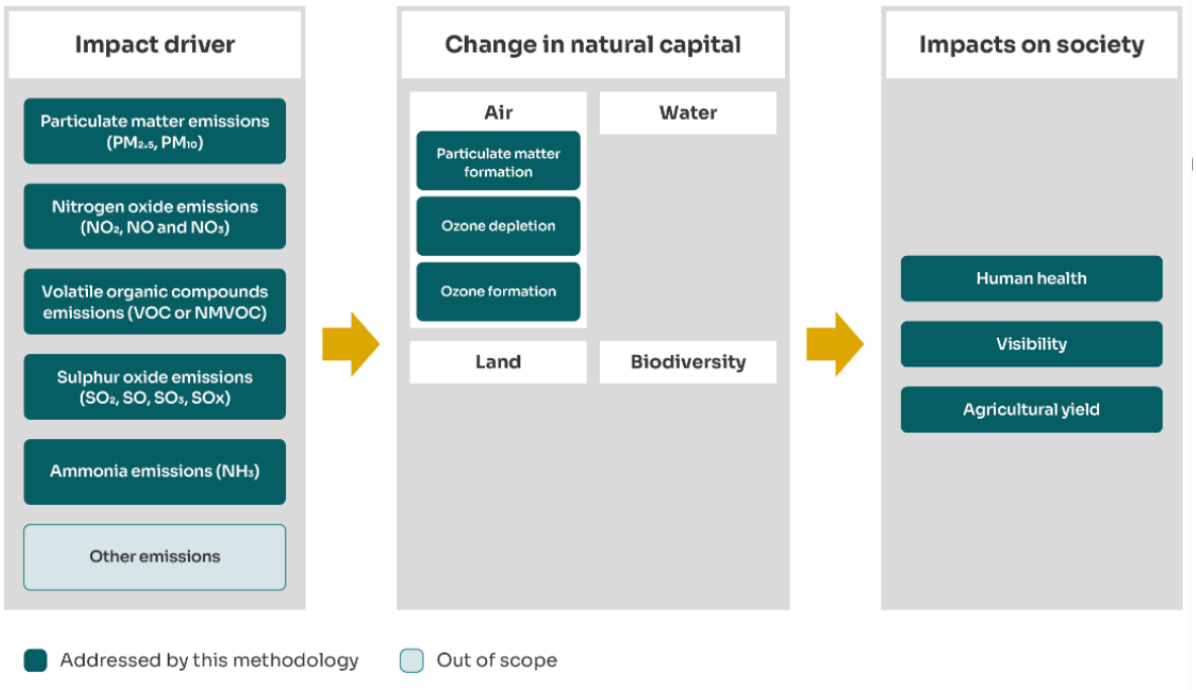
UNEP Air Quality: https://www.unep.org/explore-topics/air

3.2.4 Transparent

3.2.4.1 Introduction

Release into the air of non-GHG air emissions changes the concentration of pollutants and hence ambient air quality, which affects human health (e.g. contributing to respiratory infections and heart disease), biodiversity, and the extent and condition of habitats and ecosystem services. This can in turn lead to further impacts on society, for example, through changes in agriculture and associated loss in productivity leading to higher prices for consumers. Unlike greenhouse gas emissions, which contribute to climate change on a global scale, the impacts of air pollution are principally local or regional. Local or regional factors, such as weather conditions and population density, influence the magnitude and severity of impacts from air pollutants. Non-GHG air pollutants can be subdivided into “primary pollutants”, which directly cause negative impacts, and “secondary pollutants”, which originate from the reaction between primary pollutants and other gases in the atmosphere under certain conditions and subsequently have negative impacts.

(NCMA Methodology, page 28)



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3.2.4.2 Data Source

No explicit data sources for modelling of value factors are listed. The following list of data sources is listed if companies have no data available or need more information on air pollution (NCMA General guidance, page 29)

- Air quality indexes (if information on indicators is published)
- EEIO modelling such as Exiobase
- LCA models and databases such as ReCiPe model and Ecoinvent; these incorporate information on characterization factors
- WHO global air quality guidelines

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3.2.4.3 Calculation Logic

Formula

Monetized impact = Air pollutant activity data * value factor of air pollutant

Activity Data:

Air pollutants include: NH3, NOx, PM10, PM2.5, SOx, VOC/NMVOC

Value Factor

The value factor should include:

- Components included
  - Human health
  - Visibility (optional)
  - Agricultural yield (optional)
- Modelling of changes in natural capital (changes in particulate matter formation, ozone depletion, ozone formation) using, e.g. air dispersion models
- Valuing impacts on society in two steps:
  - Quantify impacts on society
    - Human health impact: dose-response functions
    - Visibility (optional): no need to model explicitly; implicitly covered by monetary valuation technique
    - Agricultural yield (optional): dose-response function to determine the effects of air pollutants on loss of crop production
  - Value impacts in monetary terms

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- Human health impact: stated or revealed preference approaches
- Visibility (optional): stated or revealed preference approaches
- Agricultural yield (optional): market prices

3.2.5 WifOR Institute (Environmental Prices)

3.2.5.1 Introduction

Air pollution involves the alteration of the natural atmosphere through the introduction of chemical, physical, or biological agents. Common sources contributing to this pollution include household combustion devices, vehicles, industries, and forest fires. These pollutants, notably particulate matter like PM2.5 and PM10, nitrogen oxides (NOx), sulphur oxides (SOx), non-methane volatile organic compounds (NMVOC), and ammonia (NH3), lead to resfpiratory and other diseases, posing a significant threat to public health in terms of morbidity and mortality. The impact of air pollutants varies based on their release environment, with greater severity observed in areas with higher population density and lower-down emission sources. Emissions from road traffic, for instance, are closer to the ground and tend to have more pronounced effects on nearby populations. Differentiating between urban, peri-urban, rural, and transportation environments helps categorise and understand the varying impacts of air pollution on different regions.

3.2.5.2 Activity Data Source

- EXIOBASE 3.8.1., EDGAR, Eurostat

3.2.5.3 Subcategories

NH3, NMVOC, NOX, PM10, PM2.5, SOX

3.2.5.4 Formula

- Simple multiplicative: Monetized impact = Sum of activity data x value factor (degree of detail)
- Country/Sector-specific

3.2.5.5 Impact Pathway

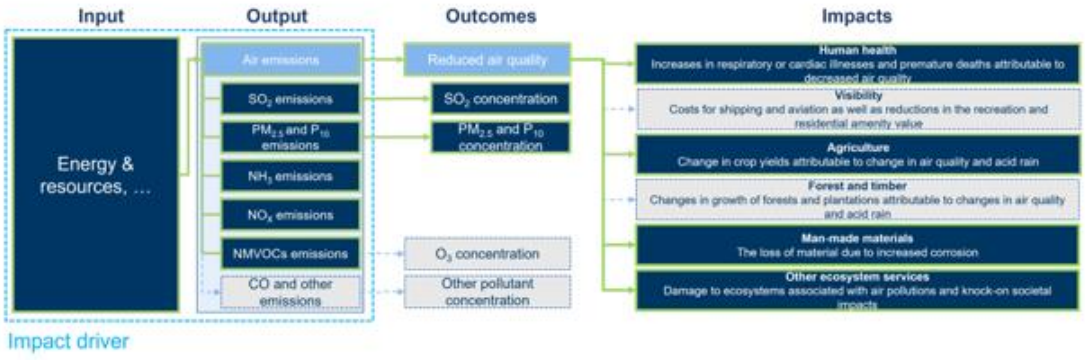

Figure 4: Impact Pathway of air pollution (source: own illustration)

[Source: Air Pollution / WifOR Institute]

3.2.5.6 Valuation Method (hui, gdp loss, …)

1. Health damage (e.g. respiratory diseases) → HUI/DALY
2. Biodiversity loss (e.g. species extinction) → Preservation Cost Approach?
3. Crop/harvest damage (e.g. losses in agricultural yield) → Economic Damage
4. Material/infrastructure damage (e.g. façade staining) → Economic Damage

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3.2.5.7 Sources of Valuation Data

The valuation of effects arising from air pollution follows the recommendation of the German Federal Environmental Agency (UBA) (Matthey and Bünger, 2019)

The underlying air quality modelling data is based on the EU project NEEDS.

3.2.5.8 Geographical Differences

- Biodiversity loss: Number of red-listed species per country
- Health damage: Population density
- Crop/harvest damage: Economic dependency on agriculture
- Material/infrastructure damage: Population density

3.2.5.9 Transfer Mechanism

Germany is set as the baseline, and values are scaled up and down for more and less densely populated countries (or for Biodiversity: depending on whether more or fewer species are endangered)

Adjusted for PPP.

3.2.5.10 Air Pollution-specific

Location differences: urban, peri-urban, rural, transport

3.2.5.11 Global Damage

USD 9.1 Trillion (2020)

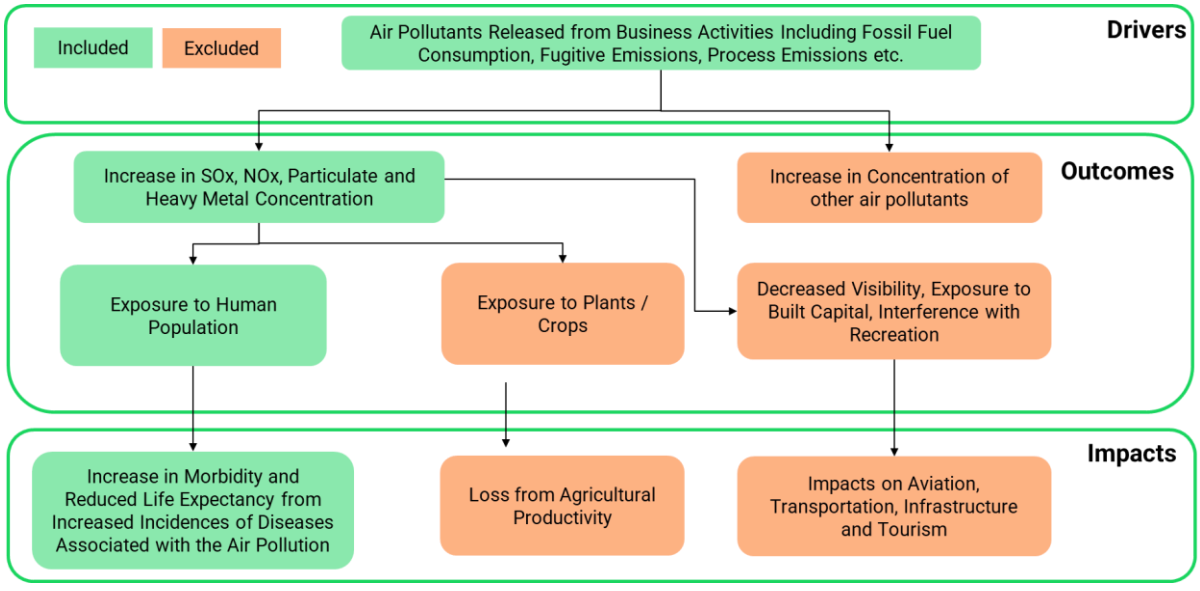
3.2.5.12 Environmental Prices

WifOR Institute: https://www.wifor.com/en/impact-valuation-factors/

3.2.6 GIST Impact

3.2.6.1 Evaluation Framework and Methodology

An outline of the evaluation framework adopted for the evaluation of impacts from air pollutants is shown below:



[Source: Impact Pathway Air Pollution / GIST Impact]

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"Drivers" for the release of air pollutants include multiple activities across the value chain of a company. Activities like the use of fossil fuels in boilers, process emissions, transportation of raw materials and finalised products, fugitive emissions during handling of raw materials and road transportation, etc. can lead to the release of one or more categories of air pollutants.

All these activities increase the concentration of air pollutants in the local environment, which can be called a biophysical change or primary "outcome". The net change in concentration of pollutants can be estimated through air dispersion modelling. Increased concentrations of pollutants can lead to multiple secondary outcomes, such as exposure to the human population, exposure to plants or crops, decreased visibility, and exposure to buildings, and can hamper recreational activities.

Finally, these outcomes can lead to "impacts" such as an increase in morbidity or mortality from increased incidences of disease, loss of agricultural productivity, and impacts on aviation, transportation, infrastructure, and tourism. In the current assessment, only human health impacts have been considered, as they contribute as much as ~95% of total impacts from air pollutants (Muller, et al., 2007).

3.2.6.2 Calculation Logic

Below are the steps followed for calculating the impacts of air pollutants:

- **Step-1:** Emissions-Sources – The amount of pollutant emitted from a source, such as a point, line, or area source.
- **Step 2:** Emissions-Concentrations – The environmental concentrations of pollutants depend not only on the emissions but also on the transport, transformation, and dilution of the contaminant in the environment. The dispersion of air pollutants is obtained using various models depending on the source (point/line/area) of air pollution. The dispersion models predict the downwind concentration of air pollutants emitted from emission sources. For the current work, the dispersion modelling is done using AERMOD, which is a Gaussian plume atmospheric dispersion modelling system.
- **Step-3:** Concentrations-Exposure – Environmental exposure to a pollutant is the measure of contact of the polluting material with the sensitive system, whether a human, a building, or an ecosystem. Since the endpoint impact is human health, exposure is a direct function of the human population density.
- **Step-4:** Exposures-Health Effects – The health effects (impacts) from the exposures are variable for a population because of differences in the vulnerability of different people or the competing risks that affect them. Dose-response assessment studies define quantitative relationships between pollutant exposure and health effects. Health impacts considered in the calculations are: cardiovascular diseases (CVD), lung cancer (LC), chronic obstructive pulmonary disease (COPD), stroke, lower respiratory infections, and type II diabetes, etc. The health impacts of the increased air pollutant concentrations are quantified in terms of attributable mortality and morbidity due to the selected disease.
- **Step-5:** Economic Valuation of Impacts – The financial cost associated with the health conditions is calculated using the Hybrid Human Capital Approach (HCA). It has two components: the first component is the Cost of Illness (COI), which considers the treatment and the medical cost (i.e. direct costs) and the second component values the lost Disability Adjusted Life Years (DALYs), which is equivalent

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to the number of productive days lost due to illness; this also includes reduced life expectancy, (i.e. indirect costs).

Benefits/Cost (in USD) = Emissions quantity released / avoided in a particular year (tonne) * Value factor for each pollutant (e.g. particulate matter) (USD/tonne)

3.2.6.3 Data Sources[7]

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[7] The reference list is intentionally limited for confidentiality reasons.

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3.2.7 Upright Project

3.2.7.1 Data Sources

Global Burden of Diseases (GBD) platform

The GBD platform, accessible at https://www.healthdata.org/research-analysis/gbd, is a source providing information on deaths attributed to air pollution that offers comprehensive data on the health impacts caused by various pollutants. In this context, deaths resulting from air pollution are multiplied by a DALY cost of USD 12,000. This platform helps quantify the overall impact on health from different types of emissions.

2017 Lancet Commission on Pollution and Health

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The Lancet Commission on Pollution and Health, specifically its 2017 report, is another significant data source considered for assessing the impact of pollution on health. This report contains comprehensive findings, analyses, and recommendations regarding the health consequences of different pollutants, contributing valuable insights to understanding the health burden associated with various emissions.

3.2.7.2 Subcategories

Upright calculates all pollution other than GHG under one category, called “non-GHG emissions”. This means that pollution to air, water, and ground are compiled under a single category.

Pollutants included in Upright’s non-GHG emission analysis that are considered air pollutants are: particulate matter air pollution, heavy metal emissions, ammonia emissions, nitrogen oxide emissions, and volatile organic compound emissions.

3.2.7.3 Impact Pathways

Currently, Upright only takes into account the effects of air pollution on human health (DALY).

Ideally, when reliable sources are found, other impacts related to air pollution should also considered in the calculations: for example, decline in ecosystem services (economic damage), damage to the built environment (economic damage), and effects on agriculture (economic damage).

3.2.7.4 Data Sources for Air Pollution Monetization

Global Burden of Diseases (GBD)

The GBD platform, accessible at https://www.healthdata.org/research-analysis/gbd, is a source providing information on deaths attributed to air pollution and offers comprehensive data on the health impacts caused by various pollutants. In this context, deaths resulting from air pollution are multiplied by a DALY cost of USD 12,000. This platform helps quantify the overall impact on health due to different types of emissions.

2017 Lancet Commission on Pollution and Health

The Lancet Commission on Pollution and Health, specifically its 2017 report, is another significant data source considered for assessing the impact of pollution on health. This report contains comprehensive findings, analyses, and recommendations regarding the health consequences of different pollutants, contributing valuable insights to understanding the health burden associated with various emissions.

3.2.7.5 Calculation Logic

Air pollution impacts are monetized by reviewing the global estimates of the social cost per emission type. In this way, it is possible to understand the global cost caused by air pollution, which can then be imputed to companies operating in the private sector (Upright’s top-down approach, see more detailed explanation in GHG emissions).

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3.2.8 VBA

3.2.8.1 Introduction

Economic activity in all sectors results in emissions of waste gases and suspended solids into the air (whether directly as a result of industrial processes or indirectly as a result of, for instance, energy or resource consumption). Changes in the concentrations of these emissions may have negative impacts on people (e.g. on their health) and on the natural and built environment. Therefore, these emissions carry a societal cost. Unlike GHGs, which contribute to climate change on a global scale, the impacts of air pollution are principally local or regional. Moreover, local or regional factors, such as weather conditions and population density, influence the severity of the impact of air pollutants.

Air pollution can be subdivided into two types: “Primary pollutants” have direct, negative impacts on the environment and people; “secondary pollutants” result from reactions between primary pollutants and other gases under certain conditions and, subsequently, have negative impacts on the environment and people.

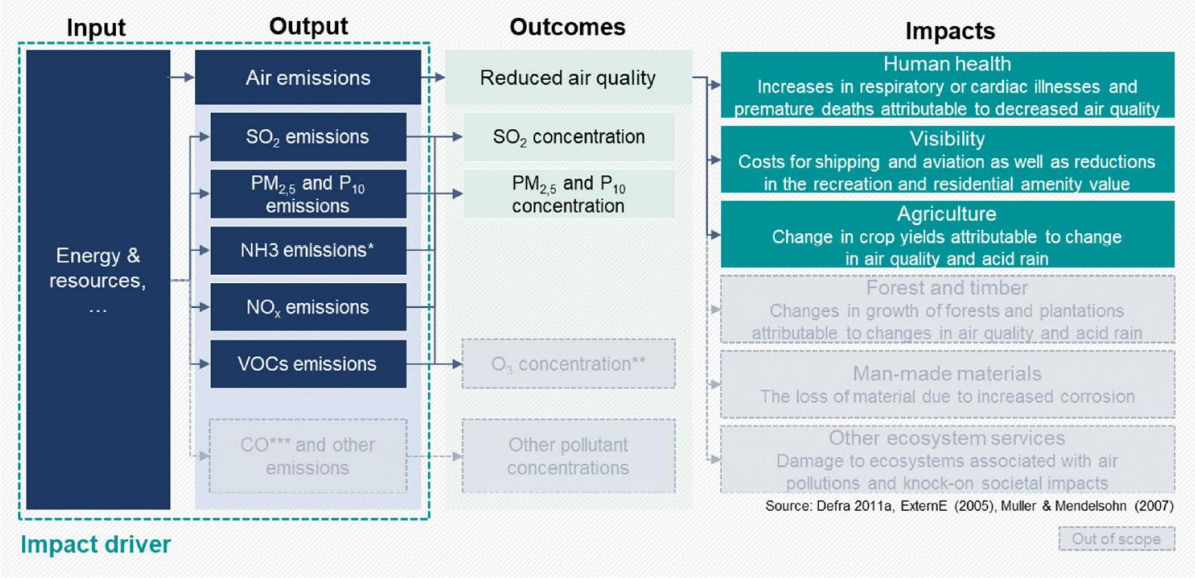

Figure 2.2.9-A: Simplified impact pathway for other air pollutation (non-GHG)

3.2.8.2 Data Sources

- Muller, N. Z. & Mendelssohn, R., (2007): Measuring the Damages of Air Pollution in the United States. Journal of Environmental Economics and Management, Vol. 54 (1), pp. 1-14.
- VSL: OECD, (2012). Mortality Risk Valuation in Environment, Health and Transport Policies.

3.2.8.3 General Calculation Logic

Monetized impact = Sum of country, region (air pollutant activity data (air pollutant in kg) * value factor of air pollutant in respective country and region)

Value factors per air pollutant are country specific; a region can be urban, rural, peri-urban, or transportation.

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3.2.8.4 Activity Data (impact driver – other air emissions – non-GHG)

Air pollutants included in impact valuation: NH3, NOx, PM10, PM2.5, SOx, VOC, measured in kg

3.2.8.5 Valuation of Other Air Emissions

Impacts from other air emissions (non-GHG) which are considered in the valuation include:

- **Human Health**: respiratory diseases caused by air pollution; increased incidents of chronic diseases, such as asthma and bronchitis, premature mortality from cardiovascular diseases, pulmonary diseases and lung cancer

  Modelling:
  - Air dispersion model to determine the change in primary and secondary pollutant concentrations over a specified area (consider local meteorological conditions as well as the persistence of pollutants in the air); air pollutant dispersion is modelled using Sim-Air ATMOS 4.0.
  - The impact on human health depends on the concentration and should be modelled using a suitable dose-response function (linear dose-response functions for pollutant exposure).
  - Mortality valuation via OECD estimate of the value of a statistical life (VSL); morbidity health outcomes are valued via WTP estimates from peer-reviewed literature.
  - Application of value transfer to translate WTP to different countries and check for income elasticity sensitivity.

- **Visibility**: reduced visibility through the formation of smog (effects on navigation, disamenity)

  Modelling:
  - Modelling and valuation in one step, through a study on WTP to reduce visibility impairment from air pollution.
  - Multivariate transfer function based on cost estimate provided by Muller & Mendelsohn (2007).
  - Transfer function provides an estimate of the societal cost of reduced visibility as a function of ambient O3 concentration, local income, local population density, temperature, and rainfall.

- **Agriculture**: crop growth/ reduced yields

  Modelling:
  - Modelling and valuation in one step, through average of marginal damage costs from Muller and Mendelsohn's (2007) US dataset and adjusted for purchasing power differences between countries.
  - Single variate transfer function taking the average of marginal damage cost estimates from Muller and Mendelsohn (2007) and adjusting internationally for PPP.

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3.2.9 CE Delft (Environmental Prices)

3.2.9.1 Calculation Logic

Monetized impact = Sum of activity data x value factor (degree of detail)

3.2.9.2 Environmental Prices

Tabel 3 - Milieuprijzen voor emissies van luchtverontreinigende stoffen, in €$_{2021}$/kg

Stof	Stofnaam	Onder	Centraal	Boven
CO_2	Koolstofdioxide	€ 0,050	€ 0,130	€ 0,160
CFC-11	Chloorfluorkoolstof	€ 283	€ 725	€ 926
$PM_{2,5}$	Fijnstof*	€ 73,3	€ 121	€ 169
PM_{10}	Fijnstof*	€ 41,4	€ 69,3	€ 97,9
$PM_{0,1}$	Ultrafijnstof	€ 296	€ 438	€ 660
NO_x	Stikstofoxiden	€ 18,3	€ 29,9	€ 44,1
SO_2	Zwaveldioxide	€ 33,7	€ 57,5	€ 83,1
NH_3	Ammoniak	€ 30,4	€ 49,3	€ 67,9
NMVOS	Vluchtige organische stoffen (niet-methaan)	€ 1,76	€ 2,73	€ 3,82
CH_4	Methaan	€ 1,81	€ 4,70	€ 5,78
As	Arseen	€ 6.987	€ 10.335	€ 15.583
Cd	Cadmium	€ 115.740	€ 171.133	€ 257.808
Cr-VI	Chroom VI	€ 1.834	€ 2.741	€ 4.203

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Stof	Stofnaam	Onder	Centraal	Boven
Pb	Lood	€ 19.664	€ 29.078	€ 43.810
Hg	Kwik	€ 10.174	€ 15.325	€ 23.824
Ni	Nikkel	€ 103	€ 190	€ 386
	1,3 Butadiene	€ 1,08	€ 1,66	€ 2,43
	Benzeen	€ 0,243	€ 0,366	€ 0,543
	Benzo(a)pyrene	€ 3.859	€ 5.704	€ 8.590
	Dioxines	€ 34.071.638	€ 50.367.398	€ 75.847.243
	Formaldehyde	€ 0,330	€ 0,520	€ 0,744

* In de analyse dient men óf $PM_{2,5}$ óf PM_{10} mee te nemen en niet beide tegelijkertijd.

[Source: CE Delft, Environmetnal Prices, 2023, Table, pp. 31-32]

3.2.10 Umwelt Bundesamt (Environmental Prices)

3.2.10.1 Valuation Technique

The assessment of air quality, exposure, and associated impacts relies on the EcoSenseWeb model (Version v1.3) developed for the EU project NEEDS, with its methodology outlined in the Methodological Convention 2.0. Although the model incorporates atmospheric dispersion findings from the EMEP model, the current version lacks the integration of more recent EMEP data. Health effects are evaluated based on contemporary literature compiled by WHO in 2013, and monetary assessment factors align with EU standards (Holland 2014). Crop failures are

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assessed using response functions from Mills et al. (2007), supplemented by value factors derived from updated NEEDS data as necessary. Similarly, building/material damage and biodiversity losses are evaluated using the same updated NEEDS data. This comprehensive approach provides a multifaceted assessment, acknowledging limitations in the integration of the latest EMEP model findings into the current version of EcoSenseWeb.

3.2.10.2 Environmental Prices

Table 45: Average environmental cost of air pollution from emissions from unknown source (in €2020 / t emission)

€2020/t emission	Value factors for emissions in Germany				
	Health damage	Biodiversity loss	Crop damage	Material damage	Total
Germany total					
$PM_{2.5}$	61,500	0	0	0	61,500
PM_{coarse}	1,000	0	0	0	1,000
PM_{10}	43,300	0	0	0	43,300

[9] The most important air pollutants in this context are particulate matter (PM), nitrogen oxides (NOx), sulphur dioxide (SO2), non-methane volatile organic compounds (NMVOC) and ammonia (NH3).

[10] Unknown sources (unknown height of release) means here that there is no specification regarding the stack height of the respective system. These are therefore average values. Emissions from low sources (installations with low stack heights) have higher costs; those from higher sources have correspondingly lower values.

13

Methodological Convention 3.1 for the Assessment of Environmental Costs – Value Factors

	Value factors for emissions in Germany				
NO_x	15,200	2,800	900	100	19,000
SO_2	14,300	1,100	-200	600	15,800
NMVOC	1,200	0	1,000	0	2,200
NH_3	22,800	11,000	-100	0	33,700

Assumption: PM_{10} consists of 70% $PM_{2.5}$ and 30% PM_{coarse}. For NO_x and SO_2, the costs represent the damage caused by secondary particulate matter formation. Source: Van der Kamp et al. (2017), own calculations. Note: The price adjustment to 2020 was made on non-rounded values to reduce rounding errors.

[https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2023-03-16_methodological-convention-3-1_value-factors_2020_bf.pdf]

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3.2.11 EPS IVL (Environmental Prices)

Figure 1 EPS architecture.

Source: [Swedish Life Cycle Center et al, EPS weighting factors - version 2020d, November 2020]

Valuation Technique

Aligned to ISO 14008:2009 Environmental Management - Monetary valuation of environmental impacts and related environmental aspects, the valuation technique follows the hierarchy of monetary valuation methods, from cost avoidance methods to monetization based on damage costs.

- Cost avoidance
- Damage
- Midpoint level

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Excerpt EPS IVS

Table 4 Monetary values of impacts on environmental goods from emissions of inorganic gases and particles.

Emission	Receiving media	Unit	Monetary impact value, €	Notes
Carbon dioxide, CO2	air	kg	2.88E-01	
Carbon monoxide, CO	air	kg	1.08E+00	
Nitrogen oxides, NOx	air	kg, as NO2	-2.64E+01	
Nitrous oxide, N2O	air	kg	7.67E+01	
Ammonia, NH3	air	kg	-4.34E+01	
Sulphur oxides, SOx	air	kg	-8.45E+00	
Hydrogen Fluoride	air	kg	-6.64E+00	
Hydrogen Chloride	air	kg	-6.80E+00	
Hydrogen Sulphide	air	kg	-1.97E+01	
PM2.5	air	kg	2.32E+02	
PAH in particles	air	kg	4.83E+00	in addition to PM2.5
As in particles	air	kg	3.25E+02	
Cd in particles	air	kg	2.73E+01	
Cr in particles	air	kg	3.43E+02	

Source: [Swedish Life Cycle Center et al, EPS weighting factors - version 2020d, November 2020]

3.2.12 EPS, Chalmers (Environmental Prices)

Particles in air, or aerosols, vary widely in size, shape, and composition, making classification challenging. However, it is still meaningful to classify them because most aerosols originate from a limited number of sources and processes. Aerosols are classified based on formation processes into dispersion aerosols (larger than 10 µm) and condensation aerosols (around 1 µm and less). Dispersion aerosols have a short residence time and are local, while condensation aerosols have longer residence times and cover larger areas.

Particle size affects their behaviour and impacts. Smaller particles require more energy to form, and particles below 2.5 µm can penetrate deep into the lungs. However, there's no sharp cut-off in measurement methods at 2.5 or 10 µm, complicating classification. Particle categorisation in ambient air faces uncertainties, as does measurement at emission sources.

The analysis provided is global in scope and covers various challenges and uncertainties in classifying and measuring particles in air, including the difficulty in relating emission measures to ambient air concentrations, especially for substances like soot and black carbon. Using measures like elemental carbon (EC) can help approximate soot and black carbon concentrations in ambient air.

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Pathways by which PM2.5 particles impact on environmental goods

Environmental Good	Impact Indicator	Unit	Pathway
Human Health	YLL	person-years	Direct Exposure
Human Health	YLL	person-years	Climate Change
Human Health	YLD	person-years	Direct Exposure
Human Health	Undernutrition	person-years	Climate Change
Human Health	Working Capacity	person-hours	Climate Change
Human Health	Diarrhoea	person-years	Climate Change
Crop	Production Capacity	kg	Climate Change
Meat	Production Capacity	kg	Climate Change
Fish	Production Capacity	kg	Climate Change
Wood	Production Capacity	m^3	Climate Change
Drinking Water	Production Capacity	m^3	Climate Change
Biodiversity	share of Threat to Redlisted Species	dimensionless	Climate Change

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 112]

Environmental Impact Factors and Uncertainties for PM2.5

- YLL via Direct Exposure:
  - Factor: 1.34E–03 YLL/kg PM2.5
  - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 3.2
- YLL via Climate Change:
  - Factor: 6.20E–04 YLL/kg PM2.5
  - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 2.7
- YLD via Direct Exposure:
  - Factor: 6.16E–05 YLD/kg PM2.5
  - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 3.2
- Undernutrition via Climate Change:
  - Factor: 5.68E–04 person-years/kg PM2.5
  - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 4.7
- Decreased Working Capacity via Climate Change:
  - Factor: 1.49 person-hours/kg PM2.5
  - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 2.7
- Diarrhoea via Climate Change:
  - Factor: 8.89E–08 person-years/kg PM2.5
  - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 3.7
- Crop Production Capacity via Climate Change:
  - Factor: 4.69 kg crop/kg PM2.5
  - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 3.7
- Meat Production Capacity via Climate Change:

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    - Factor: 1.23E–01 kg meat/kg PM2.5
    - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 3.7
- Fish Production Capacity via Climate Change:
    - Factor: 9.64E–03 kg fish/kg PM2.5
    - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 2.7
- Wood Production Capacity via Climate Change:
    - Factor: 0 kg wood/kg PM2.5
    - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 2.28E–03 m3 wood per kg PM2.5
- Drinking Water Production Capacity via Climate Change:
    - Factor: 0.299 m3 drinking water/kg PM2.5
    - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 3.7
- Decrease of Biodiversity via Climate Change:
    - Factor: 5.58E–14 shares of threat to red-listed species/kg PM2.5
    - Uncertainty: Log-normal distribution with a standard deviation corresponding to a factor of 4.7

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Summary of environmental impact factors and monetary impact values of emission of 1 kg PM2.5

Impact indicator	Unit	Pathway	Environmental impact factor	Uncertainty	Indicator value ($/unit)	Impact value ($/kg PM2.5)
YLL	personyears	direct exposure	1.34E–03	3.2	107,067	1.44E+02
YLL	personyears	climate change	6.20E–04	2.7	107,067	6.64E+01
YLD	personyears	direct exposure	6.16E–05	3.2	107,067	6.59
undernutrition	personyears	climate change	5.68E–04	4.7	6,424	3.65
working capacity	personhours	climate change	1.49E+00	2.7	30	4.48E+01
diarrhea	personyears	climate change	8.89E–08	3.7	11,242	1.00E–03
production capacity	kg	climate change	4.69E+00	3.7	0.289	1.35
production capacity	kg	climate change	1.23E–01	3.7	2.59	3.18E–01
production capacity	kg	climate change	0.009636	2.7	2.42	2.97E–01
production capacity	m^3	climate change	2.28E–03	0.0	72	1.64E–01
production capacity	m^3	climate change	2.99E–01	3.7	1.87	5.59E–01
share of threat to redlisted species	dimensionless	climate change	5.58E–14	4.7	7.61E+10	4.24E–03
					sum	2.68E+02

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 119]

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PAH

Substance Name	Substance Name
Acenaphtylene	Benzo(b)fluorene
Acenaphtene	1-Metylpyrene
4-Metylbiphenyl	Benz(a)anthracene
Dibenzofuran	Chrysene
Fluorene	Triphenylene
9-Metylfluorene	Naphtancene
9,10-Dihydroanthracene	Benzo(bjk)fluoranthenes
1-Metylfluorene	Benzo(a)pyrene
Dibenzothiophene	Benzo(e)pyrene
Phenanthrene	Perylene
Anthracene	3-Methylcholanthrene
2-Metylanthracene	m-Quaterphenyl
1-Metylanthracene	Indeno(1,2,3-cd)pyrene
9-Metylanthracene	Dibenz(a,h)anthracene
3,6-Dimethylphenantrene	Picene
1,2-Dihydropyrene	1,2,3,4-Dibenzanthracene
Fluoranthene	Benzo(g,h,i)perylene
Pyrene	Anthanthrene
Benzo(a)fluorene	

Environmental Impact Factors and Uncertainties for PAH

- YLL from Direct Exposure:
    - Factor: 4.77E–05 YLL/kg PAH
    - Uncertainty: Factor of 3 assumed due to lack of quantitative knowledge on the risk by other PAHs
- Person-years of Cancer from Direct Exposure:
    - Factor: 9.25E–06 person-years/kg PAH
    - Uncertainty: Factor of 3 assumed due to lack of quantitative knowledge on the risk by other PAHs

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Arsenic

Summary of environmental impact factors and monetary impact values of emission of 1 kg As.

Environmental good	Impact indicator	Unit	Pathway	Environmental impact factor	Uncertainty	Indicator value ($/unit)	Impact value ($/kg As)
human health	YLL	personyears	cancer	1.39E–03	3	107,067	1.49E+02
human health	YLL	personyears	CV diseases	1.94E–03	3	107,067	2.08E+02
human health	cancer	personyears	direct exposure	1.79E–05	3	21,413	3.83E–01
						sum	3.57E+02

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 126]

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Environmental Impact Factors and Uncertainties for Arsenic (As) Exposure

- YLL via Cancer:
  - Factor: 1.39E–03 YLL per year
  - Uncertainty: Factor of 3 assumed due to the simple fate model
- YLL via Cardiovascular Diseases:
  - Factor: 1.94E–03 YLL per year
  - Uncertainty: Factor of 3 assumed due to the simple fate model
- Person-years of Disability through Cancer:
  - Factor: 5.02E–04 person-years per year
  - Uncertainty: Factor of 3 assumed due to the simple fate model

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Cadmium

Summary of environmental impact factors and monetary impact values of emission of 1 kg Cd

Environmental good	Impact indicator	Unit	Pathway	Environmental impact factor	Uncer-tainty	Indicator value ($/unit)	Impact value ($/kg Cd)
human health	YLL	personyears	cancer	2.38E–04	3	107,067	2.55E+01
human health	cancer	personyears	direct exposure	2.10E–04	3	21,413	4.50E+00
						sum	3.00E+01

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 128]

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Environmental Impact Factors and Uncertainties for Cadmium (Cd) Exposure

- YLL from Cancer:
    - Factor: 2.38E–04 YLL per year
    - Uncertainty: Factor of 3 assumed due to the simple fate model
- Disability from Cancer:
    - Factor: 2.10E–04 person-years per year
    - Uncertainty: Factor of 3 assumed due to the simple fate model

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Chromium

Summary of environmental impact factors and monetary impact values of emission of 1 kg Cr

Environmental good	Impact indicator	Unit	Pathway	Environmental impact factor	Uncertainty	Indicator value ($/unit)	Impact value ($/kg Cr)
human health	YLL	personyears	cancer	3.36E–03	3	107,067	3.59E+02
human health	cancer	personyears	direct exposure	8.09E–04	3	21,413	1.73E+01
						sum	3.77E+02

[Source Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 130]

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Environmental Impact Factors and Uncertainties for Chromium (Cr6+) Exposure

- YLL from Cancer:
  - Factor: 3.36E–03 YLL per year
  - Uncertainty: Factor of 3 assumed due to the simple fate model
- Disability from Cancer:
  - Factor: 8.09E–04 person-years per year
  - Uncertainty: Factor of 3 assumed due to the simple fate model

Source

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3.2.13 Analysis

Transparent focuses on pollutants such as NH3, NOX, PM10, PM2.5, SOX, VOC/NMVOC. They directly calculate the impact using activity data and value factors for pollutants, considering human health, visibility, and agriculture in their valuation. Their approach involves stated or revealed preference techniques, and accessible sheets are available for their analysis.

VBA considers a broader range of pollutants, including NH3, NMVOC, NOX, PM10, PM2.5, SOX, and ammonia emission, aggregating activity data over countries and regions then summing it with value factors for each pollutant. Their valuation includes various aspects such as human health, visibility, agriculture, forest and timber, man-made materials, and other

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ecosystem services. They also use stated or revealed preference approaches but do not provide accessible sheets for their analysis.

GIST Impact focuses on pollutants like PM, SOX, NOX, and heavy metals. Their analysis is based on grid-level data and calculates the impact/cost in USD using emission quantities and value factors. They consider human health, agriculture, recreation, and visibility in their valuation, employing a dose-response function for determining DALY loss. They do not provide accessible sheets for their analysis.

WifOR Institute's analysis includes pollutants such as NH3, NMVOC, NOX, PM10, PM2.5, and SOX, with activity data specific to various sectors and regions. They calculate the impact by summing activity data multiplied by value factors. Their valuation covers human health, visibility, agriculture, forest and timber, man-made materials, and other ecosystem services. They use various valuation techniques such as DALYs (VSL), stated or revealed preference approaches, preservation cost approaches, and economic damage assessment. Accessible sheets are available for their analysis.

Pollutants Considered: All distributors assess a wide range of air pollutants, including NH3, NOX, PM10, PM2.5, and SOX, among others. This indicates a comprehensive approach to understanding the environmental impact of various emissions.

Valuation Aspects: Human health emerges as a common consideration among all distributors, highlighting the shared recognition of its significance in assessing the impact of air emissions. Additionally, visibility and agriculture are also commonly considered, indicating an acknowledgment of broader societal and economic impacts beyond health.

Monetization Approach: The four distributors employ a monetization approach to quantify the impact of air emissions. They calculate the impact in monetary terms by multiplying activity data with value factors assigned to pollutants. This standardised approach allows for comparability across different pollutants and impacts.

Valuation Techniques: Stated or revealed preference approaches are commonly used by two of the distributors (Transparent and VBA) to assess the monetary value of impacts. This indicates reliance on established methodologies for understanding societal preferences and willingness to pay for mitigating the impacts of air emissions.

Value Transfer: Accessibility to the use of value transfer techniques to derive country-level value factors for pollutants varies.

Accessibility of Data and Methodologies: Some distributors provide accessible sheets for their analysis, others do not. Lack of accessibility hinders transparency and reproducibility, limiting the ability of stakeholders to verify the assessment results and understand the underlying methodologies.

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3.3 Waste

3.3.1 Challenge

Measuring the total quantity of solid hazardous and non-hazardous waste produced and disposed of in landfills or through incineration, categorised by country, is essential for evaluating environmental impacts and ensuring transparent reporting. Hazardous waste, posing substantial threats to public health and the environment, demands careful consideration in the waste management process. The consequences of solid waste disposal encompass a range of environmental outcomes, each with distinct societal costs. These include the release of greenhouse gases and air pollutants, contributing to air pollution and climate change. Moreover, factors such as noise, odour, and other intrusions can compromise landscape quality, diminishing overall enjoyment of the environment and resulting in visual amenity effects. Leachate release, leading to soil and water contamination, poses risks to agricultural yields and public health. This assessment, crucial for regulatory compliance and informed decision making, underscores the importance of adopting sustainable waste management practices. Additional details on the methodology and specific considerations are available in the accompanying documentation.

SDG 11 addresses this challenge, emphasising creating inclusive, safe, resilient, and sustainable cities, with Target 11.6 focused on reducing the adverse environmental impact of cities, including air quality and waste management. SDG 9 promotes sustainable industrial development and resilient infrastructure, highlighting investments in early warning systems to mitigate climate change impacts (Target 9.5). SDG 8 advocates for decent work and economic growth, emphasising safe working environments, including waste management sectors (Target 8.8). SDG 12 promotes sustainable consumption and production, aiming to reduce food waste at various stages of the supply chain, including post-harvest losses (Target 12.3). These principles underscore the importance of waste management for sustainable development.

Several leading international organisations, including the UNEP, OECD, WHO, ILO, and UNIDO, have contributed valuable insights into global waste management. UNEP's Global Waste Management Outlook 2022 offers comprehensive analysis and strategies for addressing waste management challenges worldwide. OECD's report on the Circular Economy and Resource Efficiency highlights the importance of transitioning towards sustainable waste management practices. WHO's Global Burden of Disease 2020 report sheds light on the health impacts of improper waste management. The International Labour Organization's Global Risks Report 2022 identifies emerging risks associated with waste management practices. UNIDO's Strategic Directions for Sustainable Waste Management in the Global South provides a framework for policy development and investment in waste management infrastructure. Additionally, the World Bank's What a Waste Global Database serves as a valuable resource for understanding waste generation and management trends worldwide. Together, these documents underscore the urgent need for coordinated global efforts to address waste management challenges and promote sustainable waste practices for a healthier and more resilient future.

3.3.2 Activity Data

To comprehensively assess the environmental impact of generated waste, the systematic collection of primary data is imperative. This involves categorising waste into hazardous and non-hazardous types based on local regulatory definitions and distinguishing between disposal methods such as incineration and landfill. Country-specific data on the kilograms of each waste type disposed of is crucial, ensuring consistent reporting formats across diverse

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locations. In cases where data lacks differentiation, transparent documentation of assumptions is essential, with efforts made to extrapolate based on national statistics or publicly available sources while adhering to local regulatory limits. Simultaneously, emission factors play a critical role in the assessment, requiring reference to local regulations for accurate impact estimation. In instances where specific data is absent, the worst-case scenario assumption of landfill disposal should be documented, aligning with regional waste management regulations.

3.3.3 Databases

The GEMS Municipal Waste Database, GEMS Industrial Waste Database, GEMS E-Waste Database, and GEMS Hazardous Waste Database are four key databases managed by the UNEP that provide valuable insights into the management of municipal solid waste (MSW), industrial waste, e-waste, and hazardous waste. These databases collect data from over 40 countries, allowing organisations, policymakers, and individuals to track trends in waste generation, identify areas for improvement, and develop strategies for sustainable waste management.

GEMS Municipal Waste Database: http://www.env-data.com/

GEMS Industrial Waste Database: https://www.eea.europa.eu/data-and-maps/data/external/generation-of-waste-statistics

GEMS E-Waste Database: https://gemsrecyclers.com/

GEMS Hazardous Waste Database: https://www.envirobiz.com/hazardous-waste-shipment-database.html

3.3.4 Transparent

3.3.4.1 Introduction

Corporate activities in all sectors generate waste. The generated waste can be in gaseous, fluid, or solid form. In this document, gaseous waste is covered in the section on non-GHG air emissions, fluid waste is covered in the section on water pollution, and this section considers solid waste. The disposal of solid waste can lead to a range of changes to natural capital that adversely affect human well-being, thereby carrying a cost to society. This section is concerned with the impacts of waste disposal. It does not evaluate the costs associated with design or production inefficiencies that may be indicated by the presence of waste. For solid waste disposal, the type of waste (e.g. hazardous, non-hazardous) and the method of its disposal (incineration, landfill, or material recovery) are key factors that dictate how natural capital is affected as well as the type and magnitude of impacts. In cases where solid waste is sent to open dump sites, it may be carried into marine water (e.g. via rivers) and lead to additional impacts. Please note that these impacts are currently out of scope of the methodology.

Recommendation for circular economy models: Given that recycling essentially closes the loop in a linear value chain (e.g. from virgin raw material extraction to end-of-life treatment) and provides raw materials for a business, we recommend that material recovery (and energy recovery) be treated as averted waste generation and that it be reflected separately. Recycled waste should be treated as zero waste generated while accounting for the negative impacts due to the energy use and the processes needed to recycle, recover, or reuse the waste.

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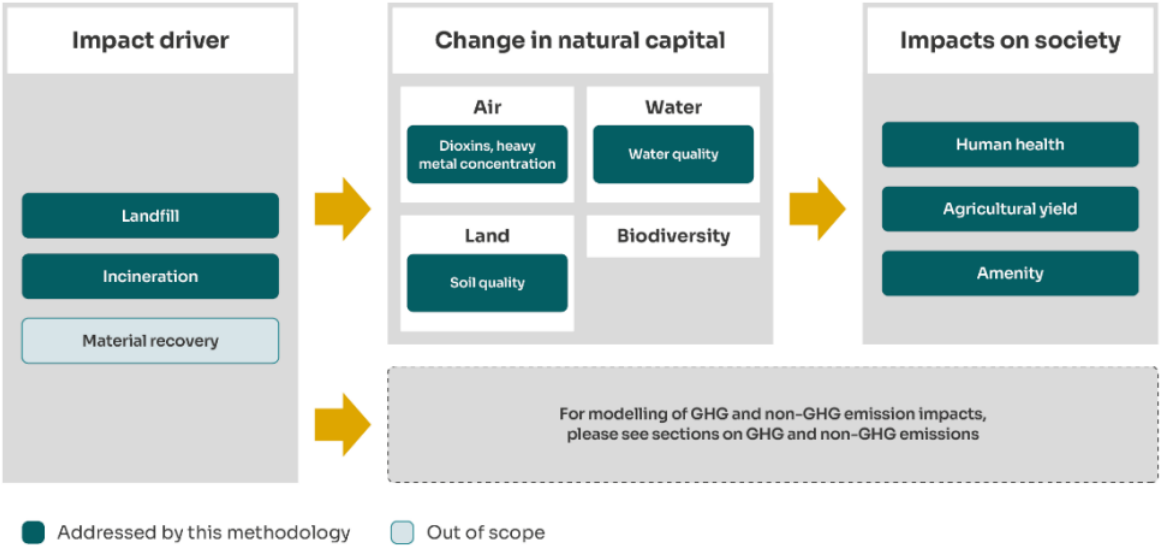
(NCMA methodology, page 46)



[Source: Transparent]

3.3.4.2 Data Sources

- GHG & non-GHG air emissions: quantification, e.g. based on Intergovernmental Panel on Climate Change Waste Model IPCC 2000.
- IPCC National Greenhouse Gas Inventories Programme, "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter - 5 Waste", Institute for Global Environmental Strategies, Japan, 2000.

3.3.4.3 Calculation Logic

Monetary impact = Quantified solid waste activity data * value factor

Activity Data (NCMA methodology, page 47):

- Mass of waste disposed to landfill or marine dump sizes (kg)
- Mass of waste incinerated (with/without energy recovery) (kg)
- Mass of waste material recovered (kg)

Measured waste should include information on composition: "… composition, including organic content, and classify waste as hazardous and non-hazardous according to regulatory classifications and thresholds. To perform the next steps, you will need to collect further information on the context in which the waste is disposed and the type of stringency with which waste management is enforced (e.g. location, weather conditions)." (NCMA methodology, page 47)

Value Factor

The value factor should include:

- Components included
  - GHG
  - Non-GHG air emission impacts
  - Human health
  - Agricultural yield

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    - Amenity
- Modelling of changes in natural capital
    - GHG & non-GHG air emissions: e.g. based on the Intergovernmental Panel on Climate Change Waste Model IPCC 2000. The following steps to be modelled and valued as explained in GHG / non-GHG air emission methodology.
    - Impacts on society due to leachate released from waste disposed to landfill and disamenity from waste incinerated or disposed to landfill. Modelled as follows:
        - Landfill (managed): changes in soil, water quality, odour, noise, visual amenity
          → Modelling of leachate accounting for hazardous / non-hazardous waste type, leachate (e.g. impermeable liner, distance to waterways), likelihood that it impacts society (e.g. proximity to sensitive ecosystems)
        - Incineration: changes in dioxin and heavy metal concentrations in air, odour, noise, visual amenity
          → Modelling of dioxin and heavy metal concentrations based on incineration emission factors
        - Landfill and incineration: disamenity impacts should be directly valued in monetary terms without the need for a quantitative physical impact metric
- Valuing impacts on society in two steps
    - GHG & non-GHG air emissions (as described in respective methodology)
    - Quantify impacts on society
        - Human health: dose-response function
        - Agricultural yield: source-pathway-receptor relationships to assess the likelihood and severity of agricultural impacts from leachates from landfills
        - Amenity: recommendation to value directly in monetary terms without the need for a quantitative physical impact metric
    - Value impacts in monetary terms
        - Human health: stated or revealed preference approaches
        - Agricultural yield: market prices, e.g. clean-up costs
        - Amenity: stated or revealed preference approaches, e.g. hedonic pricing

3.3.5 WifOR Institute (Environmental Prices)

3.3.5.1 Activity Data Source

EXIOBASE HYBRID (Merciai and Schmidt 2018)

3.3.5.2 Subcategories

Hazardous waste, non-hazardous waste

3.3.5.3 Formula

- Simple multiplicative: Monetized Impact = Sum of activity data (per sub indicator and specification) x value factor
- Country/Sector-specific

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3.3.5.4 Impact Pathway

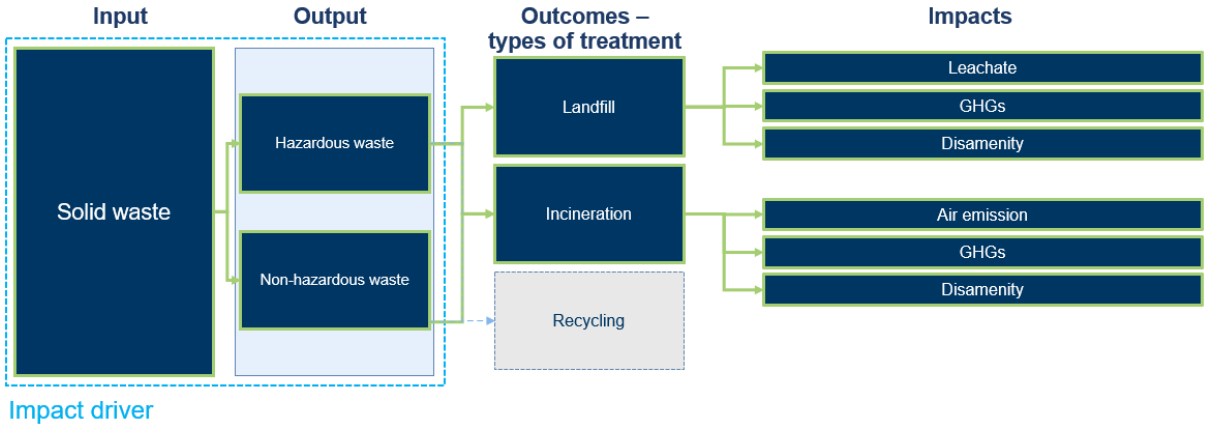

Figure: Impact Pathway of waste (source: WifOR Institute illustration)

[Source: Waste / WifOR Institute]

3.3.5.5 Valuation Method (hui, gdp loss, …)

1. GHG and Air Emissions → Health
2. Disamenity → Welfare Loss (willingness-to-pay via hedonic pricing method)
3. Leachate → Clean-up-costs

3.3.5.6 Sources of Valuation Data

- EXIOPOL (2009)
- PwC (2015)

3.3.5.7 Geographical Differences

- By population density using World Bank data.

3.3.5.8 Transfer Mechanism

Weighted by population density.

3.3.5.9 Waste Specific

Specifications: disposed (landfill), disposed (incinerated), recovered (recycling or downcycling).

3.3.5.10 Global Damage

USD 7.1 Trillion (2020)

3.3.5.11 Environmental Prices

WifOR Institute: https://www.wifor.com/en/impact-valuation-factors/

3.3.6 GIST Impact

3.3.6.1 Evaluation Framework and Methodology

The valuation framework used in the present work is shown below.

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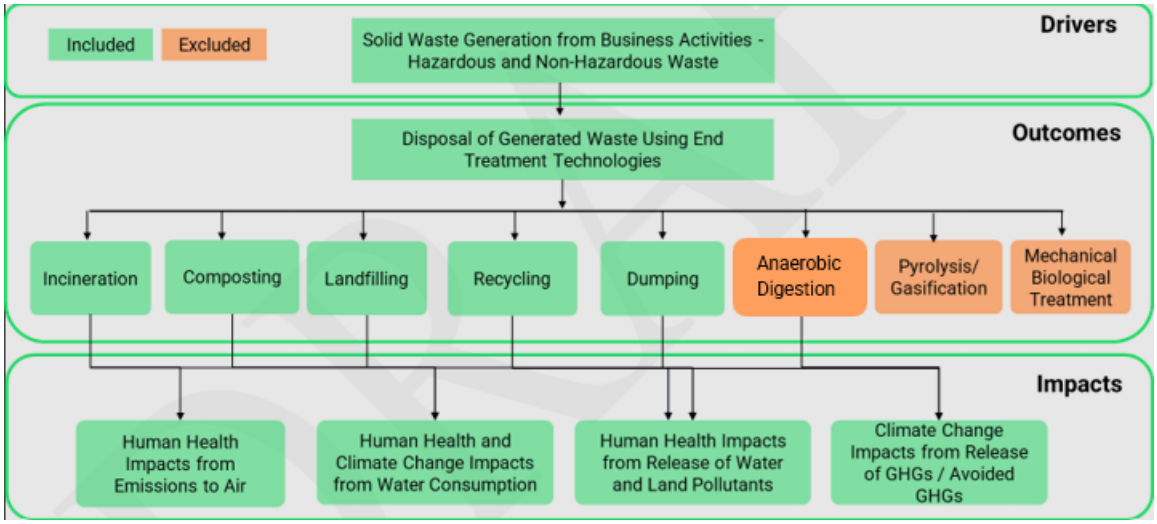

[Source: Waste / GIST Impact]

Multiple business activities can be “drivers” of hazardous and non-hazardous waste generation.

End treatment technology interventions like incineration, landfilling, composting, anaerobic digestion, pyrolysis etc. are used for disposal of generated waste which are considered “outcomes”.

Most of these technological interventions lead to “impacts” on the environment, which are generated at the collection, transport, and treatment stages and depend upon the composition of the waste and technology selected. The impacts from one or other drivers include GHG emissions, release of air pollutants, release of water and land pollutants, etc. Emissions into the air, mainly from the combustion of waste and landfills, result in health impacts to the surrounding population from inhalation of various air pollutants.

3.3.6.2 Calculation Logic

Externalities related to waste treatment and disposal are calculated for the emissions/resource consumption during treatment and disposal. Impacts arising from air pollutants, GHG emissions, water consumption, and water and land pollutant emissions during waste treatment and disposal are estimated using KPI-specific methodologies. Impacts considered in various disposal means are as documented below.

- **Emission from Incineration**: The combustion of waste in incinerators results in air pollution, GHG emission and water and land pollutants. The heat generated in incinerators can be recovered for electricity generation. Generally, hazardous waste and biomedical waste are treated in incinerators.
- **Emissions from Landfill**: The waste disposal sites are scientifically designed. Sometimes these sites are not properly designed and results in various emission like air pollutant, GHG’s into the air, leaching of pollutants into the soil and finally to the ground water.
- **Emissions from Composting**: Composting of biodegradable waste like food waste, green waste, branches, and yard or garden waste results in the emission of GHG, which results in various impacts like climate change, ocean acidification, health impacts, etc. However, the carbon recovery from composted waste which would have

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otherwise contributed to GHG emissions and carbon savings due to reduced fertiliser demand accounts for avoided emissions.

- **Emissions from Recycling**: Recycling of materials requires energy input but also results in net avoided impacts due to material recovery and energy savings when compared to production of virgin materials including ore extraction.
- **Emissions from Dumping**: Transportation of waste to the dumping site results in impacts from the release of greenhouse gases and air pollution through the burning of fuel. The valuation of transportation impacts is only covered within the dumping and the rest of the treatment systems already include the remaining impacts.

Impact due to waste generation (USD) = Waste quantity disposed by specific disposal method (tonne)* Value factor for particular disposal method (USD/tonne)

3.3.6.3 Data Sources[8]

- Defra (2004) Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes, March 2004. Available at: http://archive.defra.gov.uk/environment/waste/statistics/documents/health-report.pdf
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- LCA databases

3.3.7 VBA

3.3.7.1 Introduction

Corporate activities in all sectors generate solid waste. The disposal of this solid waste can lead to a range of environmental outcomes that adversely affect human well-being, thereby carrying a societal cost. In this paper, we set out a methodology for identifying, quantifying, and valuing that cost in monetary terms. Most material impacts associated with solid waste are covered in this paper, but two classes of related impacts are partially addressed in other papers. In terms of GHG and air-pollution outcomes, waste disposal is an intermediate step. The approaches to quantifying these outcomes as they relate to waste disposal are defined in this methodology. We believe that this increases the accuracy of societal impact estimates and increases the applicability of the results to companies, which tend to treat waste as a discrete environmental issue. This comprehensive approach adds some complexity but is

[8] The reference list is intentionally limited for confidentiality reasons.

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important because GHGs and air pollution make up a significant proportion of the societal cost of a tonne of waste. Importantly, this methodology is concerned with the impacts of waste disposal. It does not attempt to evaluate the costs associated with design or production inefficiencies that may be indicated by the presence of waste. For solid waste disposal, the type of waste and the method of its disposal are key factors that dictate the environmental outcomes. Common types of waste, disposal approaches, and environmental outcomes are discussed below. The impact pathway describes how these factors influence environmental outcomes and, subsequently, affect people.

Solid waste is typically classified as either hazardous or non-hazardous. Hazardous waste is defined as waste that is particularly dangerous or damaging to the environment or human health, usually through inclusion on official lists by regulators. Non-hazardous waste covers all types of waste not classified as hazardous. In other contexts, it may cover all waste not otherwise classified. The type of waste influences the type and extent of impacts associated with different disposal techniques.

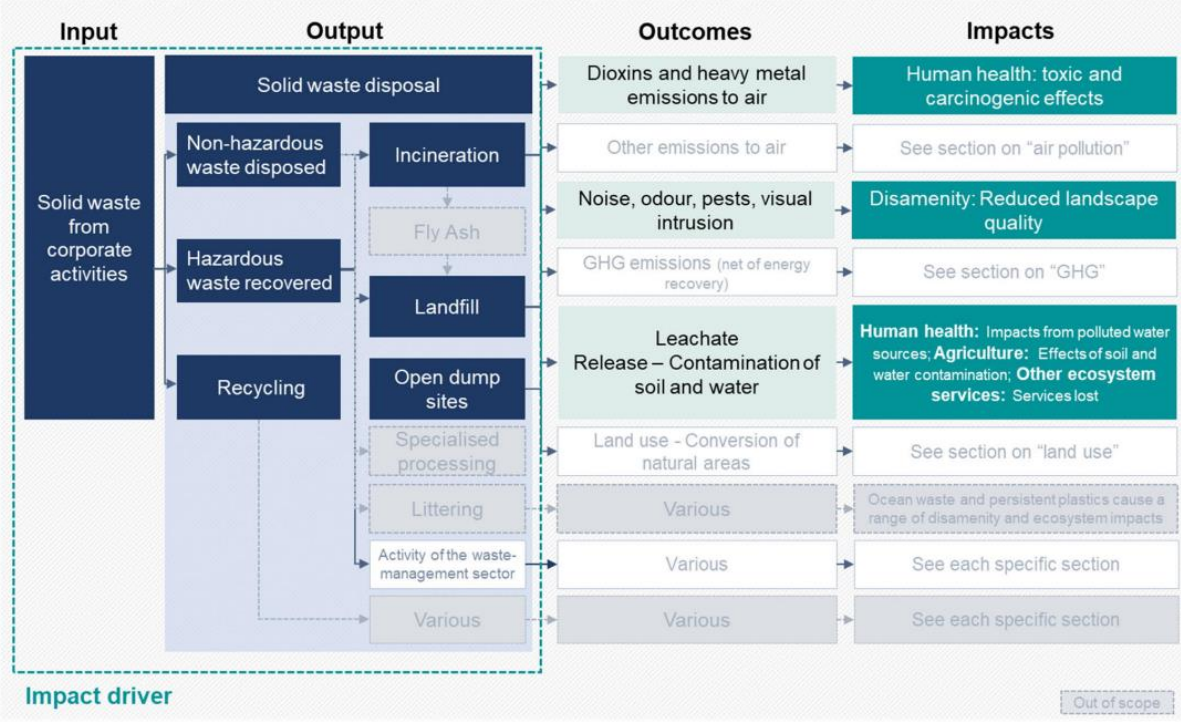

Figure 13: Simplified impact pathway waste

[Source: Waste / VBA]

3.3.7.2 Data Sources

- GHG emissions: (IPCC (2000a): CH4 Emissions from Solid Waste Disposal: Background Paper. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. IPCC (2000b): Emissions from Waste Incineration: Background Paper. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories; HM Treasury (2018): The Green Book's Social Discount Rate; Willumsen, S., (2002) in Terraza, H. (2004): World Bank LFG activities in the LAC region's number of LFGTE plants worldwide and tonnage of waste processed by plants in each country; the

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International Energy Agency provides the CO2 intensities of national and regional electricity grids around the world.

- Disamenity: A review of the literature identified six such functions from primary studies of landfill sites in the UK, Israel, South Africa, Uganda and Nigeria (Cambridge Econometrics et al., 2003; Eshet et al. 2007; Du Preez & Lottering, 2009; Nahman, 2011; Isoto & Bashaasha, 2011; Akinjare et al., 2011).
- Leachate: HARAS leachate risk model (Singh et al., 2012).
- Air pollution: VBA Air pollution methodology paper, OECD VSL: OECD (2012): Mortality Risk Valuation in Environment, Health and Transport Policies. Paris: OECD Publishing.

3.3.7.3 Calculation Logic

Monetized impact = Accumulated by country, waste treatment type and waste category (activity data in kilograms * value factor per kg of waste)

Note: The formula for GHG (it is based on estimated emissions) and leachate (it directly quantifies the total social cost) differs from this general approach.

The activity data can be derived from direct information or estimations – especially for the value chain – and should be differentiated by waste treatment type (incineration, landfill) and waste category (hazardous waste, non-hazardous waste).

3.3.7.4 Value Factors

The value factors should be specific to waste treatment types, categories and locations, considering the different impacts produce by solid waste:

- GHG emissions from landfill and incineration: The societal impacts associated with those outcomes are evaluated by applying the SCC to the net GHG emissions generated. The present value of the associated impacts is then calculated by applying a social discount rate of 3.5%.

Potential emissions (simplified) = GHG emissions for each tonne of waste * tonnes of waste

- Waste sent to landfill: GHG emissions (principally CH4) from each tonne of waste sent to a landfill are estimated over 90 years using the Intergovernmental Panel on Climate Change (IPCC, 2000a) Waste Model based on the mass and type of waste and the conditions of the landfill. Mendes, M. R., Aramaki, T., & Hanaki, K. (2004): Comparison of the environmental impact of incineration and landfilling in Sao Paulo City as determined by LCA. Resources Conservation & Recycling, 41 47–63.
- Waste sent to incineration: CO2 emissions per tonne of waste are estimated by applying the carbon intensity of the incineration process to the volume of waste sent to incineration. Table 25 presents the variables influencing CO2 emission per tonne of incinerated waste (IPCC, 2000c).

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Table 25: Variables influencing CO_2 emission per tonne of incinerated waste

Variable	Default values: Non-hazardous	Default values: Hazardous
The carbon content of wet waste	40%	50%
Fossil carbon fraction	40% (of total carbon)	90% (of total carbon)
Efficiency of combustion (depends on incinerator type)	95%	99.5%
Tonnes fossil CO_2 per tonne incinerated waste[15]	**0.557**	**1.642**

- Calculating net emissions after adjusting for net recovery: When landfill gas or incinerated waste is used to generate electricity, there is no need for that electricity to be generated by other means. Therefore, the potential emissions associated with that generation are avoided. A similar methodology is used to estimate the avoided emissions from landfill and incineration. The only divergence is the variable used for the energy potential of waste.

  Avoided emissions (simplified) = Tonne of waste * energy potential of waste (kwh/tn) * grid carbon intensity (tCO2 equivalents/kWh)

  The following parameters can be introduced in the model in the absence of more exact ones:

  - Landfill gas to energy

    Table 26: Variables required to estimate GHG emissions per tonne waste avoided through LFGTE

Variable	Explanation
Tonnes of waste sent to LFGTE site	The World Bank estimates the number of LFGTE plants worldwide (Willumsen, 2004) and reports the tonnage of waste processed by plants in each country. More recent national industry statistics should be sought wherever possible.
Energy potential of waste, kWh/tonne of waste	The energy potential of waste depends on the type of waste and the technology used to collect and convert it. For example, Mendes et al. (2004) calculate a value of 166 kWh/tonne, assuming that 50% of the CH_4 is captured and that it is burnt in a gas engine with 30% energy-recovery efficiency.[16] Site-specific values should be sought wherever possible.
Carbon intensity of national or local electricity grid, CO_2e/kWh	The International Energy Agency provides the CO_2 intensities of national and regional electricity grids around the world.

  - Incineration waste to energy

Type of energy recovery in facility	Energy potential (kWh/tonne waste)
Electricity only (assume 25% recovery rate)	625
Electricity plus heat (assume 83% recovery rate)	2,075

- **Disamenity**: Environmental outcomes (i.e. increases in odour, noise and changes to visual amenities) and societal impacts are evaluated in one step using a hedonic pricing model. This model uses price information from a surrogate market (i.e. the housing market) to measure the implicit value of a non-market benefit or disbenefit (in this case, the disamenity associated with living near a waste management site). We have developed a multivariate hedonic transfer function based on a meta-analysis of hedonic pricing studies in the academic literature. This function is used to estimate the WTP (to avoid disamenity) based on local average house prices, household density and the housing market discount rate.

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The social cost of disamenity (simplified) = WTP per tonne of waste * tonnes of waste

- **Leachate Release:** The likelihood and severity of potential environmental outcomes associated with leachate from landfills are estimated on a scale of 1 to 1,000 using the HARAS leachate risk model (Singh et al., 2012). This model is based on source-pathway-receptor relationships. The HARAS leachate risk model is peer reviewed and widely used to evaluate the leachate risk. Societal impacts are assessed by first identifying a worst-case estimate of leachate clean-up costs as a proxy for the worst-case societal impact and subsequently adjusting that estimate by multiplying it by the HARAS risk score (expressed as a fraction between 0 and 1). Adjustments should be made for local PPP.

  Societal cost of leachate (simplified) = Worst-case leachate clean-up cost × adjusted HARAS risk score (= Proportion of hazardous waste × climatic conditions × presence of liner × geology and soil permeability × population density)

- **Air Pollution**: Dioxin and heavy metal emissions are calculated using incineration-emission factors. We estimate the changes in cancer incidence and intelligence quotient (IQ) points by multiplying emissions by linear dose-response functions. Dose-response functions are based on epidemiological studies at given ambient concentrations and emission levels. The air pollutants traditionally considered are:
  - NOx
  - SOx
  - NH3
  - PM2.5
  - PM10
  - VOCs

  See “Air Pollution” for more information. The welfare values associated with the health, agriculture, and visibility impacts of air pollution are considered in the VBA air pollution methodology section.

  The social cost of air pollution (IQ points lost and cancer, simplified) = Tonne of waste * (IQ points loss per tonne of waste * WTP to avoid loss of IQ points + increased incidence in cancer per tonne of waste * social cost of cancer (based on VSL).

3.3.8 EPS, Chalmers (Environmental Prices)

Waste impacts are typically assessed based on the substances present, except for littering, which poses a common environmental threat regardless of composition. Litter, including items like cigarette butts, plastics, and food wrappers, is a significant concern on land and in marine environments. Studies show that much of the litter found in oceans originates from land-based sources, particularly public littering.

Littering on land:	A best estimate is 5 $/kg.
Littering in the sea:	A best estimate is 4.25 $/kg.

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Sources

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3.3.9 Analysis

The Transparent waste approach focuses on modelling outcomes based on waste disposal types like landfill and incineration. It considers impacts on human health, agricultural yield, and amenity and utilises the IPCC 2000 framework for dose-response functions. It values disamenity directly in monetary terms without detailed outcome modelling.

VBA waste approach considers both hazardous and non-hazardous waste. It monetizes impacts using the sum of activity data and value factor per kilogram of waste. It models the impacts on human health, disamenity, and GHG emissions using various methods like dispersion models and LCA-based approaches.

GIST Impact approach analyses impacts across different waste disposal methods, including incineration, landfilling, and material recovery. It monetizes impacts based on waste quantity and value factor for each disposal method and considers GHG emissions, air pollution, water consumption, and land pollution. Furthermore, it incorporates country-specific data and adjusts for population density.

WifOR Institute waste approach utilises life cycle assessment reports and economic data sources like EXIOPOL and PwC. It considers impacts on human health, GHG emissions, disamenity, and leachate. The monetization modelling of impacts is based on social costs of carbon and other damage costs which are adjusted for population density and provides country-specific assessments.

Consideration of Multiple Waste Disposal Methods: All methodologies analyse the impact of various waste disposal methods, such as landfilling, incineration, and material recovery.

Monetization of Impacts: Each methodology assigns monetary value to the impacts of waste disposal. This is achieved by monetizing the impacts based on factors such as waste quantity and specific value factors for each disposal method.

Adjustment for Geographic and Population Factors: Some methodologies, such as GIST Impact and WifOR Institute, incorporate country-specific data and adjust for population density. This ensures that the assessments account for geographical variations and population density, providing more bespoke and context-specific insights into the impacts of waste disposal.

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Limited Consideration of Social and Economic Impacts: While all methodologies monetize the impacts of waste disposal, they primarily focus on environmental and health impacts. There is a gap in considering broader social and economic impacts such as employment generation, community well-being, and economic opportunities associated with different waste management practices.

Insufficient Incorporation of Future Trends and Scenarios: The methodologies may lack provisions for considering future trends, scenarios, and uncertainties such as technological advancements, changes in waste composition, and population growth.

Inadequate Transparency and Accessibility of Data: While methodologies utilise various data sources and models, there may be challenges related to the transparency and accessibility of data, especially country-specific data.

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3.4 Water Consumption

3.4.1 Challenge

Water consumption is the measure of water withdrawn from a source and not returned, encompassing water used in products or rendered unsuitable for return due to contamination. This unavailability to other stakeholders holds significant societal implications, affecting human health, agricultural yields, and resource sustainability. The consequences include increased reliance on unclean water sources, higher disease incidence, reduced agricultural productivity leading to malnutrition, and environmental resource depletion. The methodology documents provide detailed insights into these dynamics, shedding light on the societal impact of corporate water consumption.

SDG 6 addresses this challenge with targeting increasing water use efficiency and ensuring sustainable freshwater supply to reduce water scarcity (Target 6.4) and implementing integrated water resources management to address water scarcity and conflicts (Target 6.5). SDG 9 aims to enhance skills for employment and increase ICT access (Target 9.1 and 9.3), while SDG 11 focuses on reducing cities' environmental impact and promoting sustainable urban management (Target 11.6 and 11.7). SDG 12 advocates for responsible consumption and production, including implementing the polluter-pays principle and sustainable consumption frameworks (Target 12.2 and 12.4). These principles collectively address the efficient use and management of water resources for sustainable development.

A range of leading international organisations, including the World Water Council (WWC), World Bank, World Economic Forum (WEF), International Monetary Fund (IMF), United Nations Development Programme (UNDP), and Water Resources Institute (WRI), have contributed valuable insights into global water consumption trends and challenges. The World Water Development Report 2023 by the WWC emphasises the importance of water security for sustainable development. The World Bank provides data on freshwater withdrawal, highlighting key indicators of water consumption worldwide. The Global Risks Report 2023 by the WEF focuses on water security as a critical global risk. The IMF's report on navigating the water crisis offers a macroeconomic perspective on water-related challenges. UNDP's Human Development Report 2022 explores the intersection of water and employment, highlighting the need for dignified water access. Finally, WRI's Aqueduct Water Risk Atlas 2023 and Aqueduct Country Rankings provide comprehensive assessments of water risk and consumption patterns globally. Together, these documents underscore the urgent need for coordinated action to ensure sustainable water management and equitable access to clean water resources worldwide.

3.4.2 Activity Data

To quantify the impact driver of water consumption, the measurement process involves assessing the amount of (blue) water withdrawn and not returned to the cycle, measured in cubic meters (m^3) per country. This includes water incorporated into products or rendered unsuitable for return due to contamination.

3.4.3 Databases

The UNEP data program for water is called the Global Environment Monitoring System/Water Programme (GEMS/Water).

Water (UNEP):	https://gemstat.org/
UNEP/GRID-Arendal Data Portal:	https://www.unep.org/resources/publication/un-environments-freshwater-strategy-2017-2021

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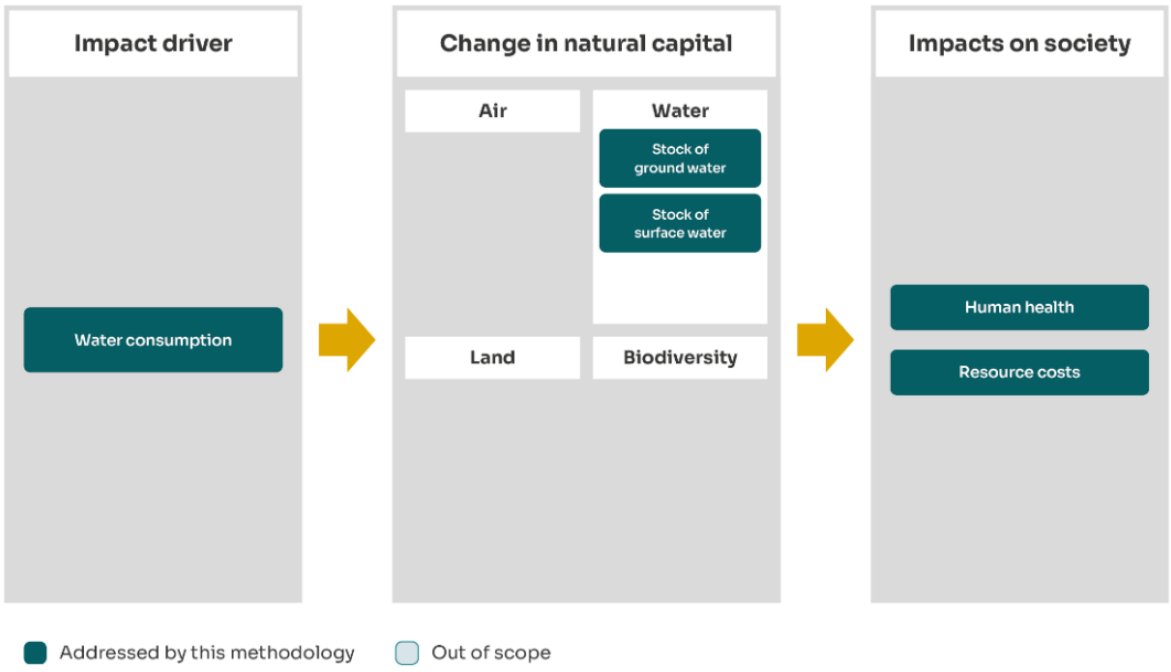
Food and Agriculture Organization of the United Nations (FAO) Water Data Portal: https://www.fao.org/water/en/

3.4.4 Transparent

3.4.4.1 Introduction

Water plays a central role in ecosystems: without water, almost no life on earth could survive. Freshwater, in particular, is an essential resource for human health, agriculture, and nature, but its supply is limited in some regions of the world and at certain times of the year (Mekonnen, Hoekstra 2016). This has led to significant global concern regarding the state of freshwater resources, which are subject to significant pressure from increasing water demand, with pressures projected to be exacerbated by climate change. Water depletion affects humans and ecosystems. The impact of water depletion on humans depends on the local demand structure (domestic, industrial, and agricultural, as well as environmental). In extreme cases, water scarcity can lead to compensation processes: Where domestic access to water is limited, people may resort to lower-quality water sources, leading to sanitation and hygiene issues (water access, sanitation, and hygiene – WASH), which can have an impact on human health. Reducing the use of lower-quality water sources is currently a priority of governments in collaboration with intergovernmental organisations. Water scarcity (most likely) may also lead communities, through local governments, to invest in (costly) water supply infrastructure, including water treatment or desalination plants, which may drive up the cost of supply and subsidisation (World Bank 2016). As well as having immediate social and economic impacts, unmet water demand within ecosystems can lead to a loss of habitat, with further impacts on biodiversity, loss of ecosystem services such as freshwater fisheries, and further impacts to social and produced capitals.

(NCMA methodology, page 32)



[Source: Water Consumption / Transparent]

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- M. M. Mekonnen and A. Y. Hoekstra, “Four billion people facing severe water scarcity”, Science Advances, vol. 2, no. 2, 2016.
- World Bank, “High and Dry: Climate Change, Water, and the Economy”, Washington DC, 2016.

3.4.4.2 Data Sources

No explicit data sources are listed for modelling of value factors. The following list of data sources is listed if companies have no data available or need more information on water scarcity (NCMA General guidance, page 31)

- Aqueduct
- AQUASTAT by FAO.
- AWARE (Available Water Remaining).
- CropWat and CLIMWAT by FAO, (focus on agricultural water consumption).
- EEIO modelling such as Exiobase.
- India water tool.
- LCA models and databases such as the ReCiPe model and Ecoinvent.
- Water Footprint Network.
- WWF Risk Filter Suite.

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3.4.4.3 Calculation Logic

Formula

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Monetized impact = Water consumption * value factor

Activity Data

- Volume (m^3) of water consumption.
    - Consumed water = input water (withdrawn) – output water (returned)
- Optional: volume of water withdrawn
- Additional information is required on the context including geography, season/time of year, and information on scarcity or other demands.
- The degree of regional specificity should be in line with the accounting goals (country-level / watershed / sub-watershed)

Value Factor

The value factor should include:

- Components included
    - Human health
    - Resource costs
- Modelling of changes in natural capital

Based on the modelling approach, e.g. hydrological models / pre-existing model

- Valuing impacts on society in two steps (taken from page 36)
    - Quantify impacts on society
        - Human health:
          "The linkage between water scarcity and human health is an extreme case and depends on a society's capability to adapt economically. In the extreme case, water consumption can lead to a lack of water for domestic users, the use of alternative (lower quality) water supply and the spread of waterborne diseases (worst case scenario). This impact is likely to occur in locations with the absence of basic water management practices in place.

          It is recommended that you estimate impacts on human health via a measure of water stress and DALYs (per cubic meters). To estimate impacts in terms of DALYs, you can either use characterization factors from life cycle assessment models, or econometric data, where the level of granularity is fit for purpose."

        - Resource costs: "No need to model explicitly. Implicitly covered by monetary valuation technique."
    - Value impacts in monetary terms
        - Human health: stated or revealed preference approaches
        - Resource costs: cost-based approaches (e.g. projected costs of supply (based on market prices), replacement costs, opportunity costs, subsidy costs of water)
- Assumptions: Apply social discount rate for future costs (e.g. due to resource depletion)

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3.4.5 WifOR Institute (Environmental Prices)

3.4.5.1 Introduction

Global water systems play a critical role in sustaining humanity and ecosystems, yet escalating water consumption rates and disproportionate withdrawals are intensifying stress on these vital systems. Predictions suggest that, by 2025, two-thirds of the world's population could face water shortages due to inadequate supply, exposing communities to waterborne diseases like cholera and typhoid fever while also leading to agricultural losses due to insufficient irrigation. The impact pathway of water consumption illustrates how commercial water use can trigger domestic water scarcity, heightening the risk of contaminated water exposure and diminishing groundwater reserves. This scarcity not only threatens human health, by potentially substituting clean water sources with polluted alternatives, but also directly impacts agricultural yields due to depleted groundwater reserves, underscoring the challenges faced in sustaining farming and food production.

3.4.5.2 Activity Data Source

- EXIOBASE 3.8.1

3.4.5.3 Subcategories

None

3.4.5.4 Formula

Simple multiplicative: Monetized impact = Activity data x value factor

3.4.5.5 Impact Pathway

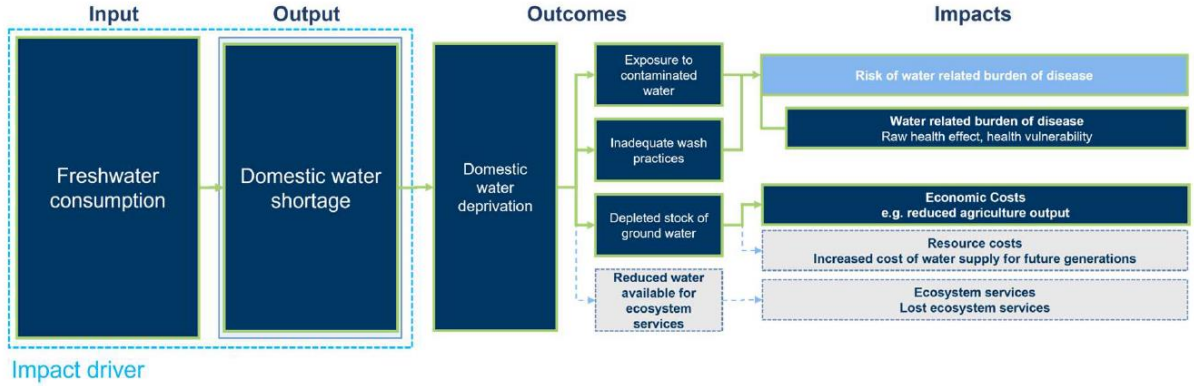

Figure 6: Impact Pathway of water consumption (source: own illustration)

[Source: Water Consumption / WifOR Institute]

3.4.5.6 Valuation Method (hui, GDP loss, …)

1. Economic costs (e.g. reduced agricultural output)
2. Damage to human health → DALY

3.4.5.7 Geographical Differences

Level of water stress in a region or country

3.4.5.8 Transfer Mechanism

Global water shadow price from Lightart and Harmelen (2019) is used as a baseline. Country-specific water scarcity factors (from the AWARE model) reflect differences in local water availability.

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Local valuation coefficients for human health impacts are used from "Freshwater consumption and domestic water deprivation in LCIA: revisiting the characterization of human health impact" published in The International Journal of Life Cycle Assessment.

3.4.5.9 Water Consumption-specific

None

3.4.5.10 Global Damage

USD 48 Trillion (2020)

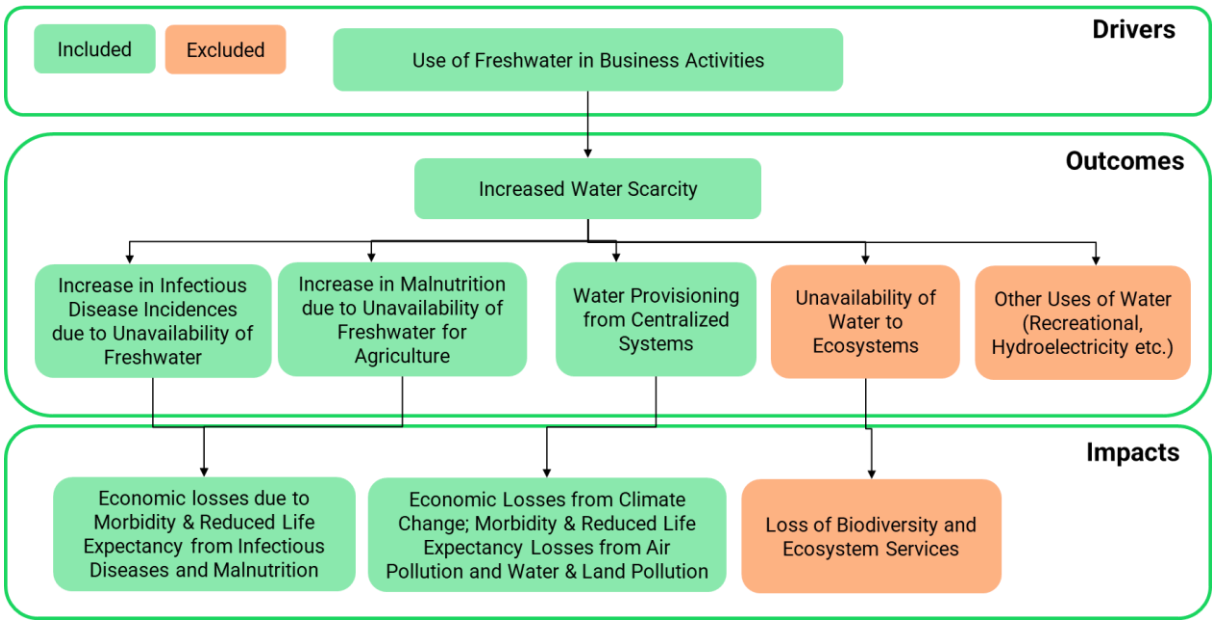
3.4.5.11 Environmental Prices

WifOR Institute: https://www.wifor.com/en/impact-valuation-factors/

3.4.6 GIST Impact

3.4.6.1 Evaluation framework and methodology

An outline of the evaluation framework adopted for evaluating impacts from water consumption is shown in the figure below:



[Source: Water Consumption / GIST Impact]

GIST Impact's methodology scope and boundary include water consumption due to the direct operations of an organisation across all the business divisions/activities/units/products and services at all geographical locations.

The valuation methodology adopted for assessing the impacts of water consumption incorporates three mutually exclusive pathways for calculating each component of impacts.

- Water Provisioning - The first component accounts for the impact of energy consumption for water provisioning due to increased demand versus supply gap leading to the transfer of water over longer distances and thus higher energy requirements (water being transferred from regions with lower water scarcity to areas with higher scarcity levels). The provisioning requirement is calculated based on the baseline water stress (differences in the water withdrawal vs availability) at a 0.5-degree grid (Alcamo et al., 2003; Gassert et al, 2014; Huang et al., 2018). An optimisation model is used to optimise the water import distance and other parameters

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in the model calculations. The impact cost associated with the transport of water (through energy requirement and associated external cost) from the optimised grid (distance) is calculated as the next step (AWWA Research Foundation, 2007).

- Malnutrition - The second component considers the impact on human health via an increase in malnutrition (in terms of DALYs) based on the methodology outlined in Pfister et al. (2009), Bayart et al. (2010) and Obsborn et. al. (2020).
- Infectious disease - The third component incorporates an increase in the incidence of infectious diseases from the consumption of unsafe water due to water scarcity, as elucidated by Motoshita et al. (2011).

3.4.6.2 Calculation Logic

Overall water valuation coefficient (USD/ m^3) at a particular location = Impact due to water provisioning + Impact due to malnutrition + Impact due to infectious disease

Impact due to water consumption (USD) = Water volume (m^3) consumed / withdrawal at location* Overall value factor (USD/ m^3) at that location

3.4.6.3 Data Sources[9]

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3.4.7 VBA

3.4.7.1 Introduction

All corporate activity directly and indirectly relies on water availability. Water consumption is defined as the volume of water that is evaporated, incorporated into a product or polluted to such an extent that it is unusable (Mekonnen & Hoekstra, 2011). Water consumption reduces

[9] The reference list is intentionally limited for confidentiality reasons.

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the amount of water available for other uses. Depending on the level of competition and the socioeconomic context, this can have consequences for the environment and people. This methodology focuses on valuing the impacts of corporate water consumption. Water is a fundamental requirement for life, and the right to water is a basic human right. Other goods or services cannot serve as substitutes for the water required to sustain life. Consequently, its worth is infinite and beyond the boundaries of economics. However, after basic needs are met, the marginal value of water can be quantified. For example, we can distinguish between the value of water in locations where (and, at times, when) there is competition among users for water and those where there is a plentiful supply. The difference in impacts associated with water consumption in these locations provides useful information for companies seeking to minimise their negative impacts and their exposure to water risks in their value chain. As demonstrated in the following discussion, water availability is typically not the sole or most significant driver of impacts of corporate water consumption. Areas in which the water-consumption impacts are the highest are often characterised by poor sanitation, inadequate water-supply infrastructure, basic public health care, poverty and high malnutrition. Responsibility for the impacts of water consumption is shared by corporate users, other water consumers and, most importantly, local and national governments. The methodology presented here estimates the impacts of corporate water consumption, taking the local context as a given, and it does not consider the level of responsibility for the prevailing socioeconomic context.

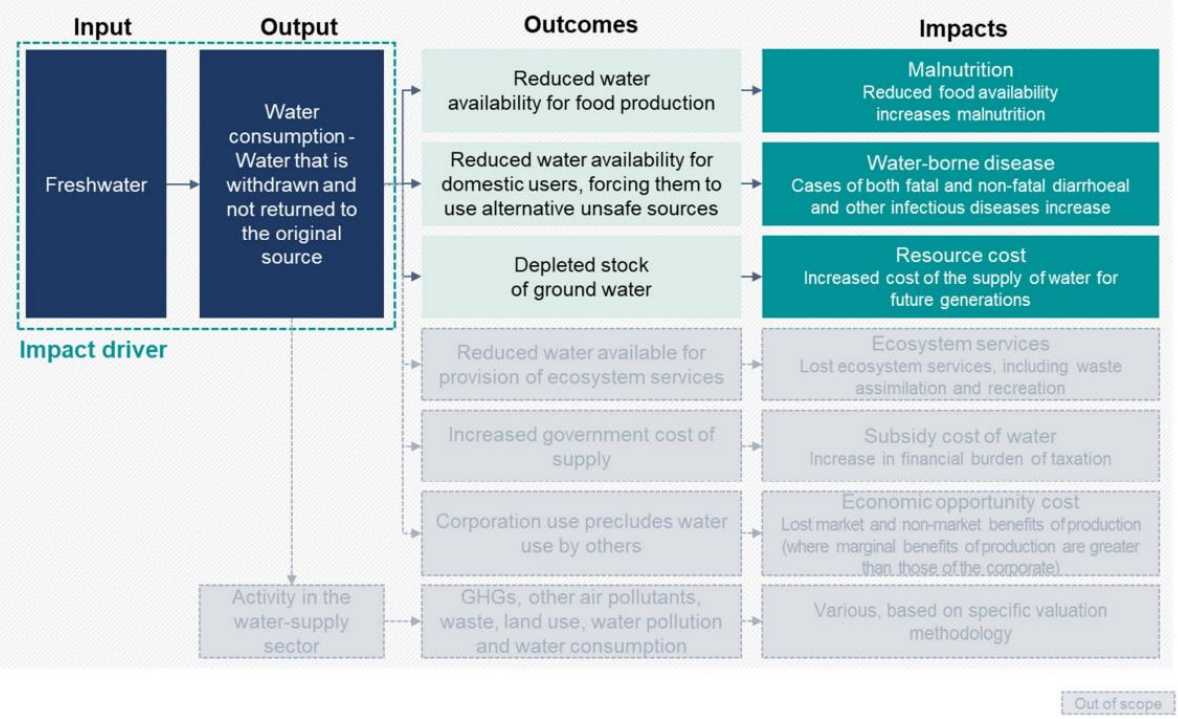

Figure 3: Simplified impact pathway water consumption

(i) Impact drivers: The volume and location of corporate water consumption
(ii) Reduced availability of water for other users, depletion of groundwater reserves at an unsustainable rate and the impact of the water supply sector.
(iii) Human health impacts, future costs to society of alternative water sources and impacts via GHGs, air pollution and waste from the water supply sector.

[Source: Water Consumption / VBA]

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3.4.7.2 Data Sources

Some data sources are used to calculate the following impacts:

- FAO (2012): AQUASTAT database, Food and Agriculture Organisation of the United Nations (FAO). These databases are comprehensive repositories of water-related information, including water use statistics, availability, and water-related diseases. UN-Water and FAO's AquaStat provide global data on water resources, water use, agricultural water management, and related issues, allowing for trend analysis and research on water-borne diseases. It is used for the calculation of the groundwater valuation.
- OECD VSL: OECD (2012): Mortality Risk Valuation in Environment, Health and Transport Policies. Paris: OECD Publishing.
- Pfister, S., Koehler, A., Hellweg, S., (2009): Assessing the Environmental Impacts of Freshwater Consumption in LCA. Environmental Science & Technology 43 (11), 4098-4104 (Water Stress index applied to calculate the amount of water that the agricultural sector is deprived of when water is consumed by a different user.

3.4.7.3 Calculation Logic

Monetized impact = Sum by country (water consumption in m_3 by country * value factor in-country)

Where the activity water consumed is either directly measured or estimated, especially in the case of the value chain (questionnaires, EEIO, LCA, etc.) and the value factor takes into account the different impacts caused by water consumed:

- **Malnutrition**: The number of cases of malnutrition is estimated in DALYs using a regression of country-level malnutrition cases and DALYs associated with malnutrition per m3 of consumed water (societal cost monetized considering the WTP for a DALY). A monetary value for each DALY is calculated based on the value of a statistical life (VSL) and the lost DALYs associated with the VSL estimate to produce an estimate of the welfare impacts.

  VF malnutrition (simplified) = HHF * value of a DALY

$$HHF_i\left(\frac{DALYs}{m^3{}_{consumed}}\right) = WDF_i\left(\frac{m^3{}_{deprived}}{m^3{}_{consumed}}\right) \times EF_i\left(\frac{capita.year}{m^3{}_{deprived}}\right) \times DF_{malnutrition}\left(\frac{DALYs}{capita.year}\right)$$

The water deprivation factor (WDF) measures the proportion of water that agriculture loses due to water consumption by other sectors. The WDF for a watershed is calculated by multiplying the water stress index (WSI) by the fraction of water consumed by agriculture in that watershed. The WSI indicates the extent of water consumption that restricts other users' access to freshwater.

The effect factor (EF) measures the number of cases of malnutrition caused by the deprivation of one cubic metre of freshwater.

$$EF_i = WR_{malnutrition}{}^{-1} \times HDF_{malnutrition,i}$$

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Source: Pfister et al. (2009).

- **Infectious Water-borne Diseases**: An econometric approach is taken to assess the influence of corporate water consumption on the prevalence of water-related diseases in different countries (societal cost monetized considering the WTP for a DALY). Quantile regression analysis is used to explain the variation in the observed DALYs per capita rate associated with water-borne infectious diseases.

  VF water-borne diseases (simplified) = DALY lost/m3 consumed * value of a DALY

$$\ln Dalys = \alpha + \beta_1 \ln dww + \beta_2 \ln undernour + \beta_3 \ln healthexp + \beta_4 \ln wsi + \beta_5 \ln govteff$$

where the variables used are: domestic water use (dww), prevalence of undernourishment (undernour), health expenditure (healthexp), government effectiveness (govteff) and water stress level using a water stress index (WSI). The second part of this calculation involves re-predicting the prevalence of disease after including the water used by corporations. We multiply the region's total corporate and industrial water use by the WSI to derive the portion that deprives other users of water. We then reallocate that quantity of water to domestic users in order to hypothesise how much lower DALYs per capita per year would be if that water was available.

- **Groundwater Depletion**: To estimate the societal impact of groundwater depletion, we calculate the replacement cost as a lower-bound estimate of the likely societal impacts of groundwater depletion (cost-based approach). When the ratio is greater than 1 (i.e. groundwater is being depleted faster than it is being replenished), we estimate the societal cost per m3 of corporate water consumption following the steps below:
  - Calculate the percentage reduction in groundwater abstraction required to achieve a sustainable groundwater-scarcity ratio.
  - Multiply the required reduction in groundwater abstraction by the percentage of the national water supply derived from groundwater using the AQUASTAT dataset (FAO, 2012) to estimate the percentage reduction in the national water supply required to achieve a sustainable groundwater-extraction rate.
  - Apply the current cost per m3 of water supply to the percentage as a cost-based approach to estimate how much it would cost today to avoid the unsustainable depletion of groundwater resources. The cost of the water supply for the US is based on data from the International Benchmarking Network and is PPP-adjusted for other countries.
  - The previous step results in an estimate of the cost per m3 of the current supply that would have to be applied to reduce the impact of unsustainable groundwater consumption. This is adjusted by the ratio of water withdrawal (supply) to water consumption, as our valuation methodology values the impact per m3 of water consumed.
  - The impacts are then projected 50 years into the future and discounted to the present day using a 3.5% social discount rate.

VF Groundwater depletion (simplified) = Projected supply costs =

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Cost of m3 of current supply * (percentage reduction in water supply) * (ratio of water withdrawal to consumption) * (1+3.5)^50.

Finally, the values are:

- Transferred to different countries based on PPP.
- Adjusted according to GNI per capita.

Note: The value of a DALY follows the same estimation formula as stated in other impact drivers, including an age-weighting factor:

$$Value\ of\ DALY = \frac{VSL}{Number\ of\ DALYs\ lost}$$

$$X_w = Cx^{-\beta x}$$

where x is the age in years. The suggested coefficients are C= 0.1658 and β = 0.04. This formula is used to calculate the relative weight applied to each of the 78 years of life expectancy associated with the OECD's VSL estimate.

People are willing to pay more to avoid disability today than to avoid it the future. Therefore, a social discount rate of 3% (as per the social discount rates used in the other methodologies) is applied to future years beyond the age of 47. The discounted age weighting is calculated as per the following equation.

$$\frac{\sum_{x=0}^{78} X_{wd}(x)}{\sum_{x=47}^{78} X_{wd}\,(x)}$$

The discounted, age-adjusted proportion of life lost ($PLLwd$) is calculated using the equation age-adjusted years of lost life. This represents the proportion of life lost for a person who is expected to live to 78 but died prematurely at 47.

3.4.8 Analysis

Transparent approach: This method primarily focuses on human health and resource costs. It employs a cost-based valuation technique, considering factors like social discount rates for future costs.

VBA approach: VBA utilises a country-level summation of water consumption multiplied by the value factor specific to each country. It considers impacts such as malnutrition and economic costs, adjusting for factors like purchasing power parity (PPP).

GIST Impact approach: GIST Impact employs a comprehensive model that accounts for various impacts including malnutrition, human health, and economic damage. It uses a hybrid human capital approach for valuation, incorporating dose-response functions. This method is suitable for different impacts and sectors.

WifOR Institute approach: WifOR Institute utilises a straightforward monetization method based on activity data multiplied by the value factor. It considers impacts such as human health, resource costs, and economic costs, applying a valuation technique known as AWARE. This approach is widely applicable, especially with its use of life cycle assessment (LCA)-based methods.

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Consideration of Impacts: Each approach considers multiple dimensions of impact beyond just water consumption itself. Commonly addressed impacts include human health, economic costs, and in some cases, malnutrition and biodiversity.

Data Sources and Models: While the specific data sources and models vary between approaches, all rely on external data sources or models to inform their valuation.

Adjustments and Assumptions: Adjustments and assumptions are made in all approaches to account for factors such as purchasing power parity, future costs, or the absence of country-specific impact data. These adjustments ensure that the valuation reflects real-world conditions as accurately as possible.

Coverage of Impacts: While all approaches consider multiple dimensions of impact, such as human health and economic costs, there are variations in the comprehensiveness of impacts addressed. For instance, some approaches may overlook important considerations like biodiversity or ecosystem services, potentially underestimating the full extent of water consumption impacts.

Data Sources and Models: There is variability among the approaches in the reliance on external data sources and models. While some approaches may utilise a wide range of datasets and models to inform their valuations, others may rely more heavily on specific sources or proprietary databases.

Monetization Method: While all approaches monetize the impacts of water consumption, they employ different monetization methods and value factors.

Applicability and Context: The suitability of each approach may vary depending on the specific context and objectives of the valuation exercise. Some approaches may be more applicable to certain sectors or geographic regions, while others offer broader applicability. Understanding these differences is necessary for selecting the most suitable approach for a particular assessment.

Transparency and Assumptions: There are differences in the transparency of assumptions and adjustments made in each approach. While some approaches provide detailed documentation of their methodologies and underlying assumptions, others may lack transparency, making it challenging to assess the robustness of the valuation results.

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3.5 Water Pollution

3.5.1 Challenge

Water pollution stands as a critical environmental challenge, reflecting the repercussions of diverse pollutants released into our water sources. In practical terms, measuring water pollution becomes crucial for understanding its societal impacts. This introduction explores the far-reaching consequences of water pollution on human health, recreational activities, property values, and commercial interests in fisheries. By examining the tangible effects of pollution, we gain insights into the complex interplay between economic activities and the well-being of communities, highlighting the need for effective strategies to address and mitigate these impacts.

SDG 6 recalls this challenge, emphasising achieving universal access to safe drinking water and sanitation (Target 6.1 and 6.2), improving water quality by reducing pollution and untreated wastewater (Target 6.3), and increasing water use efficiency across sectors (Target 6.4). Additionally, it aims to protect and restore water-related ecosystems (Target 6.5), reduce the adverse impact of hazardous chemicals and waste (Target 6.6), ensure awareness for sustainable water management (Target 6.7), and enhance local community participation in water management (Target 6.8). These principles collectively address the need to mitigate water pollution and ensure sustainable water resource management for all.

A comprehensive understanding of global water pollution is provided by leading international organisations such as the UNEP, WHO, and World Bank. UNEP's reports, including “The State of the World's Water” (2022) and the “Global Assessment of Water Pollution” (2021), offer insights into the current state of water pollution worldwide and highlight key challenges. Additionally, UNEP's initiative on “The New Water Economy” (2015) proposes solutions for addressing water scarcity in the context of worsening pollution. WHO contributes to this discourse through its “Guidelines for Drinking-Water Quality” (Fourth Edition) (2017), ensuring standards for safe drinking water, and “Water, Sanitation, Hygiene (WASH) for Health” (2017), focusing on the importance of water quality for public health. Meanwhile, the World Bank's publications, such as “Safeguarding Water for Sustainable Development: Water-Related Disaster Risk Management” (2022) and “Groundwater: The Unseen Resource” (2021), shed light on the management and preservation of water resources in the face of pollution challenges. Moreover, the UN Global SDG Database tracks progress on water-related SDGs, including indicators 6.1.1 and 6.3.2, providing valuable metrics for assessing global efforts to combat water pollution. Together, these documents underscore the urgent need for concerted action to address water pollution and ensure access to clean and safe water for all.

3.5.2 Activity Data

In the collection of activity data for own operations, employing both direct measurement and emission factors is paramount for a comprehensive environmental assessment. Direct measurement involves a meticulous identification of manufacturing processes, prioritising those with potential pollutant emissions, such as chemical reactions and water-intensive operations. Detailed data collection follows, encompassing materials used, water consumption, and comprehensive records of inputs and outputs during production. Quantifying water usage, distinguishing between various applications, and assessing the efficiency of wastewater treatment processes are integral components. Simultaneously, emission factors obtained from recognised sources are utilised to quantify pollutant releases per unit of activity. Matching these factors to specific manufacturing activities enables the calculation of emissions, providing estimates for each identified pollutant. Aggregating these results offers a holistic view of the facility's environmental impact, permitting targeted reporting based on criteria like

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water sources or geographical location. Regular review and updates of emission factors ensure ongoing accuracy, supporting effective environmental management and regulatory compliance in alignment with evolving research and regulatory standards.

Saline water: Water that has a high salt content.

Saltwater: Water that is from the ocean.

Brackish water: Water that has a moderate salt content.

Polluted water: Water that contains harmful substances.

Non-potable water: Water that is not safe to drink.

Turbid water: Water that is not clear and has a cloudy appearance.

Muddy water: Water that contains a lot of sediment.

Salty water: Water that has a salty taste.

3.5.3 Database

The Global Water Assessment Programme and Water Footprint Network (WFN) play critical roles in addressing water pollution around the world. They provide scientific information, tools, and resources to help policymakers, businesses, and communities manage and protect freshwater resources.

Global Water Assessment Programme: https://www.unesco.org/en/wwap

Water Footprint Network (WFN): https://www.waterfootprint.org/

3.5.4 Transparent

3.5.4.1 Introduction

Clean water is an essential resource for human, animal, and plant life as well as an indispensable resource for the economy. There is significant global concern regarding the state of fresh and saline water resources as human discharge of substances affects the quality of water bodies. Water bodies include inland, transitional, and coastal waters; surface and groundwaters; and the oceans, and they may all transcend national boundaries (Water Framework Directive 2000). Despite improvements in some high-income countries, water pollution is on the rise globally (e.g. UNEP 2021). Pollution and the degradation of water bodies can adversely affect human well-being and thus carry additional societal costs.

The most significant water pollutant categories (in terms of societal cost) are (Cisneros 2011):

- Organic pollutants: These are chemical substances primarily composed of carbon, hydrogen, and oxygen and may include petroleum, dyes, pesticides, surfactants, and pharmaceuticals. They are of concern due to their toxicity, semi-volatile nature, low water solubility, high bioaccumulation, and non-biodegradability under normal environmental conditions, leading to environmental degradation and impacts on human health (Bhomick et al. 2017). Of particular focus are persistent organic pollutants (POPs), which are addressed through the 2001 Stockholm Convention on POPs.
- Inorganic pollutants: Inorganic toxic substances, including heavy metals and chemical compounds, that may persist or cause undesirable changes in the natural

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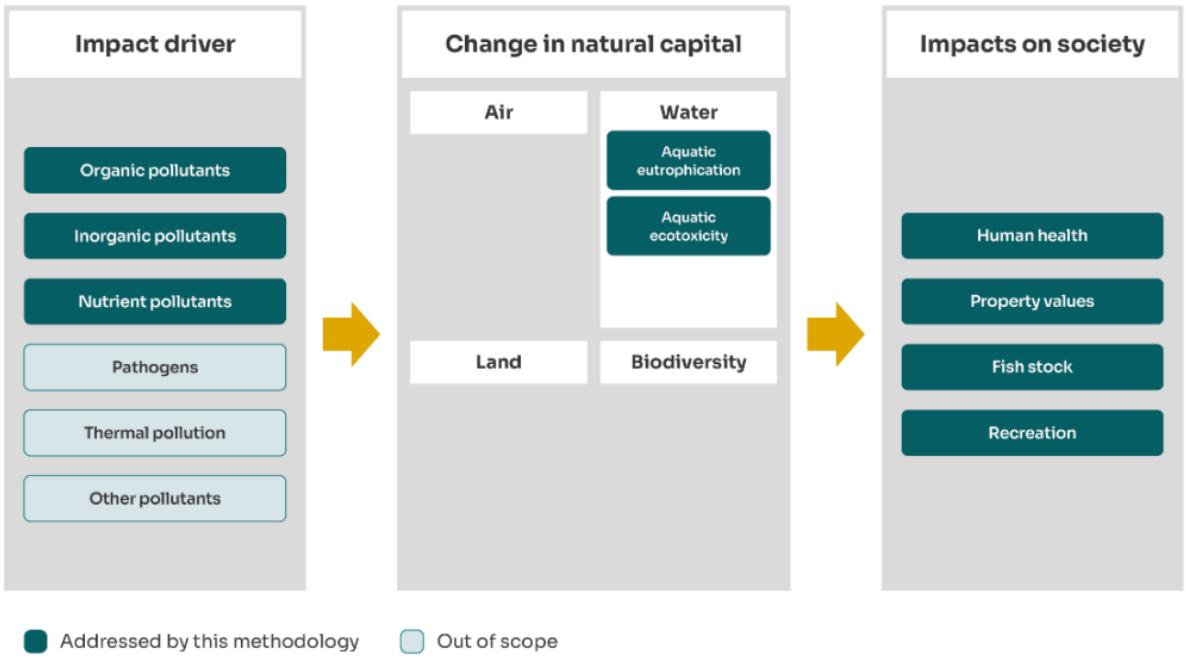
environment, bioaccumulate in the food web, and have adverse effects on human health.

- Nutrient pollutants: Nitrogen (N) and phosphorus (P) are basic building blocks of plant and animal proteins. In elevated concentrations, they can cause a range of negative effects, such as algal blooms (eutrophication) that lead to a lack of oxygen in the water, affecting water quality, fish yields, and the availability of a wide range of products and services provided by ecosystems.
- Pathogens: Pathogens in water include viruses, bacteria, protozoa, and helminths (in the form of eggs) (Jiménez 2003). They may lead to numerous waterborne diseases, such as cholera and typhoid. Coliforms are a broad class of bacteria, some of which are harmful, disease-causing organisms, such as Escherichia coli (E. coli). These can be released or encouraged to grow through discharges of inadequately treated sewage.
- Thermal pollution: Discharges of water above or below the ambient temperature of natural water bodies can change the ecological balance for aquatic species.
- Other pollutants include suspended solids and radioactive pollutants. Endocrine disruptors are also flagged for concern and may include industrial chemicals (e.g. polychlorinated biphenyls (PCBs)) and synthetic pharmaceuticals.

Pollutants may enter water bodies through municipal and industrial point sources (e.g. sewage outfalls) or non-point sources (e.g. diffuse runoff from farmland or rain).

(NCMA methodology, page 37)



[Source: Water Pollution / Transparent]

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3.5.4.2 Data Sources

No explicit data sources are listed for modelling of value factors. The following list of data sources are listed to provide potentially useful information as secondary data sources (NCMA General guidance, page 32)

- EEIO modelling such as Exiobase.
- EPA chemical databases.
- LCA models and databases such as the ReCiPe model and Ecoinvent (e.g. for freshwater eutrophication, freshwater ecotoxicity, marine ecotoxicity).
- Regulatory thresholds (in this case, you can assume that your water pollution levels are equivalent to regulatory thresholds).
- USEtox database (e.g. for ecotoxicity).
- WHO chemical databases.

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3.5.4.3 Calculation Logic

Formula

Monetized impact = Pollutant quantity * value factor for each pollutant

Activity Data (taken from NCMA methodology, pages 38-39)

- Mass of inorganic pollutants: heavy metals, chemical compounds (kg)
- Mass of nutrients: Nitrogen (kg Neq) and phosphorus (kg Peq)

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    - Nutrients can either be reported as the whole compound or as the principal element (e.g. nitrate may be reported as NO3- or N). Local laws may determine which you will be measuring.
- Additional physical, chemical, and biological parameters that can be measured (optional)
    - Physico-chemical indicators: dissolved oxygen (mg/L), pH, temperature, salinity
    - Organic pollutants: Biological oxygen demand (BOD)
    - Pathogens: coliforms (e.g. Escherichia coli)
    - Turbidity: (you will need to convert from Nephelometric turbidity units (NTU) to mg/L)
    - Hardness: (mg/L of calcium CA and magnesium mg/L)
- Information on the context of pollutants and water bodies to which pollutants are released (location, existence of wastewater treatment, etc.)

Value Factor

The value factor should include:

- Components included
    - Human health
    - Property values
    - Fish stock
    - Recreation
- Modelling of changes in natural capital based on either bespoke hydrological dispersion models that account for specific local conditions or “pre-existing models such as from life cycle inventories or similar data sources that provide characterization factors for a set of predefined contexts. Pre-existing models may either be based on dispersion models, chemical fate and exposure functions (good practice) or use proxies to characterise different contexts.” (page 40)
- Valuing impacts on society in two steps (page 36)
    - Quantify impacts on society
        - Human Health: dose-response functions; LCA characterization factors may be used
        - Property Values, Fish Stock, Recreation: no need to model explicitly; implicitly covered by monetary valuation technique
    - Value impacts in monetary terms
        - Human Health: stated or revealed preference approaches
        - Property Values: stated or revealed preference approaches
        - Fish Stock: stated or revealed preference or production function approaches
        - Recreation: stated or revealed preference approaches
    - Assumptions: no assumptions explicitly listed

3.5.5 WifOR Institute (Environmental Prices)

3.5.5.1 Introduction

The WifOR Institute approach text outlines how diverse economic activities contribute to water pollution by releasing unregulated substances, including nitrogen, phosphorus, heavy metals (such as arsenic, cadmium, mercury, chromium, lead, nickel, copper, zinc, and antimony), and other pollutants into freshwater systems. These substances pose risks to biodiversity, fish

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populations, and human health. However, the provided valuation approach for these pollutants aims to comprehend and quantify their impacts on ecosystems, especially focusing on biodiversity reduction, decreased fish production, and potential human health hazards resulting from their presence in freshwater environments.

3.5.5.2 Activity Data Source

- EXIOBASE HYBRID, DESTATIS, EEA WATERBASE – aggregated database

3.5.5.3 Subcategories

Nitrogen, Phosphorus, Antimony, Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, PAHs, Zinc

3.5.5.4 Formula

Simple multiplicative: Monetized impact = Activity data per subindicator x value factor

3.5.5.5 Impact Pathway

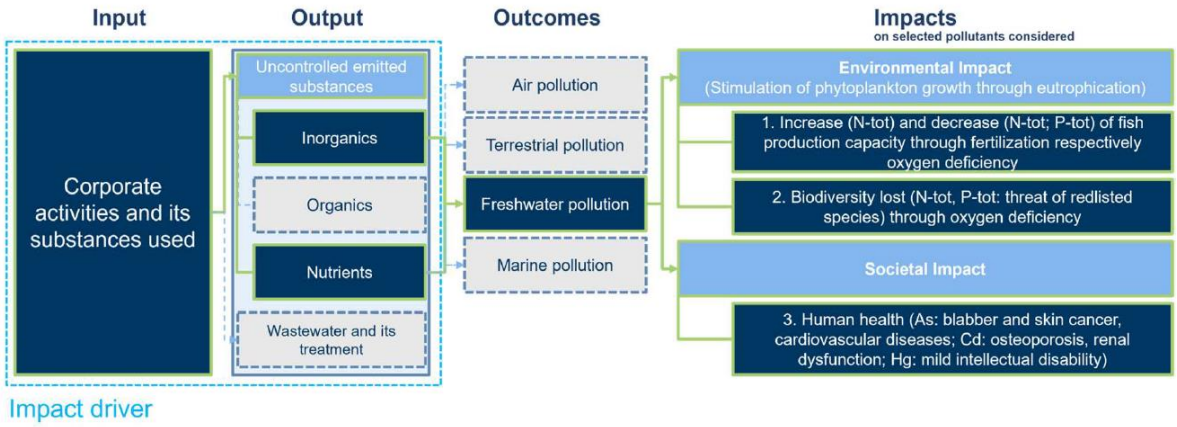

Figure 7: Simplified impact pathway of Water pollution (source: own illustration based on Steen (2020).[48]

3.5.5.6 Valuation Method (hui, gdp loss, …)

1. Increase or decrease of fish production capacity through fertilisation → Economic damage
2. Loss of biodiversity → Preservation cost?
3. Damages to human health (e.g. cancer, cardiovascular disease) → DALY

3.5.5.7 Geographical differences

Level of water stress in a region or country

3.5.5.8 Transfer Mechanism.

For the regional distribution of global data, we use water scarcity data per country from the world bank.

3.5.5.9 Global Damage

USD 0.4 Trillion (2020)

3.5.5.10 Environmental Prices

WifOR Institute: https://www.wifor.com/en/impact-valuation-factors/

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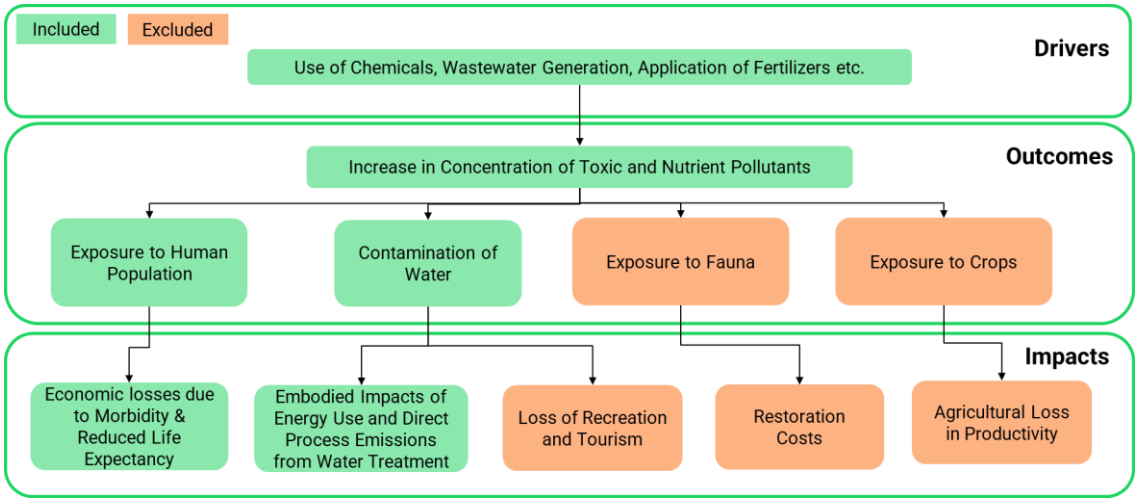
3.5.6 GIST Impact

3.5.6.1 Evaluation framework and methodology

An outline of the evaluation framework adopted for evaluating impacts from Water & Land Pollution is as shown below:



[Source: Water Pollution / Gist Impact]

"Drivers" for the release of water and land pollutants include different activities such as application of sewage generation by employees, use of cleaning agents, pesticide and fertiliser application etc.

These chemicals can be classified into two broad categories including toxic pollutants and nutrient pollutants.

1. Toxic pollutants include compounds that are toxic or carcinogenic to humans (e.g. pesticides).
2. Nutrient pollutants include those pollutants which are non-toxic and non-carcinogenic, but their addition to water bodies degrades water quality. Conventional water pollutants like nitrogen, phosphorus, biodegradable organic matter, etc. fall under this category.

Net change in the concentration of these pollutants once released depends on their physical properties. Increased concentration of these pollutants in the local environment (primary "outcome") then leads to multiple secondary "outcomes" such as exposure to human population, fauna (birds, bees, insects and fish), contamination of water, direct emissions (N_2O), etc. "Impacts" from outcomes include worsening of human health, restoration costs, loss of recreation and tourism, climate change and human health impacts from water treatment, loss of agricultural productivity, etc. (Global Water Research Coalition, 2011).

3.5.6.2 Calculation Logic

In the case of nutrient pollutants, the impact cost associated with the pollutant removal or treatment is taken into account (externality cost due to energy required for wastewater treatment) along with direct emissions released during wastewater treatment (AWWA research foundation, 2007; ENER WATER, 2019; USEPA, 2008).

Whereas, in the case of toxic pollutants, impacts on human health (cancers and non-cancer) are considered for valuation. For estimation of the externality cost of these pollutants,

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characterization factors published in the USEtox model are used which quantifies human toxicological impacts of ~3,000 chemicals, in terms of several disease cases and DALYs (Disability Adjusted Life Years) (Fantke, et al., 2017; Rosenbaum el al., 2008)).

USEtox provides the number of cancer and non-cancer cases and respective YLL, YLD, and DALY loss due to various types of health conditions listed under these categories. GIST Impact uses a human capital approach based on GDP loss per capita values for years of life lost (YLL) in case of cancer and non-cancer cases. For the valuation of the years lost due to disability (YLD) fraction, we are using the cost of illness (COI) approach, which accounts for the productivity loss and medical cost of the health condition due to cancer and non-cancer cases.

Impact due to water and land pollutants (USD) = Impact due to nutrient pollutants (USD) + Impact due to toxic pollutants (USD)

Impact due to water and land pollutants (USD) = Nutrient (N, P etc.) pollutant quantity released (tonne)* Value factors for nutrient pollutants (USD/tonne) + Toxic pollutant quantity released (tonne)* Value factors for Toxic Pollutants (USD/tonne)

3.5.6.3 Data Sources[10]

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[10] The reference list is intentionally limited for confidentiality reasons.

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3.5.7 VBA

3.5.7.1 Introduction

Economic activities across sectors contribute to the discharge of substances into water, either directly through industrial processes and agriculture or indirectly through resource and energy consumption. Despite advancements in some developed nations, global water pollution is on the rise. The consequences of pollution on water bodies pose risks to human well-being and carry significant societal costs. This discussion introduces a methodology aimed at identifying and quantifying the monetary costs associated with water pollution. The impacts of water pollution are predominantly local or regional, influenced by the physical environment and demographic exposure, making it essential to assess and value these costs for effective environmental management.

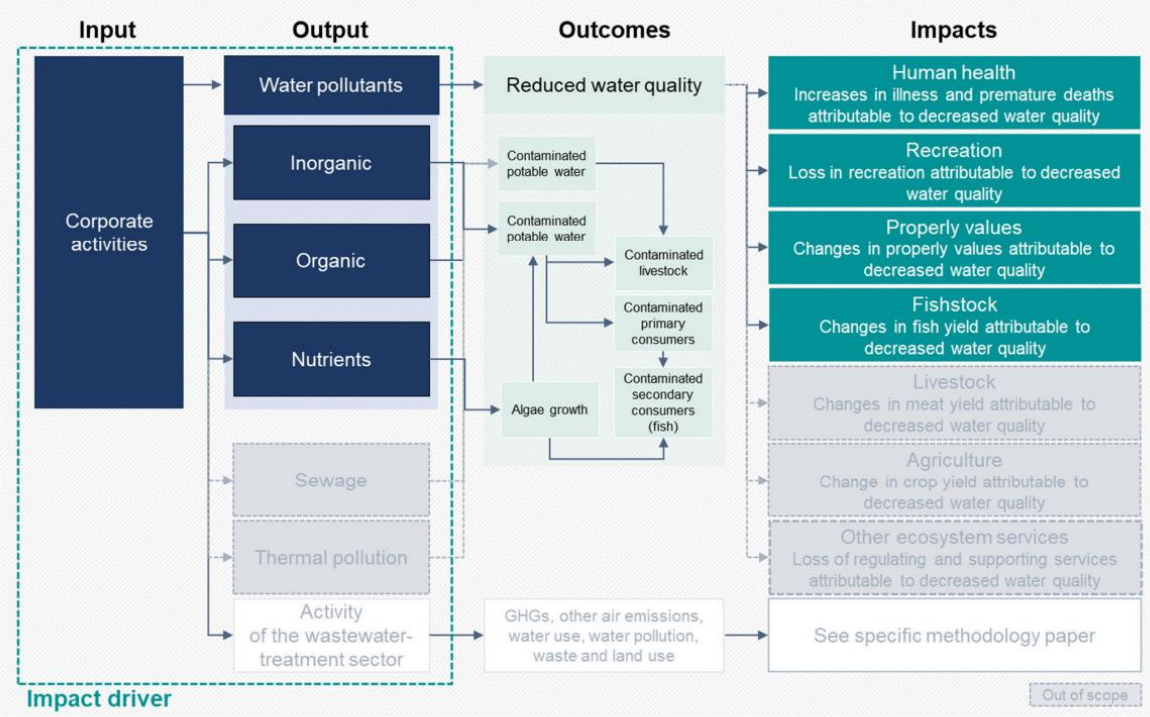

Figure 5: Simplified impact pathway water pollutants

i. Impacts are driven by the release of different types of chemicals and compounds into the water
ii. Changes in the state of natural capital (or outcomes): These are primarily identifiable as increased concentrations of pollutants and associated reductions in water quality. Secondary effects include the bioaccumulation of pollutants in the food web.
iii: Impacts on society are principally related to health but also include impacts on amenity values, recreation and the market economy.

[Source: Water pollution / VBA]

3.5.7.2 Data Sources

Toxic pollutant valuation:

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- Ahlroth, S. (2009): Developing a Weighting Set Based on Monetary Damage Estimates: Method and Case Studies. US AB : Stockholm - Welfare-based approach using WTP estimates for nitrogen and phosphorus damage values. Generic Damage Values for Marine Water - Values for phosphorus and nitrogen in marine water.
- Regional statistical adjustments (OECD, IMF, UN, WB).

3.5.7.3 Calculation Logic

Monetized impact = Accumulated by country, pollutants, and water source (measured activity data * value factor)

Where “measured activity includes” the metric quantity of water pollutants (e.g. Nitrogen, Phosphorus, Antimony, Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, PAHs, Zinc) and the value factor to be multiplied by said metric considers the different channels through which water pollution causes well-being changes (i.e. human health, recreation, property values, fish stocks). A welfare-based valuation approach can help calculate the generic damage values per kg of pollutant:

- Toxic pollutant VF (simplified): Characterization factor * DALY * DALY value
- Nutrient VF (simplified): Eutrophication potential * WTP

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Characterization factor is the number of disease incidences per kilogram of a pollutant substance released into freshwater or marine water in a given country. Please, note that the characterization factors are different for each kg of pollutant released into freshwater or marine water.

The DALY values per incidence are determined using the documented critical effects (associated with substance-specific ED50s from the IRIS and CPDB databases). For pollutants with multiple critical effects, we applied a weighted average. Average values for cancerous and non-cancerous effects (11.0 and 2.7, respectively) were used when critical effects were not identified in the reference databases. These average values were calculated in Huijbregts (2005) and weighted by incidence cases.

Table 9: Sample of DALYs for health harms from pollutants

Pollutant	Cancer		Non-cancer	
	Critical effect	DALY	Critical effect	DALY
Antimony	None	NA	Longevity, blood glucose, and cholesterol	2.7
Arsenic	Skin	9	Hyperpigmentation, keratosis and vascular	9
Barium	None	NA	Nephropathy	2.7
Benzene	Leukaemia	19	Decreased lymphocyte count	2.7
Cadmium	Kidney	11.5	Proteinuria	2.7
Copper	None	NA	Accumulation in the liver, kidney and spleen	16
Lead	Kidney	11.5	Mental development	15.9
Mercury	Stomach	10	Neurological changes, liver	17.6
Molybdenum	None	NA	Increased uric acid levels	2.7
Nickel	None	NA	Decreased body and organ weight	2.7
Selenium	None	NA	Clinical selenosis	2.7
Vanadium	None	NA	Decreased hair cystine	2.7
Zinc	None	NA	Decreases in erythrocyte Cu, Zn-superoxide dismutase (ESOD) activity	2.7

The DALY values are derived from the OECD's VSL (USD 3.4m).

$$DALY = \frac{VSL}{Number\ of\ DALYS\ lost}$$

The number of DALYs are weighted following this equation:

$$X_w = Cx^{-\beta x}$$

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where *Xw* is the relative weighting of each year of life, x is the age in years, and the suggested coefficients are C= 0.1658 and β = 0.04. This formula is used to calculate the relative weighting applied to each of the 78 years of life expectancy associated with the OECD's VSL estimate.

$$X_{wd} = \begin{cases} Cx^{-\beta x} when\ x < 47 \\ \dfrac{Cx^{-\beta x}}{(1 + SDR^{x-47})\ when\ x \geq 47} \end{cases}$$

$$X_{wd} = \begin{cases} Cx^{-\beta x} when\ x < 47 \\ \dfrac{Cx^{-\beta x}}{(1 + SDR)^{x-47}\ when\ x \geq 47} \end{cases}$$

People are willing to pay more to avoid disability today than to avoid it in the future. Therefore, a social discount rate of 3% (as per the social discount rates used in the other methodologies) is applied to future years beyond the age of 47. The discounted age weighting is calculated as per the following equation.

$$PLL_{wd} = \frac{\sum_{x=0}^{78} X_{wd}(x)}{\sum_{x=47}^{78} X_{wd}(x)}$$

The discounted, age-adjusted proportion of life lost ($PLLwd$) is calculated using the equation age-adjusted years of lost life. This represents the proportion of life lost for a person who expected to live to 78 but died prematurely at 47.

The methodology for the nutrient valuation is adapted from Ahlroth (2009), who uses WTP to estimate damage values per kilogram of N or P. This approach makes the best use of the somewhat limited literature on the valuation of eutrophication impacts. We convert the published values to cover other countries using the benefit-transfer approach.

- **Step 1**: Ahlroth (2009) presents an approach that uses WTP estimates for reduced eutrophication impacts to calculate a generic damage value per kilogram of P released into freshwater in Sweden. Studies in other parts of the world are limited. The benefit-transfer approach presented below is based on Ahlroth's (2009) values, but it can be applied to other source data where available. When applying values from a benefit-transfer approach, it is important to consider the applicability of the values to other areas. For example, whether values derived from a study in Sweden could be applied to developing countries is questionable. Ahlroth (2009) analysed existing valuation studies that estimated the value of improving water quality in a lake or watercourse. The author constructed a generic damage value per kilogram of P in Sweden using a structural benefit-transfer approach from eight studies to calculate the total WTP and the annual deposit amount. For additional details on Ahlroth's (2009) work and the structural benefittransfer method, see Appendix IX. The underlying studies were similar in design and valued a quality change. Respondents were presented with different water-quality scenarios, which were described using a water-quality ladder. The ladder presented five incremental improvements in water quality based on the water's suitability for drinking, bathing, irrigation, recreational fishing and boating (Norwegian State Pollution Control Agency, 1989). Respondents

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provided their WTP for moving between the scenarios. An average WTP per unit of emission was calculated based on the reduction in nutrient loading necessary to move between water-quality scenarios. Ahlroth (2009) assumes a constant marginal WTP, which results in a price of USD 136 per kilogram of P. To transfer this value from Sweden to other countries, we adjusted the WTP values by PPP. For a further discussion of benefit transfer and WTP, see Box 2.

- **Step 2:** Value eutrophication in marine water Our approach to valuing marine water nutrients is similar to our approach for freshwater nutrients. For coastal areas, Ahlroth (2009) analysed existing valuation studies that estimated the value of improving the quality of marine water. As in the approach for freshwater, Ahlroth (2009) calculated a per kilogram WTP value for phosphorus and nitrogen using a structural benefit-transfer method. The price of per kilogram of phosphorus in marine water is USD 68, while the price of nitrogen is USD 9. To transfer these values from Sweden to other countries, we adjust the WTP values by PPP. Ahlroth (2009) constructed generic damage values for phosphorus, nitrogen, ammonia and nitrogen oxide (NOx). The scope of our water-pollution methodology does not cover emissions to air that lead to eutrophication. Therefore, only the generic damage values for phosphorus and nitrogen are used for the E P&L. However, the aerial eutrophication emissions are likely to be trivial given the results of general research on the amount of eutrophying nutrients emitted to air versus water.
- **Step 3:** Sum to societal impacts of all excess nutrients After we have established the eutrophication potential and the damage value (via WTP) for N and P in fresh and/or marine water, calculating the total societal cost of excess nutrients requires straightforward arithmetic. For N and P, the change in eutrophication potential arising from a release of N or P into the water course is multiplied by the relevant PPP-adjusted WTP value to give the total costs associated with excessive nutrients emissions in the country. Equation Country-specific pollutant cost for eutrophication summarises the matrix multiplication used to derive the societal cost figure for each country.

The value factors should be:

- Transferred to different countries based on PPP
- Adjusted GNI per capita

3.5.8 Impact Weighted Accounts (IWA)

3.5.8.1 Introduction

The Corporate Environmental Impact: Measurement, data, and information of impact weighted accounts assess the environmental impact associated with the emission of greenhouse gases (GHG) and related substances into water utilising a combination of Waterfund and EPS data.

3.5.8.2 Data Sources

The environmental impact of water is calculated using Waterfund's global average water price, known as the Water Cost Index (WCI). Waterfund considers the global average price of water as the sum of all economic costs associated with water supply. Additionally, the EPS weighting factors from IVL Swedish Environmental Research Institute (version 2020d) contribute to the impact assessment.

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3.5.8.3 Impact Pathway

The impact pathways include water production and water consumption, both determined by multiplying economic cost with the AWARE (Availability WAter REmaining) factor.

3.5.8.4 Calculation Logic

The environmental impact of water involves the sum of the environmental impact of water production and water consumption. The calculation considers factors such as water production cost, water distribution cost, net water consumption, and associated AWARE factors.

1. $Environmental\ Impact\ of\ Water$ organisation ('i'), year ('t') =$Water\ Production$ & $Delivery\ Cost$ i, t +$Wastewater\ Treatment\ Cost\ i,t$
2. $Environmental\ Impact\ of\ Wateri,t$=($Net\ Water\ Consumedi,t$∗ $AWARE\ Factorj,t$∗$Water\ Production$ & $Delivery\ Unit\ Costj$)+($Net\ Water\ Consumedi,t$∗$Wastewater\ Treatment\ Unit\ Costj$)
3. $Environmental\ Impact\ of\ Emissions\ i,t$= Σ($Emissions\ Volumee,i,t$ ∗ $EPS\ Monetary\ Coefficiente$)
4. $Environmental\ Impacti,t$=$Environmental\ Impact\ of\ Emissionsi.t$+$Environmental\ Impact\ of\ Water\ i,t$

3.5.8.5 Valuation Technique

The AWARE model, developed by the Water Use in Life Cycle Assessment (WULCA) working group, provides supplemental water monetization factors. AWARE factors represent the available water remaining per unit of surface in a watershed relative to the world average after meeting human and aquatic ecosystem demands. EPS Monetization is determined by multiplying emissions with EPS weighting factors.

3.5.8.6 SDR

A discount rate of 3% is applied in the assessment.

3.5.9 CE Delft (Environmental Prices)

3.5.9.1 Introduction

The implementation of pricing mechanisms within environmental policies follows a concept of attributing value to pollution impacting the water, wherein waste serves as a primary source of this detrimental pollution. By orienting pricing structures around pollution, there exists an attempt to internalise the external costs associated with land pollution caused by waste disposal and negligent practices. This approach aims to account for the environmental harm caused by pollutants, encouraging industries and individuals to reconsider their waste generation and disposal methods. Through pricing, the goal is to incentivise the adoption of sustainable and eco-friendly practices, discourage activities that contribute to land pollution, and ultimately promote a more responsible and conscientious approach to waste management for the preservation of our natural landscapes.

3.5.9.2 Data Sources

- United States Environmental Protection Agency (USEPA)
- Global Environment Monitoring System (GEMS)
- National Oceanic and Atmospheric Administration (NOAA)
- US Geological Survey (USGS)
- Global Water Quality Monitoring Database (GWQMD)

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3.5.9.3 Calculation Logic

Identify the environmental impacts of water pollution. This can be done using a LCA or other environmental impact assessment method.

Quantify the environmental impacts in terms of midpoint environmental indicators. Midpoint environmental indicators are intermediate measures of environmental impact that are not directly related to human health or welfare.

Assign environmental prices to the midpoint environmental indicators. Environmental prices are expressed in terms of the relative value of environmental impacts.

Multiply the environmental impacts by the environmental prices to obtain a monetary estimate of the environmental costs.

Midpoints:

- GWP: the potential of a substance to cause global warming.
- Ozone depletion potential (ODP): the potential of a substance to deplete stratospheric ozone.
- Acidification potential (AP): the potential of a substance to acidify water bodies.
- Eutrophication potential: the potential of a substance to promote the growth of algae and other aquatic plants.
- Human toxicity potential (HTP): the potential of a substance to cause harm to human health.
- Ecotoxicity potential: the potential of a substance to cause harm to ecosystems.

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3.5.9.4 Environmental Prices

Tabel 4 - Milieuprijzen naar water voor enkele veelgebruikte stoffen in het waterbeleid, in €2021/kg

Stofnaam	Emissies naar zoetwater			Emissies naar zoutwater		
	Onder	Centraal	Boven	Onder	Centraal	Boven
Arseen	€ 233	€ 3.288	€ 15.494	€ 0	€ 257	€ 1.306
Barium	€ 2,84	€ 8,28	€ 27	€ 0,0064	€ 0,222	€ 1,09
Benzo(a)antraceen	€ 0	€ 50,1	€ 64,8	€ 0	€ 8,03	€ 10,4
Benzo(a)pyreen	€ 132	€ 196	€ 294	€ 10,2	€ 15,1	€ 22,5
Cadmium	€ 4,22	€ 43,2	€ 197	€ 0,176	€ 12,3	€ 61,6
Carbendazim	€ 1,13	€ 1,61	€ 2,12	€ 0,0203	€ 0,0288	€ 0,0372
Cypermethrin	€ 1.414	€ 2.009	€ 2.614	€ 180	€ 257	€ 340
Deltamethrin	€ 144	€ 205	€ 266	€ 13,2	€ 18,8	€ 24,3
Esfenvaleraat	€ 1.833	€ 2.601	€ 3.369	€ 50	€ 70,9	€ 91,7
Fluorantheen	€ 15,1	€ 21,5	€ 28,2	€ 1,32	€ 1,87	€ 2,43
Fosfaat	€ 0,845	€ 1,82	€ 3,34	€ 0	€ 0	€ 0
Imidacloprid	€ 0,381	€ 0,551	€ 0,770	€ 0,00479	€ 0,00680	€ 0,00882

[11] Overigens konden niet voor alle stoffen die in het waterbeleid een rol spelen een milieuprijs worden vastgesteld.

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Stofnaam	Emissies naar zoetwater			Emissies naar zoutwater		
	Onder	Centraal	Boven	Onder	Centraal	Boven
Irgarol/Cybutryne	€ 0	€ 3.163	€ 4.095	€ 0	€ 85,8	€ 111
Kobalt	€ 0,128	€ 0,288	€ 0,844	€ 0,0434	€ 0,216	€ 0,895
Koper	€ 3,27	€ 5,11	€ 8,15	€ 1,16	€ 3,37	€ 9,70
Kwik	€ 12,5	€ 1.841	€ 9.300	€ 0,59	€ 758	€ 3.854
Lambda-cyhalothrin	€ 1.084	€ 1.543	€ 2.015	€ 207	€ 298	€ 399
Methylpirimifos	€ 30,2	€ 43,5	€ 60,2	€ 0,466	€ 0,663	€ 0,873
Nikkel	€ 13,1	€ 49,7	€ 184	€ 0,324	€ 6,26	€ 30
Nitraat (N-totaal)	€ 2,27	€ 4,23	€ 8,19	€ 7,64	€ 14,3	€ 27,6
Seleen	€ 0,318	€ 0,670	€ 1,83	€ 0,108	€ 0,440	€ 1,74
Thallium	€ 10,1	€ 199	€ 970	€ 0,157	€ 28,0	€ 156

[Source: CE Delft, Environmental Prices, 2023, Table, pp. 32-33.]

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3.2.2 Environmental prices for emissions to water

For emissions to water, prices were calculated for the 'prioritary pollutants' for which targets are laid down in the European Water Framework Directive, supplemented by total nitrogen,total phosphorus and phosphate, key factors in eutrophication. Table 6 reports the lower, central and upper values.[16]

Table 6 Environmental prices for emissions to water of prioritary and eutrophying pollutants (€2015 per kg 2015 emission)

Pollutant	Environmental price (€/kg emission)			Relevant midpoints		
	Lower	Central	Upper	Eutrophic.	Human tox.	Ecotox.
1,2-Dichloorpropane	€ 8.48	€ 11.6	€ 17.9		x	x
Atrazine	€ 1.69	€ 10.1	€ 11.7		x	x
Aldrin	€ 762	€ 1048	€ 1616		x	x
Benzene	€ 0.0264	€ 0.0381	€ 0.0578		x	x
Beryllium	€ 3.84	€ 25	€ 29.7		x	x
Captan	€ 0.0109	€ 0.0779	€ 0.0886		x	x
DDT	€ 22	€ 33.3	€ 49.8		x	x
Dichloromethane	€ 0.09	€ 0.225	€ 0.296		x	x
Dichlorvos	€ 0.826	€ 1.13	€ 1.75		x	x
Dicofol	€ 115	€ 159	€ 245		x	x
Ethylbenzene	€ 0.00266	€ 0.0102	€ 0.0124		x	x
Hexachlorobenzene	€ 0.25	€ 1.86	€ 2.11		x	x
Naphthtalene	€ 0.0825	€ 0.614	€ 0.696		x	x
Pentachlorophenol	€ 189	€ 260	€ 401		x	x
Phosphate (PO_4)	€ 0.0876	€ 0.159	€ 0.226	x		
Tetrachloroethylene	€ 1.14	€ 8.47	€ 9.6		x	x
Total nitrogen (N)	€ 3.11	€ 3.11	€ 3.11	x		
Total phosphorus (P)	€ 3.45	€ 4.75	€ 7.32	x		
Trichloromethane (chloroform)	€ 1.44	€ 1.98	€ 3.06		x	x
Trifluralin	€ 6.04	€ 9.01	€ 13.5		x	x
Zinc	€ 0.0838	€ 0.795	€ 1.68		x	x

[Source: CE Delft, Environmental Prices 2016, Table, p. 34]

3.5.10 Umwelt Bundesamt (Environmental Price)

Table 33: Environmental costs of nitrogen emissions to groundwater and of nitrogen and phosphorus as respective growth-limiting factors in surface waters

Substance	Impact pathway	Value factor €2020 /kg N
Nitrogen	Groundwater	1.9
	Inland waters	7.3
	Coastal and marine waters	20.8
Phosphorus	Inland waters	153.5
	Coastal and marine waters	441.4

Source: Schäppi et al (2019), own calculations.

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Table 34: Environmental costs of nitrogen and phosphorus emissions into surface waters when it is unknown which is the limiting substance in the affected water bodies

	Value factor nitrogen €2020 / kg N	Value factor phosphorus €2020 / kg P
Emission into surface water	20.8	153.5

Source: Schäppi et al. (2019), own calculations.

3.5.11 EPS IVL (Environmental Prices)

Valuation Technique

- ISO 14008:2019
- UNEP/SETAC GLAM initiative and the EU JRC LCIA

Table 10 Monetary values of environmental impacts from emission to water

Emission	Receiving media	Unit	Monetary impact value, €
BOD	freshwater	kg O2	3.20E-04
Ntot	freshwater	kg N	2.18E-03
Ntot	seawater	kg N	5.45E-03
Ptot	freshwater	kg P	4.14E-02
As	freshwater	kg	7.30E+03
Cd	freshwater	kg	2.38E+04
Hg	all	kg	3.95E+02

Table 11 Weighting factors for midpoint impact indicators recommended by UNEP/SETAC's GLAM project (UNEP/SETAC 2016, 2019)

Midpoint impact indicator	Indicator Unit	Weighting factor	Note
		€/indicator unit	
GWP 100	kg CO2 equivalents	0.288	
Premature deaths from PM2.5 or precursor	DALY /kg emitted	77300	
Water use: water scarcity		n/a	Unclear link to damages
Water use: human health effects	DALY /m3 consumed	77300	
Land occupation impact on biodiversity	PDF	69180000000/PDFglo	share of global sum of PDF
Land transformation impact on biodiversity		n/a	in EPS all land use impacts are accounted for in the occupation activity
Acidification, terrestrial	kg SO2 equivalents	0.003715785	global average
Eutrofication, freshwater	kg phosphorus-equivalents	0.041363636	
Eutrification, marine	kg nitrogen-equivalents,	0.005454545	
Human Toxicity	kg intake per kg substance	n/a	too unspecific for meaningful valuation
Human Toxicity, cancer effects	cases/ kg intake	n/a	too unspecific for meaningful valuation
Human Toxicity, non-cancer effects	cases/ kg intake	n/a	too unspecific for meaningful valuation
Ecotoxicity, all forms	CTUe/kg	n/a	link to endpoints missing
Natural Resources (minerals)	kg Sb-eq	28800	Relevant for scarce minerals. For Al, Fe and fossil minerals specific WF should be used
Land Use Impacts on Soil Quality	kg C deficit	n/a	lack of models for impact pathways

[Source: Swedish Life Cycle Center et al, EPS weighting factors - version 2020d, November 2020]

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3.5.12 EPS, Chalmers (Environmental Prices)

3.5.12.1 Introduction

Only real impacts on environmental goods, like fish production capacity, human health and biodiversity are included. No exceeded-concentration criteria, which often is of concern for water environments, is included. Pathways modelled, impact factors, and uncertainty estimates are shown in the table below.

A conclusion from the assessment of monetary impact values of BOD emissions to freshwater is that this is a moderate economic problem, on average. An efficient abatement strategy should therefore focus on local conditions.

The environmental impact of N-tot on freshwater ecosystems is primarily linked to the portion that reaches the sea via rivers. This N-tot can then contribute to marine eutrophication (excessive nutrient enrichment).

As for N-tot, the impact value is moderate, and emissions of P-tot will not be a significant aspect unless it is central for the product or service, e.g. wastewater treatment.

It is notable that the impacts via increased cardiovascular diseases due to As is so large compared to the other types of impacts.

The monetary impact value for osteoporosis due to Cd is quite high. It is clear that it is a very large handicap and reduces the working capacity considerably. But it is unclear how prevalent the severe cases are.

3.5.12.2 Calculation Logic

BOD emissions in freshwater act like a pollutant, causing oxygen deficiency. This harms fish and other aquatic life, reducing biodiversity and fish populations. The severity depends on local factors like water flow and temperature. Some BOD gets carried by rivers to the ocean, but the impact on marine life is thought to be minimal and is not modelled here.

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Environmental impact factors and monetary impact values for BOD emissions to freshwater

Environmental good	Impact indicator	Unit	Pathway	Environmental impact factor	Uncertainty	Indicator value ($/unit)	Impact value ($/kg BOD)
fish	production capacity	kg	oxygen deficiency	1.03E–04	2	2	2.49E–04
biodiversity	share of threat to redlisted species	dimensionless	oxygen deficiency	1.35E–15	3	7.61E+10	1.03E–04
						sum	3.52E–04

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 173]

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Summary of environmental impact factors and monetary impact values of emission of 1 kg N-tot to freshwater

Environmental good	Impact indicator	Unit	Pathway	Environmental impact factor	Uncertainty	Indicator value ($/unit)	Impact value ($/kg N-tot)
fish	production capacity	kg	oxygen deficiency	2.06E–03	2	2.42	4.99E–03
fish	production capacity	kg	fertilization	–1.25E–03	10	2.42	–3.03E–03
biodiversity	share of threat to redlisted species	dimensionless	oxygen deficiency	5.89E–15	3	7.61E+10	4.48E–04
						sum	2.40E–03

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 176]

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Summary of environmental impact factors and monetary impact values of emission of 1 kg P-tot to freshwater

Environmental good	Impact indicator	Unit	Pathway	Environmental impact factor	Uncertainty	Indicator value ($/unit)	Impact value ($/kg P-tot)
fish	production capacity	kg	oxygen deficiency	1.30E–02	2	2	3.15E–02
biodiversity	share of threat to redlisted species	dimensionless	oxygen deficiency	1.83E–13	3	7.61E+10	1.40E–02
						sum	4.55E–02

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 180]

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Summary of environmental impact factors and monetary impact values of emission of 1 kg Cd to freshwater

Environmental good	Impact indicator	Unit	Pathway	Environmental impact factor	Uncertainty	Indicator value ($/unit)	Impact value ($/kg Cd)
human health	cases	personyears	osteoporosis	1.91E–01	10	137,045	2.62E+04
human health	YLD	personyears	renal dysfunction	1.34E–04	10	107,067	1.43E+01
						sum	2.62E+04

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 185]

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3.5.13 Analysis

The Transparent approach focuses on water pollution, measuring inorganic pollutants and nutrients. It utilises dispersion models and dose-response functions and considers human health, property values, fish stock, and recreation, employing stated or revealed preference approaches for valuation.

VBA approach analyses water pollution in cubic meters, including a wider range of pollutants. It utilises the USEtox model and characterization factors and considers human health, recreation, property values, and fish stock, employing stated or revealed preference approaches and damage cost assessment.

GIST Impact approach analyses wastewater generated, distinguishing between toxic and non-toxic pollutants. It utilises various databases and literature sources for modelling and considers human health, productivity loss, cost of illness, water treatment costs, biodiversity, and agriculture, employing stated or revealed preference approaches and a hybrid human capital approach.

WifOR Institute approach focuses on freshwater pollution, considering various heavy metals and organic compounds. It employs an LCA-based method, focuses on health damage, economic damage, and preservation cost approach. It considers human health, fish stock, biodiversity, and water scarcity, and adjusts for water scarcity in valuation.

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Consideration of Multiple Impact Pathways: Each approach considers multiple impact pathways of water pollution, such as its effects on human health, property values, recreational activities, fish stock, biodiversity, agriculture, and water treatment costs. This comprehensive approach ensures a more holistic understanding of the implications of water pollution on various aspects of society and the environment.

Utilisation of Models and Data Sources: They all utilise models, databases, scientific literature, and potentially other sources of data to accurately estimate the impact of water pollution. This includes dispersion models, toxicity models (e.g. USEtox), and various databases for toxic releases and activity data.

Incorporation of Valuation Techniques: All approaches include stated or revealed preference approaches, damage cost assessments, and hybrid human capital approaches, depending on the specific context and objectives of the valuation.

Adjustment for Factors like PPP and Water Scarcity: Some approaches, like VBA and WifOR Institute, mention adjustments for factors such as PPP and water scarcity to provide more accurate estimations of the societal costs of water pollution across different regions and contexts.

Data Sources and Transparency: There is variability in the transparency and specificity of the data sources used in each approach. While some approaches provide detailed information on data sources and methodologies, others lack explicit documentation, making it challenging to assess the reliability and accuracy of their findings.

Scope of Impact Assessment: The scope of impact assessment varies across the approaches. While some focus on specific impact pathways such as human health or property values, others adopt a more comprehensive approach by considering multiple impact pathways. Addressing a broader range of impacts can provide a more holistic understanding of the consequences of water pollution.

Valuation Techniques: There is diversity in the valuation techniques employed by each approach. While some utilise sophisticated models and methodologies such as damage cost assessments and hybrid human capital approaches, others rely on valuation techniques like stated or revealed preference approaches.

Adjustment for Contextual Factors: While some approaches mention adjustments for factors like PPP and water scarcity to account for regional variations, not all explicitly consider these contextual factors.

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3.6 Land Use

3.6.1 Challenge

To assess the impact of land use, it is essential to quantify the occupied hectares per type of occupation and by country, as detailed in the methodology provided below. This measurement aims to align reporting with sector-specific guidelines and addresses the direct impact drivers of biodiversity loss related to land use changes. Understanding the intricate relationship between land use and societal well-being is critical. Ecosystems, by providing stable climates, flood protection, crop pollination, fertile soils, clean water, and contributing to recreation, tourism, as well as the production of food, fuel, and fibre, play a fundamental role in supporting economic activities and human life. However, the increasing demand for land often leads to the conversion of new areas, resulting in the loss of vital ecosystem services. Further insights into this assessment's intricacies and its significance in comprehending and mitigating the impacts of land use on both ecological and societal landscapes can be found in the methodology documents provided.

SDG 11 addresses this challenge aiming to create inclusive, safe, resilient, and sustainable cities and settlements (Target 11.1) while specifically addressing the need to reduce the adverse per capita environmental impact of cities, including air quality and waste management (Target 11.6). SDG 13 emphasises urgent action to combat climate change, including integrating climate measures into national policies and enhancing education and awareness on climate issues (Targets 13.1, 13.2, and 13.3). Additionally, SDG 15 focuses on protecting and restoring terrestrial ecosystems, halting deforestation, restoring degraded land, and combating desertification (Targets 15.2 and 15.3). These principles collectively aim to promote sustainable land use practices and address environmental challenges in urban and natural settings.

Leading international organisations such as the FAO, World Resources Institute (WRI), and World Bank provide valuable insights into land use and its implications. FAO's publications, including “The State of Food and Agriculture (SOFA) 2022” and the “Global Forest Resources Assessment 2020”, offer comprehensive assessments of global agrifood systems, forest resources, and their transformations. Moreover, FAO's “The Future of Land: Global Land Outlook 2 (GLO 2)” highlights the interconnectedness of food systems, forests, and urban areas, emphasising the need for sustainable land management practices. WRI contributes to this discourse with reports like “Forest Landscape Restoration 2.0” and “Climate Risk Hotspots”, which examine strategies for achieving healthy and resilient forests and analyse the global impacts of climate change on ecosystems and poverty. Additionally, the World Bank's publications, such as “Land Governance for Equitable Development” and “Sustainable Land Management in Africa”, provide frameworks and solutions for addressing land governance challenges and unlocking opportunities for sustainable development. Together, these documents underscore the importance of responsible land use practices in promoting environmental sustainability, food security, and equitable development on a global scale.

3.6.2 Activity Data

In the meticulous evaluation of land use associated with production or operational activities, employing a dual approach of direct measurement and the utilisation of emission factors is indispensable for a thorough environmental assessment. The initial step involves the identification and categorisation of occupied land, disregarding the conversion timeline, and classifying it into distinct types of occupation according to the VBA methodology. These range from agricultural and forestry activities to fully paved areas devoid of ecosystem services. Quantifying the hectares of each land occupation type establishes a foundational

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understanding of the scope of land use. Emission factors, drawn from recognised sources, are then aligned with specific occupation types to capture the diverse impacts on ecosystem services. The subsequent calculation entails multiplying the quantified land use by the corresponding emission factors for each category, providing estimates of the overall land use impact. This aggregated data fosters a holistic perspective on the company's land use, with materiality considerations tailored to industry-specific contexts. Whether in agriculture, forestry, or other sectors, this approach ensures a nuanced assessment, bolstering informed decision making and environmental reporting in harmony with sustainability objectives.

3.6.3 Databases

- UNEP databases provide valuable insights into the state of land use around the world.
- The Land Use and Land Cover Change (LUCC) Global Database: N/A
- The Global Ecosystems Monitoring Service (GEMS): https://glad.umd.edu/dataset/GLCLUC2020
- The International Soil Reference and Information System (ISRIC): https://www.isric.org/
- The World Bank Global Forest Resources Assessment (FRA): https://www.fao.org/3/ca9825en/ca9825en.pdf

3.6.4 Transparent

3.6.4.1 Introduction

Land use, and by extension seabed use, refers to human intervention or management of a given area of the solid surface of the Earth. It includes activities undertaken (e.g. conversion to farming, building infrastructure) and institutional arrangements put in place (SEEA 2012). Use of and change to land and seabed are some of the main drivers of biodiversity loss and degradation of a broad range of ecosystem services (MEA 2005). This includes the degradation of soil quality or marine sediments which further affects ecosystem services (UNEP 2017).

The value of land and seabed to society is largely determined based on the surface type and the ecosystems it supports. This is described in terms of land cover, the physical and biological material covering the Earth’s surface including natural vegetation and abiotic (non-living) components.

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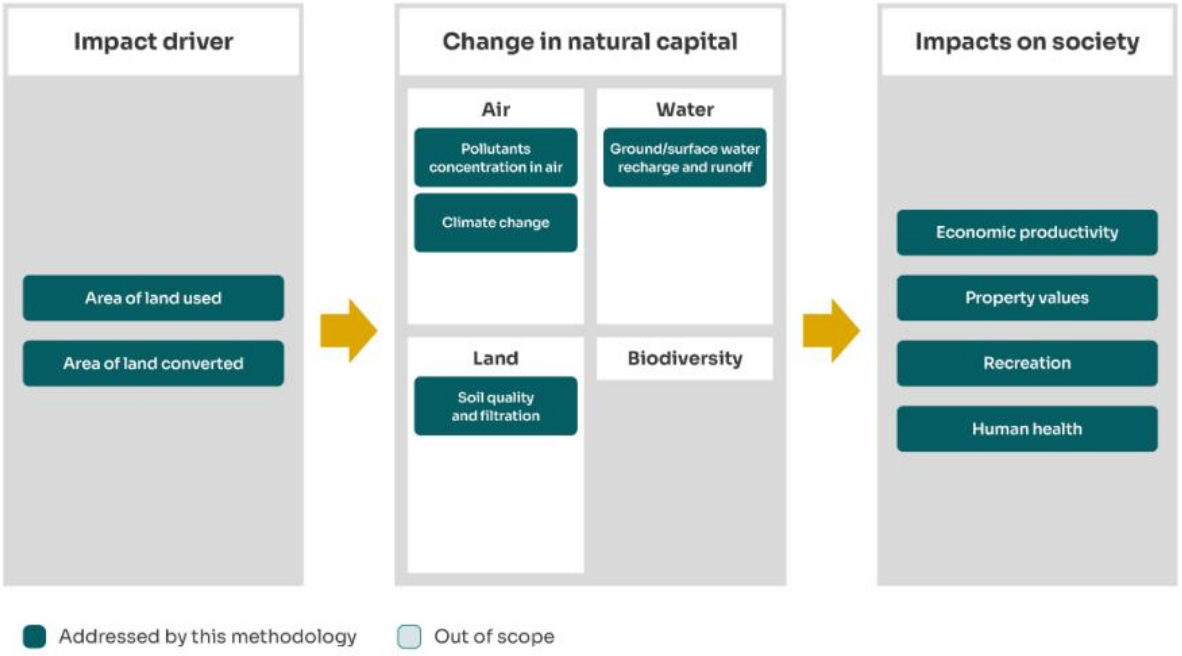
(NCMA methodology, page 42)



[Source: Land Use / Transparent]

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3.6.4.2 Calculation Logic

Formula

Monetized impact = Land use * value factor

Activity Data (NCMA methodology, page 43):

- Area of land (or seabed) used (ha): occupied by activities driven by business (e.g. used for agriculture or other raw materials or for living/working space).
- Area of land (or seabed) converted (ha): area of land where land cover (the observed physical and biological cover of the Earth’s surface including natural vegetation and abiotic (non-living) components) is changed through activities driven by business.

Value Factor

The value factor should include:

- Components included
  - Economic productivity

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    - Property values
    - Recreation
    - Human health (optional)
- Modelling of changes in natural capital
    - Measurement and modelling of changes in natural capital relative to a pre-defined baseline. The baseline can be the natural ecosystem of the region, a fixed cut-off year (see recommendations of Science Based Targets Network).
- Valuing impacts on society in two steps (taken from page 36)
    - Quantify impacts on society
        - Economic productivity, property values, recreation: no need to model explicitly; implicitly covered by monetary valuation technique
        - Human health (optional): land use activities and human health can be indirectly linked through the effects of ecosystem changes on GHG emissions, and pollutants in air and water; can be measured via respective methods
    - Value impacts in monetary terms
        - Economic productivity: productivity change methods
        - Property values: stated or revealed preference approaches
        - Recreation: stated or stated preference approaches
        - Human health (optional): stated or revealed preference approaches
- Assumptions:
    - If land used has multiple uses/users, allocation of impacts based on economic, or physical allocation
    - Assign a reduction in the value of the ecosystem service reduction in the current year relative to the chosen baseline to the current occupant of the land, irrespective of whether that occupant was directly responsible for the land's conversion
    - Use marginal values to value the land
    - Include a qualitative assessment of the ecosystem condition

3.6.5 WifOR Institute (Environmental Prices)

3.6.5.1 Activity Data Source

- EXIOBASE 3.8.1

3.6.5.2 Subcategories

- Agriculture: animal rearing, cereal grains nec, crops nec, oilseeds, paddyrice, plant-based fibres, sugarcane sugarbeet, vegetables fruits nuts, wheat
- Forestry
- Paved

3.6.5.3 Formula

- Simple multiplicative: Monetized impact = Sum of area of land use data (per subindicator and specification) x value factor
- Country-specific

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3.6.5.4 Impact Pathway

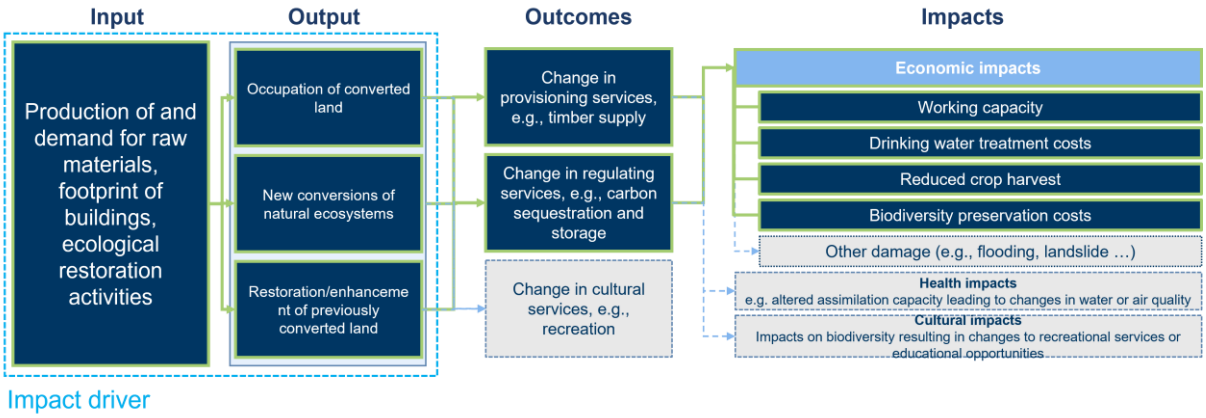

Figure: Impact Pathway of waste (source: WifOR Institute illustration based on EPS, 2015)

3.6.5.5 Valuation Method

- Working capacity → Productivity loss due to heat islands from urban land use, based on GDP per working person and empirical estimates on relationship between temperature increase and productivity
- Drinking water treatment costs → Empirical costs on an increase of drinking water production costs from urban land use near water source
- Reduced crop harvest → Higher food prices due to loss of crop growth capacity as a result of urban land use
- Loss of biodiversity → Preservation cost

3.6.5.6 Sources of Valuation Data

- EPS (2015, Swedish Life Cycle Center)
- Steen (2016)
- Price and Heberling (2020)
- Deutz et al. (2020)
- Frauenhofer IBP (2021): LANCA characterization factors
- OECD, World Bank

3.6.5.7 Geographical Differences

Calculating country-specific impact values from global values using LANCA characterization factors

3.6.5.8 Transfer Mechanism

Values in USD. No adjustment for PPP.

3.6.5.9 Land Use-specific

The value factor for some land use subcategories may consist of averages of more disaggregated subcategory types.

3.6.5.10 Global Damage

CO_2

USD 12.46 Trillion (2020)

3.6.5.11 Environmental Prices

WifOR Institute: https://www.wifor.com/en/impact-valuation-factors/

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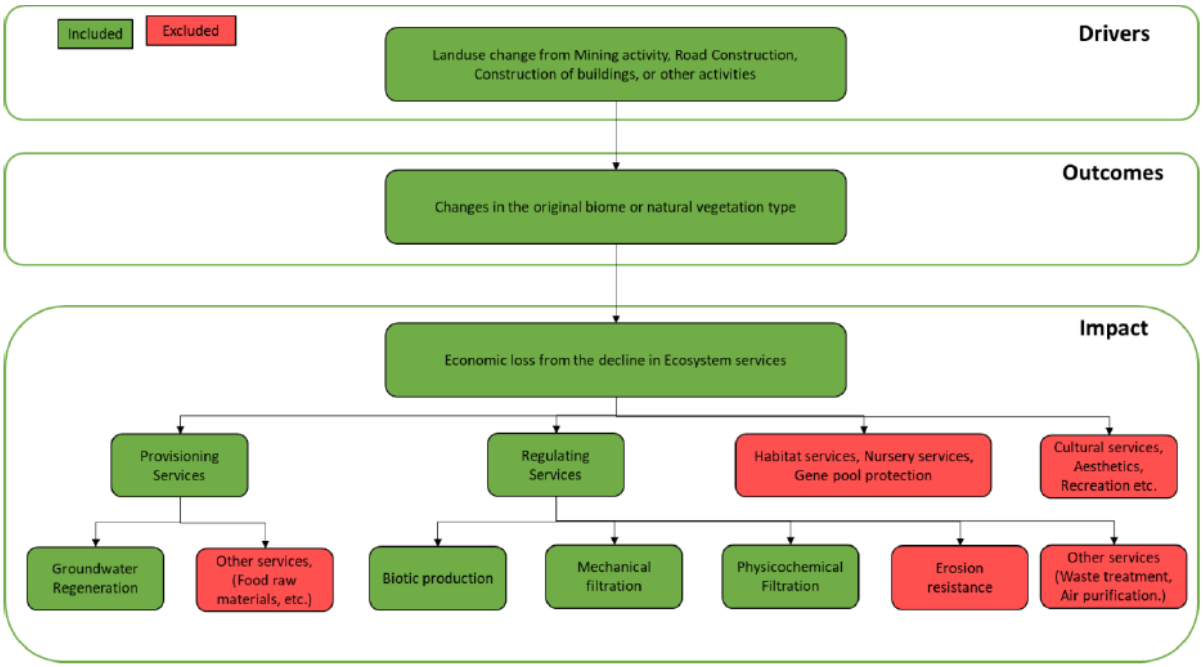
3.6.6 GIST Impact

3.6.6.1 Evaluation Framework and Methodology

The evaluation framework of land use change impact is as shown below:



[Source: Land Use / GIST Impact]

The "driver" for the change includes activities like the construction of new roads and buildings, conversion of forest plantations to agricultural land, etc. In most cases, the supply chain could be a significant contributor to land use changes, especially for industries dependent on agricultural and mining raw materials. Land transformation can be directly estimated by getting details on any new construction activity. Other estimation methods include using time series land use land cover data to estimate net change in the land area using tools like GIS (Geographic Information Systems).

The "outcome" and "impacts" include a change in the original biome or natural vegetation type leading to loss of ecosystem services respectively. Ecosystem services can include services like water regeneration, soil loss prevention, carbon sequestration, air quality regulation, etc.

3.6.6.2 Calculation Logic

Valuation is carried out based on the impact drivers. For example, biotic potential is converted in terms of carbon conserved and then the social cost of carbon (GHG driver valuation method) is used to convert it in economic terms. Similarly, for valuing the mechanical filtration potential, the impact cost associated with the energy consumption in traditional treatment methods (such as rapid sand filters) is considered.

Impact due to land use change (USD) = Land use change occurred at a specific location in a reporting period (m^2) * Value factor (USD/m^2) at a specific location

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3.6.6.3 Data Sources[11]

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[11] The reference list is intentionally limited for confidentiality reasons.

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3.6.7 VBA

3.6.7.1 Introduction

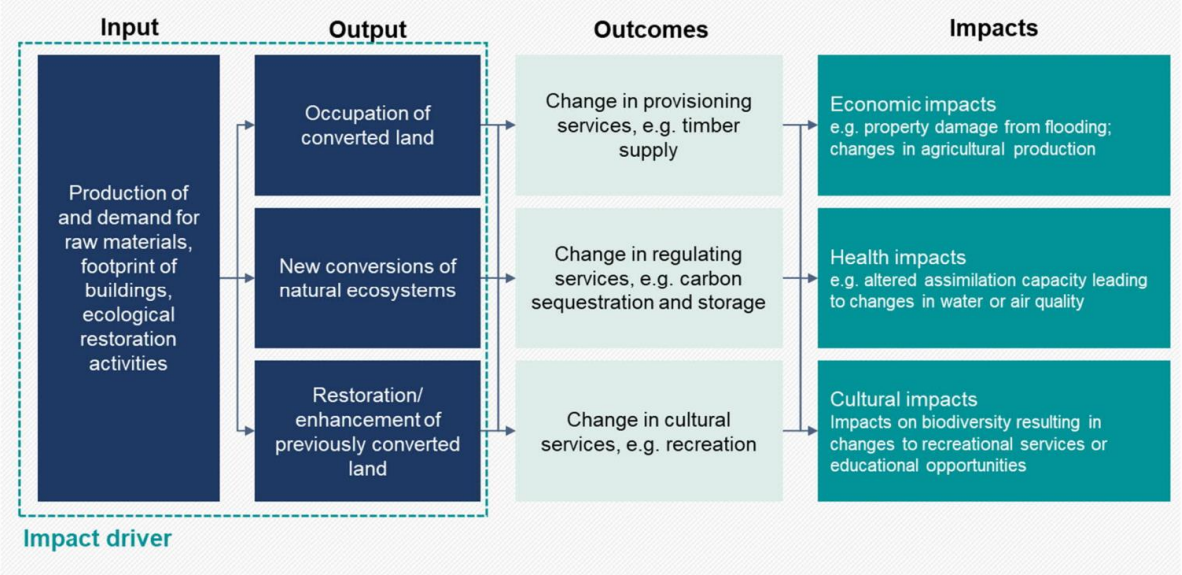

Figure 9: Simplified impact pathway land use

[Source: Land Use / VBA]

Natural land areas, teeming with biodiversity, play a vital role in providing indispensable services to society. These areas regulate the environment, offer goods and services crucial for livelihoods, serve as recreational spaces, and contribute to cultural and spiritual enrichment. Disturbingly, the Millennium Ecosystem Assessment found that 63% of these services are already degraded, with significant social and economic consequences. The Economics of Ecosystems and Biodiversity estimates an annual economic cost of USD 2 trillion to USD 4.5 trillion due to biodiversity and ecosystem service loss. Agricultural expansion, covering 25% of the Earth's terrestrial surface, is identified as a major driver of these losses. The presented methodology focuses on estimating the economic value of lost ecosystem services resulting from the conversion and occupation of natural land areas. Emphasising the temporal dimension, it assigns current-year losses to the present land occupant, encouraging sustainable practices and avoiding uncertain assumptions about future losses or past conversion dates.

3.6.7.2 Data Sources

- The Economics of Ecosystems and Biodiversity (TEEB) Valuation Database. Note: More than 1300 ecosystem values are available from diverse academic studies.
- To adjust the WTPs for each ecosystem service, economic accounts can be considered (population, income accounts, etc.). Traditional statistical sources such as the OECD, UN, IMF, the WB or national statistical offices can provide the necessary data for the calculations.
- Additional note: The estimation of the ecosystem service loss can be derived from the WWF Wildfinder, IPCC (2016), and Więski, Guo, Craft and Pennings (2008) provide biomass estimates for generic land use. IPCC (2006) provides rates of SOC change for different land uses dependent on climate and land-management practices, Guo, Craft and Pennings (2008) estimate species richness in different biomes, among other sources.

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3.6.7.3 Calculation Logic

Monetized impact = Accumulated by country, type of land use (measured activity data * value factor)

The methodology considers the following land use occupation types:

- Agriculture subtypes
  - Wheat
  - Vegetables, fruit and nuts
  - Cereal grains
  - Oilseeds
  - Sugarcane and sugar beets
  - Plant-based fibres
  - Crops n.e.c.
  - Animal rearing
  - Paddy rice
- Forestry
- Paved (land fully converted; no ecosystem services provided)

The available activity data for land use depends on the value chain level, but can refer to the primary or estimated land use footprint of buildings or the land use footprint of raw materials.

The value factor represents the lost ecosystem service value in USD/ha. The WTP should be derived from the change in the "ecosystem service" that the land was providing before and after the business establishment, considering eco-regions and countries. The valuation technique will depend on the source used, but TEEB cites scientific studies whose methods include:

- Avoided cost
- Benefit transfer
- Choice modelling
- Contingent valuation
- Direct market pricing
- Group valuation
- Group valuation
- Hedonic pricing
- Income factor
- Mitigation and restoration cost
- Other
- Replacement cost
- Total economic value
- Travel cost

The VF should be calculated taking into account the eco-region types affected following WWF classification for each country and location. The value of the ecosystem services provided based on scientific studies from sources such as TEEB should be adjusted after excluding outliers, considering regional socioeconomic factors and scarcity – marginal value adjustments can be introduced to reflect incremental cost increase after a particular point of loss function.

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3.6.8 Umwelt Bundesamt (Environmental Prices)

3.6.8.1 Environmental Prices

Table 2: **a) Costs (negative sign) and benefits (positive sign) rounded per hectare and year [€ ha^{-1} a^{-1}] in the year of conversion in above and below ground biomass after land use change for the year 2017 at a value factor of 195€/t $CO_{2\ eq.}$**

	Forest	Field	Grassland in the narrower sense	Woody plants	Terrestrial wetlands	Water-bodies	Settle-ments
	Assessment of mean carbon stocks in above- and belowground biomass						
[€ ha^{-1}]	39,100	4,800	4,900	30,900	13,500	0	8,900
	Costs for a change in biomass [€ ha^{-1} a^{-1}]						
Forest		-34,300	-34,200	-8,200	-25,500	-39,100	-30,200
Field	2,500		100	26,100	8,700	-4,800	4,100
Grassland in the narrower sense	2,300	-100		26,000	8,700	-4,900	4,100
Woody plants	1,400	-26,100	-26,000		-17,300	-30,900	-21,900
Terrestrial wetlands	2,500	-8,700	-8,700	17,300		-13,500	-4,600
Waterbodies	2,600	4,800	4,900	30,900	13,500		8,900

Source: Own calculations based on UBA (2019a). Grassland in the narrow sense includes meadows and pastures.

[https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2023-03-16_methodological-convention-3-1_value-factors_2020_bf.pdf]

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Table 3: **b) Costs (negative sign) and benefits (positive sign) rounded per hectare and year [€ ha^{-1} a^{-1}] in the year of conversion in above- and below-ground biomass after land use change for the year 2017 at a value factor of 680€/t $CO_{2\,eq.}$**

	Forest	Field	Grassland in the narrower sense	Woody plants	Terrestrial wetlands	Water-bodies	Settle-ments
	Assessment of mean carbon stocks in above- and belowground biomass						
[€ ha^{-1}]	136,300	16,700	17,000	107,600	47,200	0	31,100
	Costs for a change in biomass [€ ha^{-1} a^{-1}]						
Forest		-119,600	-119,300	-28,700	-89,100	-136,300	-105,100
Field	8,600		300	90,900	30,500	-16,700	14,400
Grassland in the narrower sense	8,100	-300		90,600	30,200	-17,000	14,200
Woody plants	4,800	-90,900	-90,600		-60,400	-107,600	-76,500
Terrestrial wetlands	8,700	-30,500	-30,200	60,400		-47,200	-16,100
Waterbodies	9,100	16,700	17,000	107,600	47,200		31,100
Settlements	8,500	-14,400	-14,200	76,500	16,100	-31,100	

Source: Own calculations based on UBA (2019a). Grassland in the narrow sense includes meadows and pastures.

[Source :https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2023-03-16_methodological-convention-3-1_value-factors_2020_bf.pdf]

3.6.9 CE Delft (Environmental Prices)

3.6.9.1 Introduction

The implementation of pricing mechanisms within environmental policies follows a concept of attributing value to pollution impacting the land, wherein waste serves as a primary source of this detrimental pollution. By orienting pricing structures around pollution, there exists an attempt to internalise the external costs associated with land pollution caused by waste disposal and negligent practices. This approach aims to account for the environmental harm caused by pollutants, encouraging industries and individuals to reconsider their waste generation and disposal methods. Through pricing, the goal is to incentivise the adoption of sustainable and eco-friendly practices, discouraging activities that contribute to land pollution, and ultimately promoting a more responsible and conscientious approach towards waste management for the preservation of our natural landscapes.

3.6.9.2 Calculation Logic

Impact = Sum of measured pollutant per country on land x specific value factor of the pollutant per the land

Recipe

NEEDS Project

Midpoint

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- Forest conversion into agriculture (AGF): a measure of the release of carbon dioxide from the burning of forests or from the decomposition of organic matter in the soil after deforestation.
- Change in carbon storage in soil (SS): a measure of the change in the amount of carbon stored in the soil due to LUC.
- Loss of carbon stock in peatland (CL): a measure of the loss of carbon stock from peatlands, which are a type of wetland that stores large amounts of carbon.
- Change in methane emissions from rice cultivation (CH4-RICE): a measure of the change in methane emissions from rice cultivation, which is a major source of methane emissions from agriculture.
- Change in nitrous oxide emissions from agriculture (N2O-AG): a measure of the change in nitrous oxide emissions from agriculture, which is another major source of greenhouse gas emissions from agriculture.

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3.6.9.3 Environmental Prices

Tabel 5 - Milieuprijzen voor de emissies naar boden, in €$_{2021}$/kg

	Onder	Centraal	Boven
Antimoon (Sb)	€ 7,08	€ 26,3	€ 96,2
Antraceen	€ 0,176	€ 0,249	€ 0,322
Arseen (As)	€ 26,6	€ 229	€ 1.204
Barium (Ba)	€ 21,2	€ 35,1	€ 66,1
Benzo(a)antraceen	€ 0	€ 0,324	€ 0,420
Benzo(a)pyreen	€ 2,06	€ 3,04	€ 4,58
Cadmium (Cd)	€ 12,8	€ 3.049	€ 15.520
Chroom (Cr) (III)	€ 0,00374	€ 0,0135	€ 0,0435
Fenantreen	€ 0,042	€ 0,0595	€ 0,0769
Fluoranteen	€ 0,19	€ 0,27	€ 0,356
Kobalt (Co)	€ 0,000822	€ 0,095	€ 0,554
Koper (Cu)	€ 0,0242	€ 0,591	€ 2,94
Kwik (Hg)	€ 2,32	€ 382	€ 1.948
Lood (Pb)	€ 1,33	€ 31,6	€ 161
Molybdeen (Mo)	€ 6,28	€ 38,4	€ 195
Naftaleen	€ 0,053	€ 4,09	€ 6,16
Nikkel (Ni)	€ 7,63	€ 59,3	€ 377

[12] Bij de selectie van stoffen hebben we ons laten leiden door een verkennende analyse van de milieuschade door afval, zie (CE Delft, 2022a). Bij de milieuprijzen naar de bodem zijn er geen IQ-effecten gemonetariseerd.

	Onder	Centraal	Boven
Seleen (Se)	€ 0,00545	€ 0,208	€ 1,17
Tin (Sn)	€ 0,000211	€ 0,0711	€ 0,419
Vanadium (V)	€ 0,314	€ 2,19	€ 10,2
Zink (Zn)	€ 0,0717	€ 1.081	€ 5.502

Emissies naar bodem geven alleen effecten op menselijke gezondheid en ecosystemen. Bij de effecten op menselijke gezondheid is geen inschatting gemaakt van de effecten op het IQ.

[Source: CE Delft, Environmental Prices, 2023, Table, pp. 33-34.]

Table 7 **Environmental prices for key emissions to the soil (€$_{2015}$ per kg emission)**

Pollutant	Lower	Central	Upper
Cadmium	€ 11.2	€ 1151	€ 3533
Arsenic*	€ 10	€ 37.7	€ 95.3
Lead*	€ 0.0497	€ 8.01	€ 24.6
Mercury*	€ 400	€ 816	€ 1673
Nickel	€ 0.0157	€ 0.206	€ 0.546
Formaldehyde	€ 0.699	€ 0.956	€ 1.48
P-fertilizer	€ 0.0132	€ 0.0987	€ 0.112
N-fertilizer	€ 0.227	€ 0.227	€ 0.227

* These values do not include loss of IQ associated with soil pollution.

[Source: CE Delft, Environmental Prices, 2016, Table, p. 35]

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3.6.10 EPS, Chalmers (Environmental Prices)

3.6.10.1 Introduction

Land use typically includes transformation, with impacts allocated across the entire use period following the IUCN land use categories.

Land use activity	Unit
Residential & commercial developments in cities > 0.5 million inhabitants	
Housing and urban areas, arable land	m^2 year
Housing and urban areas, forestland	m^2 year
Housing and urban areas, impediment	m^2 year
Commercial & industrial areas, arable land	m^2 year
Commercial & industrial areas, forestland	m^2 year
Commercial & industrial areas, impediment	m^2 year
Tourism & recreational areas	m^2 year
Residential & commercial developments in rural and cities < 0.5 million inhabitants	
Housing and urban areas, arable land	m^2 year
Housing and urban areas, forestland	m^2 year
Housing and urban areas, impediment	m^2 year
Commercial & industrial areas, arable land	m^2 year
Commercial & industrial areas, forestland	m^2 year
Commercial & industrial areas, impediment	m^2 year
Tourism & recreational areas	m^2 year
Agriculture and Aquaculture	
Annual&perennial non-timber crops	m^2 year
Wood & pulp plantations	m^2 year
Livestock farming and ranching	m^2 year
Marine and freshwater aquaculture	kg produced
Energy production and mining	
Oil and gas drilling	kg produced
Mining and quarrying	m^2 year
Renewable energy	m^2 year
Transportation and service corridors	
Roads and railroads	m^2 year
Utility and service lines	m^2 year
Biological resource use	
Logging and wood harvesting	m^2 year

['in cities with > 0.5 million inhabitants' in Source Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 217]

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Cities with > 0.5 million inhabitants

Environmental good	Impact indicator	Unit	Pathway
human health	YLL	personyears	urban heat islands
human health	working capacity	personhours	heat stress
crop	production capacity	kg	land occupation
wood	production capacity	m^3	land occupation
drinking water	production capacity	m^3	land occupation
biodiversity	share of threat to redlisted species	dimensionless	land occupation

[Impact Pathway 'in cities with > 0.5 million inhabitants' in Source Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 218]

3.6.10.2 Calculation Logic

Impact factors and monetary values vary by development area type; see Table 14.3 for housing/urban areas and Table 14.4 for all areas in large cities.

Cities with > 0.5 million inhabitants

- Heat Stress and Cold Moderation: In large cities, heat islands cause a 1.5°C temperature increase. This translates to an extra 4.51E+05 Years of Life Lost (YLL) per year for 25% of the global population living in large cities.
- Decreased Working Capacity: Urban heat islands decrease working capacity by an estimated 1.25% globally.
- Decreased Crop Production: Building on agricultural land reduces crop production by an average of 0.6 kg/m2 per year.
- Decreased Wood Production: Building on forest land reduces wood production by an average of 0.0006 m3/m2 per year.
- Decreased Drinking Water Production: Urban areas lose their natural water filtration capacity, with an estimated loss of 0.308 m3/m2 of drinking water production per year.
- Decreased Biodiversity: Residential and commercial development threatens 2.60E-13 and 1.30E-13 shares of red-listed species per square meter per year, respectively.

Cities with < 0.5 million inhabitants

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Environmental impact factors and monetary impact values for housing and urban areas built on arable land

Environmental good	Impact indicator	Unit	Pathway	Environmental impact factor	Uncertainty	Indicator value ($/unit)	Impact value ($/m² year)
human health	YLL	personyears	urban heat islands	1.10E–06	± 6.5E–07	107,067	1.18E–01
human health	working capacity	personhours	heat stress	3.21E–01	± 1.9E–01	30	9.64E+00
crop	production capacity	kg	land occupation	6.00E–01	2	0.289	1.73E–01
wood	production capacity	m^3	land occupation	0	2	72	0
drinking water	production capacity	m^3	land occupation	3.08E–01	3	1.87	5.76E–01
biodiversity	share of threat to redlisted species	dimensionless	land occupation	2.60E–13	3	7.61E+10	1.98E–02
						sum	1.05E–01

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 221]

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Environmental impact factors and monetary impact values for residential & commercial developments in cities with > 0.5 million inhabitants

Land use activity	Unit	Environmental impact factors						Impact value ($/m² year)
		YLL/unit	Working capacity (p-yr/unit)	Crop (kg/unit)	Wood (m3/unit)	Drinking water (m3)	Biodiversity (dimension-less)	
Residential & commercial developments in cities > 0.5 million inhabitants								
Housing and urban areas, arable land	m² year	1.10E–06	3.21E–01	6.00E–01		3.08E–01	2.60E–13	1.05E+01
Housing and urban areas, forestland	m² year	1.10E–06	3.21E–01		6.00E–04	3.08E–01	2.60E–13	1.04E+01
Housing and urban areas, impediment	m² year	1.10E–06	3.21E–01			3.08E–01	2.60E–13	1.03E+01
Commercial & industrial areas, arable land	m² year	1.10E–06	3.21E–01	6.00E–01		3.08E–01	1.30E–13	1.05E+01
Commercial & industrial areas, forestland	m² year	1.10E–06	3.21E–01		6.00E–04	3.08E–01	1.30E–13	1.04E+01
Commercial & industrial areas, impediment	m² year	1.10E–06	3.21E–01			3.08E–01	1.30E–13	1.03E+01
Tourism & recreational areas	m² year	1.10E–06					9.25E–14	1.25E–01

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 222]

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Environmental impact factors and monetary impact values for residential & commercial developments in cities > 0.5 million inhabitants

Land use activity	Unit	Environmental impact factors						Impact value ($/m² year)
		YLL/unit	Working capacity (p-yr/unit)	Crop (kg/unit)	Wood (m3/unit)	Drinking water (m3)	Biodiversity (dimension-less)	
Residential & commercial developments in rural and cities < 0.5 million inhabitants								
Housing and urban areas, arable land	m² year	7.35E–07	2.14E–01	6.00E–01		3.08E–01	2.60E–13	7.27E+00
Housing and urban areas, forestland	m² year	7.35E–07	2.14E–01		6.00E–04	3.08E–01	2.60E–13	7.14E+00
Housing and urban areas, impediment	m² year	7.35E–07	2.14E–01			3.08E–01	2.60E–13	7.10E+00
Commercial & industrial areas, arable land	m² year	7.35E–07	2.14E–01	6.00E–01		3.08E–01	1.30E–13	7.26E+00
Commercial & industrial areas, forestland	m² year	7.35E–07	2.14E–01		6.00E–04	3.08E–01	1.30E–13	7.13E+00
Commercial & industrial areas, impediment	m² year	7.35E–07	2.14E–01			3.08E–01	1.30E–13	7.09E+00
Tourism & recreational areas	m² year	7.35E–07					9.25E–14	8.57E–02

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 223]

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Environmental impact factors and monetary impact values for various land use categories

Land use activity	Unit	Environmental impact factors						Impact value ($/m² year)
		YLL/unit	Working capacity (p-yr/unit)	Crop (kg/unit)	Wood (m³/unit)	Drinking water (m³)	Biodiversity (dimension-less)	
Agriculture and Aquaculture								
Annual & perennial non-timber crops	m² year						1.07E–14	8.16E–04
Wood & pulp plantations	m² year						2.00E–14	1.52E–03
Livestock farming and ranching	m² year						3.33E–15	2.54E–04
Marine and freshwater aquaculture	kg produced						6.27E–14	4.77E–03
Energy production and mining								
Oil and gas drilling	kg produced						4.99E–16	3.79E–05
Mining and quarrying	m² year				6.00E–04	3.08E–01	6.86E–14	6.24E–01
Renewable energy	m² year						2.95E–15	2.24E–04
Transportation and service corridors								
Roads and railroads	m² year			6.00E–01		3.08E–01	4.01E–12	1.05E+00
Utility and service lines	m² year				6.00E–04		1.71E–15	4.33E–02
Biological resource use								
Logging and wood harvesting	m² year						3.76E–15	2.86E–04

[Source: Bengt Steen, Monetary Valuation of Environmental Impact, Models and Data, CRC Press, 2020, p. 225]

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3.6.10.3 Data Sources

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3.6.11 Analysis

Transparent approach considers economic productivity, property values, and human health impacts, with monetized impact calculated using value factors. It implicitly applies monetary valuation techniques and considers the allocation of impacts based on economic or physical allocation.

VBA approach assesses economic costs, health impacts, and a wide range of land use types, with valuation techniques including WTP and adjustments based on PPP. It intends to consider health impacts and allocates impacts based on economic or physical allocation.

GIST Impact approach focuses on assessing impacts on ecosystem services, cultural aspects, and habitat, utilising GIS processing and economic proxies for specific ecosystem services. Health impacts are not explicitly considered, and cultural values are one of the assessed factors.

WifOR Institute approach for land use impact assessment, emphasises economic costs, health impacts, and cultural values, with monetized impact calculated using a multiplicative model. It considers country-specific data and does not explicitly address health impacts, while cultural values are one of the assessed factors.

Factors Considered: All distributors consider multiple factors beyond just economic costs, including human health impacts and various aspects of land use such as recreation, cultural values, and ecosystem services.

Inconsistent Consideration of Health Impacts: The consideration of health impacts varies across distributors, with some explicitly addressing them while others do not. This inconsistency indicates a potential gap in understanding the full scope of the health consequences associated with land use change, which could lead to incomplete assessments of its overall impact.

Explicit Consideration of Cultural Values: While some distributors mention considering cultural values as one of the assessed factors, it is not explicitly addressed by others. This

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gap suggests a potential oversight in recognising the importance of cultural ecosystem services and the impacts of land use change on communities and societies.

Lack of Clarity on Valuation Techniques: While all distributors imply the use of valuation techniques to monetize impacts, not all explicitly mention the specific techniques employed. This lack of clarity could hinder transparency and comparability across assessments, making it difficult to fully understand and interpret the monetary values assigned to land use impacts.

Allocation of Impacts: While some distributors mention the allocation of impacts based on economic or physical allocation, others do not address this aspect. This gap could lead to inconsistencies in how impacts are distributed among different stakeholders or geographic regions, potentially skewing the overall assessment results.

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3.7 Biodiversity

Disclaimer: guidance on this indicator is not yet available based on piloting experience. It will be integrated with results from corporate experience.

3.7.1 Challenge

Sustaining nature is critical for economic prosperity and human welfare. It is incumbent upon both individuals and corporations to address critical ecosystems and services, maintaining and regulating the stability and resilience of the planet's environment. The challenge is to reduce risks of abrupt environmental changes that could jeopardise the ability of human civilisation to flourish.

The main claim of the planetary boundaries concept is that there are nine critical Earth system processes that regulate the stability and resilience of the planet's environment, and if these boundaries are exceeded, it could lead to abrupt environmental changes and jeopardise the ability of human civilisation to thrive.

The challenge for nature and biodiversity underscores the critical need to integrate ecosystem and biodiversity values into national and local planning, development processes, and poverty reduction strategies, aligning with SDG 15: Life on Land (Target 15.9). It may be to some extent connected to enhancing education, awareness, and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning, as outlined in SDG 13: Climate Action (Target 13.4), but goes beyond to substantially reduce waste generation through prevention, reduction, recycling, and reuse (SDG 12: Responsible Consumption and Production; Target 12.5).

The Global Assessment Report on Biodiversity and Ecosystem Services, the UN Biodiversity Lab, and the Final Report of The Economics of Biodiversity: The Dasgupta Review collectively provide comprehensive insights into biodiversity conservation and ecosystem management. The Global Assessment Report offers a detailed examination of global biodiversity trends and their implications for ecosystems and human well-being. Meanwhile, the UN Biodiversity Lab provides valuable geospatial data and tools to support decision making and policy formulation aimed at biodiversity conservation. Additionally, The Economics of Biodiversity: The Dasgupta Review offers an in-depth analysis of the economic aspects of biodiversity, highlighting the critical role of nature in sustaining economic prosperity and human welfare. Together, these reports offer a holistic understanding of the challenges facing biodiversity and provide essential guidance for policymakers, stakeholders, and communities to implement effective strategies for biodiversity conservation and sustainable development.

Underestimating Nature's True Value:	Traditional economic models fail to properly account for the benefits provided by nature, leading to its undervaluation and unsustainable exploitation.
Dependencies:	Dependencies on nature and the services it provides to people and the economy are often poorly understood within corporate accounting and decision making. Risks arising from the loss of biodiversity and the loss of the ecosystem services nature provides are identified by NGFS as a systemic risk to the financial system. The Taskforce on Nature-related Financial Disclosure (TNFD) has developed a framework to assess and address such financial risks from a perspective of financial institutions and corporates.

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Incentive Misalignment:	Current economic systems incentivise activities that deplete biodiversity, lacking mechanisms to reward its conservation and sustainable use.
Knowledge Gaps:	Gaps in scientific understanding and data on biodiversity limit our ability to accurately assess its value and inform effective policies.
Unprecedented Decline of Nature:	Alarming rate of biodiversity loss, which it claims is "unprecedented" in human history. It states that around one million species are threatened with extinction, and ecosystem services are rapidly declining.
Accelerating Extinction Rates:	Not only is biodiversity loss extensive, but the rate of decline is also accelerating. The report emphasises that current trends, driven by factors like habitat loss, climate change, and unsustainable resource use, will worsen without urgent action.
Transformational Change Needed:	To address these challenges, the report emphasises the need for "transformational change" across numerous societal and economic systems. This includes transforming production and consumption patterns, reforming financial and economic systems, and strengthening global cooperation for sustainable development.

3.7.2 Activity Data

23 Targets and related indicators of the The Kunming-Montreal Global Biodiversity Framework (GBF). https://www.cbd.int/gbf/targets

3.7.2.1 Reducing threats to biodiversity

TARGET 1: Plan and Manage all Areas to Reduce Biodiversity Loss

"… bring the loss of areas of high biodiversity importance, including ecosystems of high ecological integrity, close to zero by 2030 …"

TARGET 2: Restore 30% of all Degraded Ecosystems

"Ensure that by 2030 at least 30 per cent of areas of degraded terrestrial, inland water, and marine and coastal ecosystems are under effective restoration …"

TARGET 3: Conserve 30% of Land, Waters and Seas

"Ensure and enable that by 2030 at least 30 per cent of terrestrial and inland water areas, and of marine and coastal areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed …"

TARGET 4: Halt Species Extinction, Protect Genetic Diversity, and Manage Human-Wildlife Conflicts

TARGET 5: Ensure Sustainable, Safe and Legal Harvesting and Trade of Wild Species

TARGET 6: Reduce the Introduction of Invasive Alien Species by 50% and Minimize Their Impact

TARGET 7: Reduce Pollution to Levels That Are Not Harmful to Biodiversity

TARGET 8: Minimize the Impacts of Climate Change on Biodiversity and Build Resilience

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3.7.2.2 Meeting people's needs through sustainable use and benefit-sharing

TARGET 9: Manage Wild Species Sustainably to Benefit People

TARGET 10: Enhance Biodiversity and Sustainability in Agriculture, Aquaculture, Fisheries, and Forestry

TARGET 11: Restore, Maintain and Enhance Nature's Contributions to People

TARGET 12: Enhance Green Spaces and Urban Planning for Human Well-Being and Biodiversity

TARGET 13: Increase the Sharing of Benefits from Genetic Resources, Digital Sequence Information and Traditional Knowledge

3.7.2.3 Tools and solutions for implementation and mainstreaming

TARGET 14: Integrate Biodiversity in Decision-Making at Every Level

TARGET 15: Businesses Assess, Disclose and Reduce Biodiversity-Related Risks and Negative Impacts

TARGET 16: Enable Sustainable Consumption Choices to Reduce Waste and Overconsumption

TARGET 17: Strengthen Biosafety and Distribute the Benefits of Biotechnology

TARGET 18: Reduce Harmful Incentives by at Least $500 Billion per Year, and Scale Up Positive Incentives for Biodiversity

TARGET 19: Mobilize $200 Billion per Year for Biodiversity from all Sources, Including $30 Billion Through International Finance

TARGET 20: Strengthen Capacity-Building, Technology Transfer, and Scientific and Technical Cooperation for Biodiversity

TARGET 21: Ensure That Knowledge is Available and Accessible to Guide Biodiversity Action

TARGET 22: Ensure Participation in Decision-Making and Access to Justice and Information Related to Biodiversity for all

TARGET 23: Ensure Gender Equality and a Gender-Responsive Approach for Biodiversity Action

3.7.3 Transparent

The scope of the NCMA methodology includes the principal natural capital assets of air, water, land and biodiversity, and the ecosystem services they provide. Because businesses measure the drivers that impact these assets and the people depending on them, the methodology is structured according to impact drivers as shown in the figure below. Impact drivers in blue boxes are addressed in detail in the NCMA methodology, greyed boxes, as well as ecosystem services are not explicitly modelled in the NCMA methodology.

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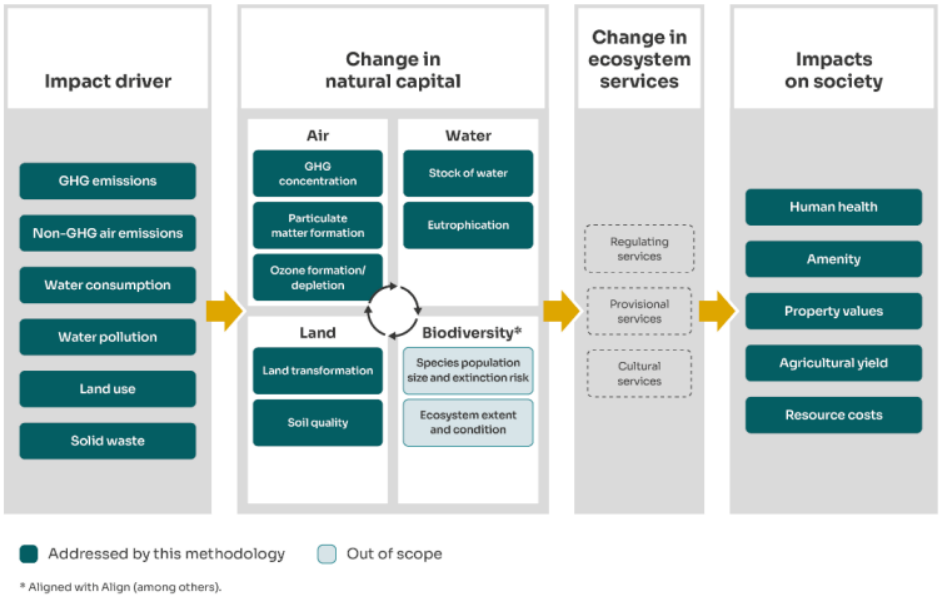
(NCMA methodology, page 7)

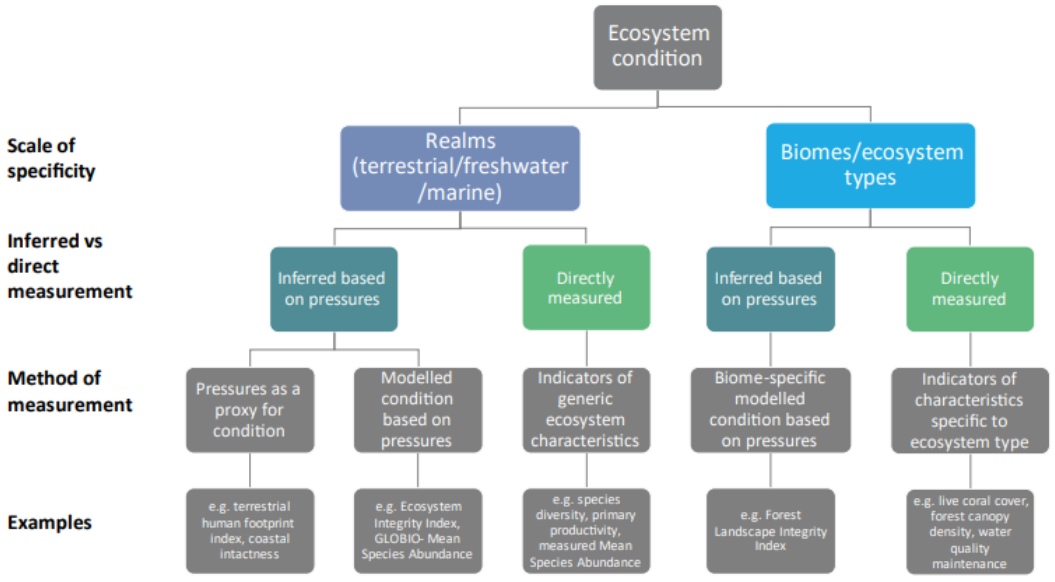
Figure 2. Relation between impact drivers, impact pathways, and the value to society perspective



This is an illustration of impact pathways. All ecosystem services are underpinned by ecosystem assets, whereby changes in the assets lead to changes in the ecosystem services, which eventually impact societies.

[Source: Biodiversity / Transparent]

3.7.4 ALIGN



[Source: ALIGN https://capitalscoalition.org/wp-content/uploads/2023/10/Align_eco_condition_primer.pdf]

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3.7.5 WifOR Institute (Environmental Prices)

3.7.5.1 Introduction

Biodiversity, a cornerstone of our planet's resilience, presents a formidable challenge when attempting to quantify its value and assess the repercussions of human activities. This document navigates the intricate landscape of biodiversity valuation and impact assessment methodologies, spotlighting Steen's model that endeavours to gauge the significance of various human actions in biodiversity decline. Delving into the costs associated with conserving biodiversity on a global scale, this exploration elucidates the quantifiable environmental impact factors linked to activities affecting endangered species. Recognising the need for localised considerations, it addresses the disparities across regions and the evolving nature of assessment methods, emphasising the ongoing quest for refinement in evaluating the immense worth of Earth's biodiversity.

3.7.5.2 Activity Data Source

- No physical data for biodiversity itself
- Activities that threaten biodiversity are air pollution, water pollution, and land use (sources for these activities are listed above)
- Direct impact drivers of biodiversity loss as identified by the IPBES Global Assessment Report (2019):
    1) Climate change
    2) Land use change freshwater use - change and sea use change
    3) Direct exploitation
    4) Invasive alien species
    5) Pollution
    6) Others

3.7.5.3 Subcategories

None

3.7.5.4 Formula

- Additive multiplicative: Monetized impact = Sum of biodiversity-threatening activity x value factor
- Country-specific value factors (per activity)

3.7.5.5 Impact Pathway

Impact pathways for biodiversity are largely unclear; valuation based on impacts of human activities on threatened species.

3.7.5.6 Valuation Method

The valuation method is based on the biodiversity conservation costs: The necessary costs to prevent biodiversity from declining. These costs are distributed to different countries and sectors depending on what proportion of species-threatening activities a sector causes and how many species are threatened in a given country (as a percentage of global threatened species and relative to average country in the world).

3.7.5.7 Sources of Valuation Data

- ESVD: https://www.esvd.net/
- Steen (2020)
- Deutz et al. (2020)
- IUCN (2022)

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3.7.5.8 Geographical Differences
Based on threatened species per country.

3.7.5.9 Transfer Mechanism
Values in USD. No adjustment for PPP.

3.7.5.10 Biodiversity Specific
There is no underlying physical biodiversity indicator.

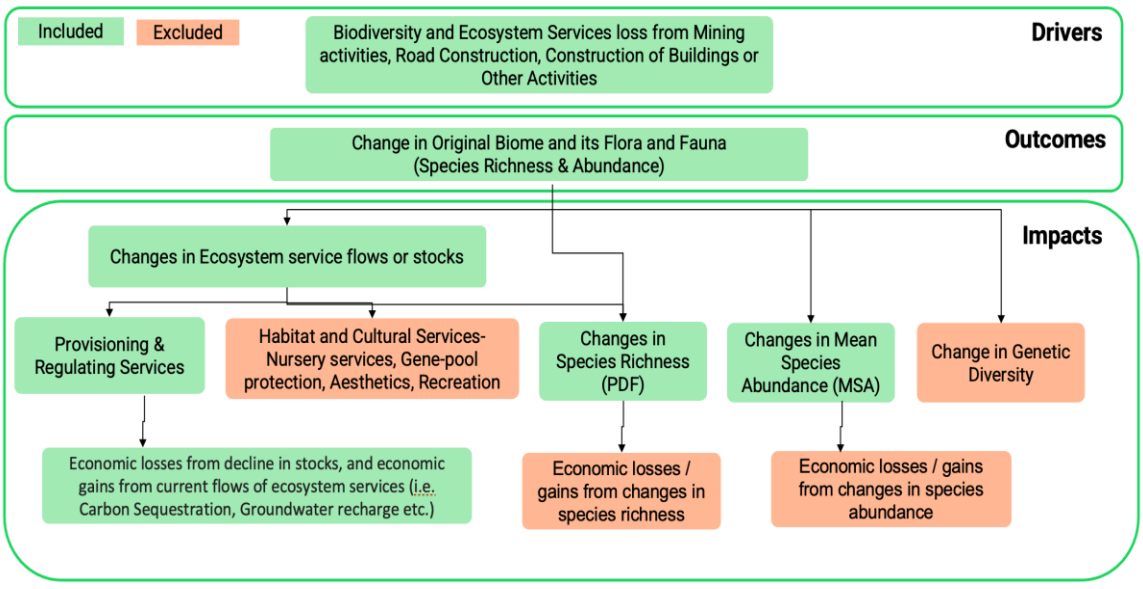
3.7.5.11 Global Damage
USD 3.75 Trillion (2020)

3.7.5.12 Environmental Prices
WifOR Institute: https://www.wifor.com/en/impact-valuation-factors/

3.7.6 GIST Impact

3.7.6.1 Evaluation Framework and Methodology
GIST Impact's biodiversity impacts framework defines all material elements to be captured at different tiers of biodiversity, i.e. ecosystem services, and at species level. It covers both **flows** from owned or operated natural areas as well **changes in stocks** due to business activities. All companies in all sectors can use the framework (i.e. it is universal), and it is comprehensive, i.e. it covers all material third-party impacts (so-called externalities). However, different use cases and sectors will explore and estimate its elements to different degrees of depth. For example, the species tier element for a **national park** with public access may apply the travel cost method (TCM) to estimate its eco-tourism benefits and surpluses, whereas a **technology** firm will naturally ignore that element. Conversely, a technology firm will estimate in depth its **indirect impacts** on nature from fossil fuel usage and GHG emissions, while they would not even touch a TCM calculation. The species-focused tier of the framework captures the impacts of business activities on species **richness** and **abundance**, which are widely used metrics to define species biodiversity.

GIST Impacts Biodiversity Framework (Source: GIST Impact, 2023)



[Source: Biodiversity / GIST Impact]

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Thus, one of the key features of this framework is that it goes beyond direct drivers (such as land transformation, habitat fragmentation, hunting, etc.) to indirect impact drivers, including pressure indicators such as greenhouse gas emissions (GHGs), water extraction, water & land pollution (Nitrogen & Phosphorus), air emissions (such as oxides of Nitrogen and Sulphur) and impacts from end treatment or disposal of hazardous and non-hazardous waste.

3.7.6.2 Calculation Logic

Ecosystem level calculations are based on the evaluation framework and the approach highlighted in the section on land use. Land use is a key driver for the loss of ecosystems and habitats and, thus, change in the stocks or flows of ecosystem services. Any land transformation from original landscape to a new land use form will lead to a certain loss of ecosystem services, which is first captured in a traditional unit of measurement, e.g. tonnes of CO_2 sequestration loss, followed by applying an economic proxy, such as social cost of carbon in this particular case. The approach is also applicable for land occupation impact driven by business activities.

Species-level biodiversity can be affected both by direct and indirect drivers. The direct drivers such as land transformation, habitat fragmentation, hunting, etc. can have immediate impact on biodiversity and are associated with business activities that are typically directly involved in activities leading to land transformation or occupation. The indirect impact drivers include pressure indicators such as greenhouse gas emissions (GHGs), water extraction, water & land pollution (Nitrogen & Phosphorus), air emissions (such as oxides of Nitrogen and Sulphur) and impacts from end treatment/disposal of waste. The indirect impact drivers may not have immediate impacts on biodiversity, but the impacts they do have are significant. Most companies can have a combination of both direct and indirect impacts on biodiversity.

Business Life-Cycle Impact Assessments (LCIA) are used to calculate the impacts of a business on ecosystem quality. This is done by first quantifying a standard set of drivers at an asset or company level. These drivers (for example, m^3 of water used or kg NO_x emitted) can in turn be converted to an endpoint metric that is consistent across all drivers (in this case, the Potentially Disappeared Fraction, or PDF, of species). Note that we currently use no economic proxy to value the loss of species richness or increase in the extinction risk to species.

Species abundance is measured through the approach proposed by Globio 4, which also measures the change in the status of biodiversity over some time from drivers including land use, land cover, road disturbance, habitat fragmentation, atmospheric nitrogen deposition, climate change and hunting. Mean Species Abundance (MSA) is used as a metric to assess the change in abundance over a period of time. It should be noted that we currently use no economic proxy to value the change in MSA levels.

3.7.6.3 Data Sources[12]:

- Arets, E. J. (2011). Global wood production: assessment of industrial round wood supply from forest management systems in different global regions. *Alterra*.
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[12] The reference list is intentionally limited for confidentiality reasons.

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3.7.7 VBA

Biodiversity topics are covered in the methodology through other impact drivers such as land use, water consumption, water pollution, waste, other air emissions and greenhouse gas emissions. The reason is that each of these impact drivers produces effects on biodiversity. Therefore, biodiversity effects are seen as final impacts rather than specific impact drivers of corporate activity. Recently, impact pathways for forest resource use and invasive alien species have been developed in order to cover all impact drivers for biodiversity loss identified by IPBES (2019), as required by ESRS. The impact pathways are being tested within the current VBA piloting.

3.7.8 Analysis

WifOR Institute utilises an additive multiplicative model to quantify the environmental impact of activities threatening biodiversity, such as air and water pollution and land use, providing country-specific value factors for these activities. Its valuation method is based on biodiversity conservation costs, distributing costs to different countries and sectors based on the percentage of globally threatened species and the severity of activities causing threats, with values assigned in USD without adjustment for purchasing power parity.

GIST Impact employs a comprehensive framework covering both direct and indirect drivers of biodiversity loss, including factors like greenhouse gas emissions, water and land pollution, and habitat destruction, utilising Life-Cycle Impact Assessments (LCIA) to quantify impacts on ecosystem quality. It draws from various studies and sources related to biodiversity impacts and focuses more on quantifying impacts rather than economic valuation, although it considers proxies like the social cost of carbon for assessing losses in ecosystem services.

Both WifOR Institute and GIST Impact aim to assess and quantify the impacts of human activities on biodiversity. They both consider a range of activities threatening biodiversity, such as air and water pollution, land use, and habitat destruction. Additionally, both frameworks utilise data from various sources to inform their assessments, although they differ in the specifics of their data sources and methodologies. Despite their differences, both WifOR Institute and GIST Impact contribute to ongoing efforts to understand and address the complex challenges facing global biodiversity conservation.

While both WifOR Institute and GIST Impact share commonalities in their aim to assess biodiversity impacts, several gaps exist in their approaches. Firstly, both frameworks focus heavily on quantifying the environmental impacts of human activities but may lack a comprehensive consideration of socioeconomic factors that influence biodiversity conservation efforts. Additionally, neither framework explicitly incorporates dynamic ecosystem processes or feedback loops that may affect biodiversity outcomes over time. Furthermore, there may be limitations in the geographical coverage and specificity of their assessments, potentially overlooking localised nuances in biodiversity threats and conservation needs.

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SOCIAL

3.8 Occupational Health and Safety

3.8.1 Challenge

Assessing the impact of occupational health and safety involves a comprehensive examination of the societal consequences arising from work-related incidents and illnesses. The key focus is on quantifying reported cases of work-related injuries and diseases, categorised by absence duration (short, long, partial incapacity, full incapacity, fatality), and analysed on a country-specific basis. The significance of this assessment lies in its ability to gauge the direct effects on the employer company, including lowered productivity, increased costs, and potential reputational damage – all of which contribute to diminished financial performance. Additionally, the indirect impacts extend to employees' families, local communities, and society at large, leading to heightened healthcare and administrative costs due to the utilisation of medical resources, reduced revenues, reduced purchasing power, and an overall decline in the quality of life. This evaluation is crucial for fostering a safer and more secure working environment while addressing the broader societal implications associated with occupational health and safety incidents. For a detailed understanding of the methodology employed in this assessment, please refer to the accompanying documentation.

In the context of occupational health and safety, the principles mentioned align with SDG 8, emphasising the protection of labour rights and the promotion of safe and secure working environments for all workers, including those in the informal economy (Target 8.8). Additionally, SDG 9 underscores the importance of enhancing infrastructure resilience, including investing in early warning systems to mitigate the adverse impacts of climate change and natural disasters on workers and workplaces (Target 9.5). These targets intersect with SDG 11, which seeks to reduce the adverse environmental impacts of cities, including aspects related to air quality and waste management, crucial for safeguarding occupational health (Target 11.6).

The Global Burden of Occupational Disease (GBOD) 2020 report by the WHO and the ILO provides a comprehensive assessment of the health impacts resulting from occupational hazards worldwide. Eurostat's European Statistics on Occupational Accidents and Diseases (ESAPOD) 2021 offers valuable insights into occupational safety and health trends specifically within the European Union. Additionally, the Annual Survey of Occupational Safety and Health Statistics (ISSA) 2022, conducted by the International Social Security Association (ISSA), provides crucial data on workplace accidents and illnesses globally. Furthermore, the ILOOSH Statistical Update 2022, published by the ILO, offers the latest statistics and trends related to occupational safety and health at the international level. These leading international documents collectively contribute to enhancing our understanding of occupational health and safety issues, facilitating evidence-based policymaking, and promoting initiatives aimed at improving workplace conditions and preventing occupational hazards.

3.8.2 Activity Data

In assessing occupational health and safety impacts, the systematic collection of primary data is imperative, necessitating the quantification of reported work-related injuries and illnesses by their absence duration. Clear differentiation between illness and injury is essential, considering the varying societal costs associated with each. Should the dataset lack this specificity, consultation of regional reporting requirements becomes pivotal to discern relevant cases. The quantification of cases by severity, following the guidelines from Safe Work Australia, further refines the assessment, counting from the first full absence day and excluding instances of short absence. In instances where data gaps persist, estimates can be

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derived by extrapolating based on regional reporting standards and Safe Work Australia's severity definitions. Transparent documentation of assumptions and methodology ensures accuracy and aligns with best practices, supporting a nuanced evaluation of occupational health and safety impacts.

Category label	Severity Category	Definition
Short absence	Less than 5 days off work	A minor work-related injury or illness, involving less than 5 working days absence from normal duties, where the worker was able to resume full duties.
Long absence	Five days or more off work and return to work on full duties	A minor work-related injury or illness, involving 5 or more working days and less than 6 months off work, where the worker was able to resume full duties.
Partial incapacity	Five days or more off work and return to work on reduced duties or lower income	A work-related injury or illness which results in the worker returning to work more than 6 months after first leaving work.[a]
Full incapacity	Permanently incapacitated with no return to work	A work-related injury or disease, which results in the individual being permanently unable to return to work.
Fatality	Fatality	A work-related injury or disease, which results in death.

[a] We assume cases in this category result in a return to work on reduced duties or income, with a resumption of normal duties. This category includes permanent incapacities for which a minimal duration of absence from work occurred and therefore the worker was able to return to work in some capacity, or for which a return to work in some capacity is possible.

Figure 1 definition and labelling of severity categories- (source: Safe Work Australia, 2015)

3.8.3 Databases

The ILO's Occupational Safety and Health (OSH) Data Portal	https://www.ilo.org/global/standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm
The National Institute for Occupational Safety and Health (NIOSH)'s Occupational Safety and Health Database (OSH Database):	https://www.cdc.gov/niosh/index.htm
The European Agency for Safety and Health at Work (EU-OSHA)'s Occupational Safety and Health Data Portal:	https://osha.europa.eu/en

3.8.4 WifOR Institute

3.8.4.1 Introduction

Occupational injuries and illnesses refer to health impairments resulting from incidents occurring during employment. These cases encompass fatal and non-fatal injuries affecting employers, employees, and broader society. The negative consequences include various costs such as production and human capital losses, healthcare expenses, administrative burdens, and adverse effects on human well-being and quality of life. The distribution of these costs across stakeholders varies by country and social security system.

3.8.4.2 Activity Data Sources

- ILO (International Labour Organization): Provides estimates for the median age of the labour force by sex (Indicator EAP_2MDN_SEX_NB).

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- WDI (World Development Indicators) database: Offers information on life expectancy at birth, total (years) (Indicator SP.DYN.LE00.IN).
- Eurostat: Offers data on work-related health problems by sex, age, type of problem, accidents at work by type of injury, severity, days lost, and periods off due to health problems (datasets: hsw_pb5, hsw_mi07, hsw_pb3, hsw_mi02).
- Global Burden of Disease Collaborative Network (2020): Global Burden of Disease Study 2019 (GBD 2019) Disability Weights Seattle, United States of America: Institute for Health Metrics and Evaluation (IHME), 2020.

3.8.4.3 Subcategories

Illness: fatal, non-fatal

Injury: fatal, non-fatal

3.8.4.4 Calculation Logic

Simple multiplicative: Monetized impact = Activity data (per subcategory) x value factor

3.8.4.5 Impact Pathway

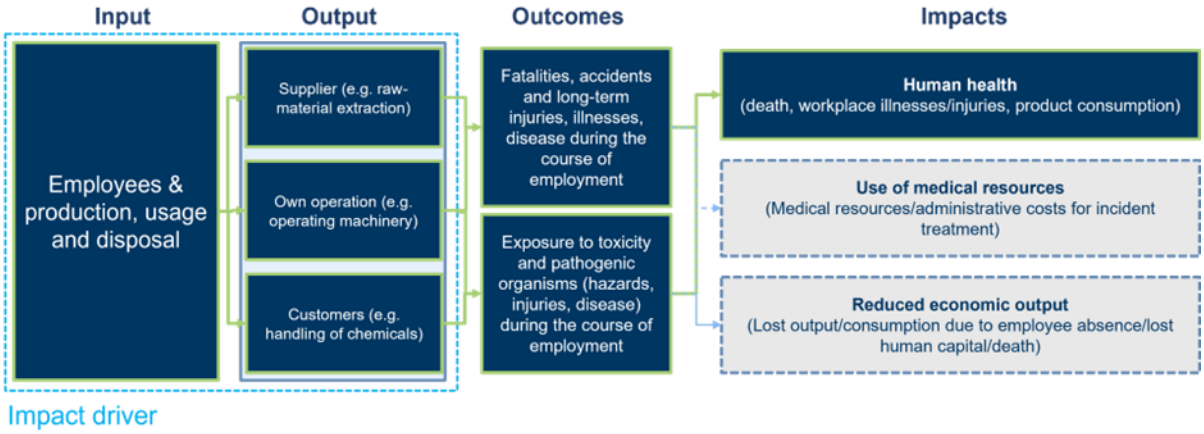

Figure: Simplified impact pathway of Occupational injuries and illnesses

[Source: Occupational Health and Safety / VBA]

3.8.4.6 Valuation Approach

Fatality injuries

$$DALY_fatality = \sum_{x=median\ age\ life\ expectations}^{life\ expectations} \frac{C * x * e^{-\beta x}}{(1+SDR)^{(i-median\ age)}}$$

Valuation of fatal incidents (years of life lost - YLL)

- Estimation of the years of life lost due to premature mortality caused by occupational incidents. This involves calculating the difference between the age of death and life expectancy.
- Applying age weighting to account for different values of years lived without disability across ages.
- Applying a social discount rate (SDR) to future years.

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- C = 0.1658 and β = 0.04 are age-weighting parameters which give higher weight to persons which are closer to the median age.

Non-fatality injuries

$$DALYs = YLD = disability\ weights * \frac{days\ of\ absence}{365} * C * x * e^{-\beta}$$

There is no discounting because only impacts on life quality in the present year are valued.

$$valuation\ of\ the\ mental\ health = \frac{disability\ adjusted\ weights\ DALY}{case} * \frac{Value\ of\ Statistical\ Life\ USD}{DALY}$$

- Valuation of non-fatal incidents (years lived with disability - YLD)
- Estimation of years lived with a disability caused by occupational injuries/illnesses.
- Calculating disability weights based on Eurostat data on diagnoses and severity of health problems.
- Determining the duration of impairment using Eurostat data on the length of absence weighted by the number of cases.
- Provides standardised “disability weights” that reflect the relative severity of a health state.

Calculation of DALYs

- Applying age weighting to both fatal and non-fatal incidents based on the median age of the workforce.
- Computation of DALYs per country using country-specific coefficients influenced by age-weighting and discounting factors.

Valuation of DALYs

Each category of DALYs (fatal incidents, non-fatal injuries, non-fatal illnesses) is valued using an assumed impact of USD200,000 per case.

3.8.4.7 Sources of Valuation Data

- Murray, C.J.L. (1994): “Quantifying the burden of disease: the technical basis for disability-adjusted life years”, in WHO Bulletin OMS, Vol. 72, pp. 429-445.
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- Eurostat (2022c): “Persons reporting a work-related health problem resulting in time off work by period off” [hsw_pb3].
- Eurostat (2022d): “Accidents at work by days lost, sex and age (NACE Rev. 2 activity A, C-N)” [hsw_mi02].

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3.8.4.8 Geographical Differences
Exist due to demographic differences.

3.8.4.9 Transfer Mechanism
We assume a global value of DALYs.

3.8.4.10 Global Damage
USD 14.2 Trillion

3.8.5 Upright Project

3.8.5.1 Introduction
Upright wishes to emphasise that, while the impacts of occupational health and safety are indeed substantial, it is crucial to also acknowledge and comprehend the subsequent health effects of products and services (downstream impacts). Referring to data from the Global Burden of Disease (GBD) database (https://www.healthdata.org/research-analysis/gbd), we observe that occupational diseases contribute to approximately 66 million DALYs. In comparison, tobacco usage is responsible for 228 million DALYs, and dietary risks account for 188 million DALYs.

3.8.5.2 Data Source
Occupational Injury Statistics per Industry from ILOSTAT
The ILO maintains a database called ILOSTAT, which provides comprehensive statistics on occupational injuries categorised by industry sectors. This database contains information regarding the types, frequencies, and severity of injuries or illnesses occurring within different sectors of the workforce.

Occupational Injury Statistics per Industry (from ILOSTAT) Obtain data on occupational injury statistics categorised by industry from the International Labour Organization's (ILO) database, ILOSTAT. This data provides insights into the prevalence and severity of injuries related to various industries.

Global Burden of Diseases (GBD) Database
The Global Burden of Diseases database, accessible at https://www.healthdata.org/research-analysis/gbd, is a valuable resource managed by the Institute for Health Metrics and Evaluation (IHME). This database provides extensive data on the burden of diseases worldwide, offering insights into various health conditions, risk factors, disabilities, injuries, and their impact on populations globally.

Global Burden of Diseases (GBD) data utilise the Global Burden of Diseases database (accessible at https://www.healthdata.org/research-analysis/gbd) to understand the burden of diseases associated with specific risk factors and conditions.

In the field of health and safety, we have used the ILOSTAT datasets to understand the probability of OHS risks per country, for example:

- https://www.ilo.org/shinyapps/bulkexplorer52/?lang=en&id=INJ_FATL_ECO_NB_A
- https://www.ilo.org/shinyapps/bulkexplorer39/?lang=en&id=INJ_NFTL_ECO_NB_A

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3.8.5.3 Calculation Logic

DALY (disability-adjusted life year) cost of USD 12,000 per DALY is a measure that combines years of life lost due to premature mortality and years lived with disability. The assigned cost of 12,000 USD per DALY represents the economic impact associated with this health burden.

Calculation Process

Use occupational injury statistics per industry to estimate the number and severity of injuries or illnesses attributable to particular products or services within each industry sector.

Attribution of Health Impacts

Associate specific health conditions or injuries with products and services based on available data and research. For instance, certain manufacturing processes or services might be linked to particular types of injuries or diseases (e.g. respiratory issues due to exposure to certain chemicals, stress-related mental health issues in specific service industries).

Quantifying the Health Impact

Utilise DALYs as a common measure to quantify the health impact. Multiply the number of injuries or illnesses associated with products and services by the relevant DALY cost (in this case, USD 12,000 per DALY) to estimate the economic impact of these health burdens.

Segmentation by Industry or Product/Service Type

Analyse and segment the health impacts by industry or specific products/services to understand the differential effects across different sectors or offerings.

Comprehensive Analysis

Aggregate the calculated impacts across industries or products/services to obtain an overall assessment of the health impacts attributed to the consumption or utilisation of various goods and services.

Geographic Adjustments

As for the valuation of OHS-related health impacts, the Upright Project uses the same DALY value independent of region. Thus, the geographical difference would only affect the “amount of injuries”, not the value of DALYs.

3.8.6 VBA

3.8.6.1 Introduction

Incidents can occur during operations, and illnesses can arise due to working conditions (e.g. diseases related to dust, noise, or ergonomics). Occupational illnesses and incidents can lead to lower productivity, higher costs, and reputational damage for a company, all of which are reflected in the financial results. However, incidents can also affect employees’ families as well as the broader local communities and society through healthcare and administrative costs, lower tax revenues (and a lower spending), and reduced quality of life.

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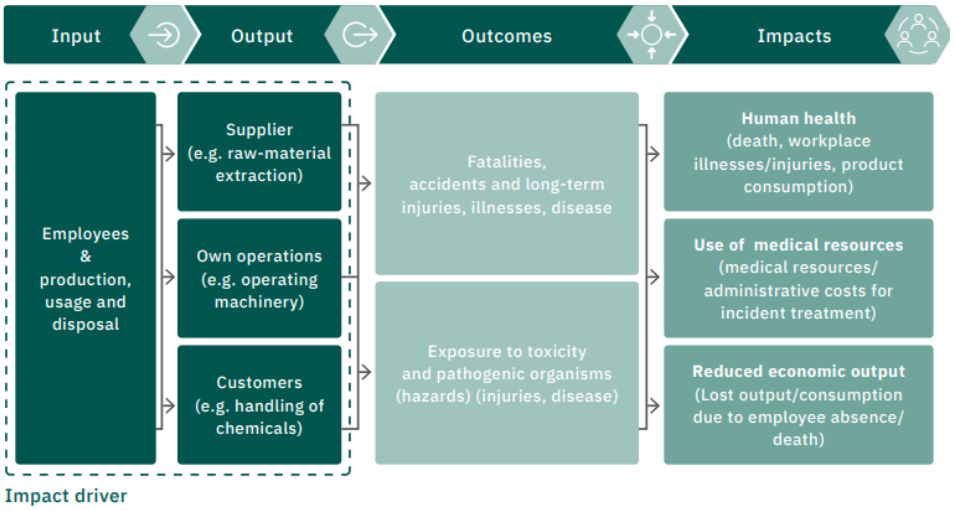

[Source: Occupational Health and Safety / VBA]

3.8.6.2 Data Source

The main data source for the valuation factor is the Safe Work Australia report cited in the methodology: https://www.safeworkaustralia.gov.au/system/files/documents/1702/cost-of-work-related-injury-and-disease-2012-13.docx.pdf

Further adjustments are done based on GNI and inflation, so other statistical information databases are needed (IMF, WB, OECD, etc). Calculation of the impact of occupational health and safety incidents is based on the number of incidents by severity. Our categorisations of severity are based on the Safe Work Australia study:

- Illness by severity: short absence, long absence, partial incapacity, full incapacity, fatality
- Injuries by severity: short absence, long absence, partial incapacity, full incapacity, fatality

Company data should be supplied in this format (i.e. as in Table 1) according to the duration of absence and whether the employee is able to return to full duties. Note that the costs of incidents that do not result in absence from work are assumed to be negligible and are not considered.

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Table 1: Definition and labelling of severity categories.

Category Label	Severity Category	Definition
Short absence	Less than 5 days off work	A minor work-related injury or illness involving less than 5 working days absence from normal duties, where the worker was able to resume full duties
Long absence	Five days or more off work and return to work on full duties	A minor work-related injury or illness involving 5 or more working days and less than 6 months off work, where the worker was able to resume full duties
Partial incapacity	Five days or more off work and return to work on reduced duties or lower income	A work-related injury or disease which results in the worker returning to work more than 6 months after first leaving work*
Full incapacity	Permanently incapacitated with no return to work	A work-related injury or disease which results in the individual being permanently unable to return to work
Fatality	Fatality	A work-related injury or disease which results in death

* We assume cases in this category result in a return to work on reduced duties or income, with a resumption of normal duties. This category includes permanent incapacities for which a minimal duration of absence from work occurred and therefore the worker was able to return to work in some capacity, or for which a return to work in some capacity is possible.

Source: Safe Work Australia (2015)

[Source Safe Work Australia 2015]

3.8.6.3 Calculation Logic

Accumulated by severity category of incidents, country (incidents * value factor)

The valuation is based on a study by Safe Work Australia[13] which derives value factors by:

- Considering total costs for the worker and the community, excluding employers' costs.
- Multiplying costs with number of incidents by severity.
- Extrapolating costs to respective country via GDP per capita, since listed data are for Australia (or if available use medical system situation in different countries).
- Inflation-adjustments, since data is from 2012 / 2013.

13 *The Cost of Work-related Injury and Illness for Australian Employers, Workers and the Community*: 2012–13: https://www.safeworkaustralia.gov.au/system/files/documents/1702/cost-of-work-related-injury-and-disease-2012-13.docx.pdf)

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Table 2: Average costs (AU $ per incident) for work-related incidents, Australia, 2012-13*

		Short absence	Long absence	Partial incapacity	Full incapacity	Fatality	Average
Employee	Injury	700	8 800	16 400	13 400	26 600	**4 400**
	Disease	700	11 200	12 100	31 900	72 400	**9 600**
Worker	Injury	300	4 500	696 900	2 154 200	1 728 700	**52 000**
	Disease	400	4 200	681 800	1 912 000	1 185 500	**189 200**
Community	Injury	3 200	22 800	95 400	1 578 800	585 100	**19 100**
	Disease	5 200	15 200	44 700	956 000	212 700	**24 800**
All	Injury	4 200	36 200	808 600	3 746 400	2 340 400	**75 400**
	Disease	6 300	30 600	738 700	2 899 900	1 470 600	**223 600**
	All cases	**4500**	**34 100**	**766 300**	**3 496 100**	**1 597 100**	**116 600**

*Unit costs are rounded to the nearest AU $100

Source: Safe Work Australia (2015)

[Source Safe Work Australia 2015]

The valuation approach thereby considers treatment costs to society.

- Bearers of the healthcare and administrative costs are employers, workers/family, or community.
- Direct effects on the employer are excluded from the scope as already reflected in financial results (GVA).

The focus of the indicator is limited to indirect societal impacts arising from injuries and illnesses resulting from incidents that happen during employment.

3.8.7 Safe Work Australia (Social Prices)

The study employs a methodology that combines details from new workers' compensation cases for the reference year 2012. This involves estimating the future costs associated with each new case. Additionally, the study incorporates data from the Australian Bureau of Statistics (ABS) Work-related Injuries Survey (WRIS) to enhance the reliability of the estimates.

The use of the incidence approach concentrates on new cases occurring during the reference year, utilising expected future costs to estimate the total costs; the prevalence approach, however, considers all cases, both new and ongoing, at a specific point in time during the reference year, providing a broader perspective on the impact of occupational injuries and illnesses on the system.

Incidence Approach:

The incidence approach focuses on measuring new cases that arise during the reference year. Specifically, it assesses the number of individuals entering the compensation or medical

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systems as a consequence of work-related incidents or illnesses within a particular timeframe. Under this approach, the costs associated with these new cases, encompassing both current and expected future costs, are meticulously evaluated. Given that the incidence approach concentrates solely on new cases, an estimation technique is employed to gauge the total costs. This involves using the expected future cost of new cases throughout their lifetime as a proxy for the cost in the reference year of cases that were already present in the system at the beginning of the current reference year.

Prevalence Approach:
By contrast, the prevalence approach takes a broader perspective by measuring all cases, irrespective of whether new or ongoing, within the system at a specific point in time during the reference year. Rather than focusing exclusively on new incidents, the prevalence approach provides a snapshot of the entire landscape of work-related injuries and illnesses at a given moment. This includes both newly reported cases and those that have persisted from previous years. Consequently, the prevalence approach captures the cumulative effect of incidents, offering a more comprehensive understanding of the overall burden on the compensation or medical systems.

Access Economics (2004) Costs of Workplace Injury and Illness to the Australian Economy: Reviewing the Estimation Methodology and Estimates of the level and distribution of costs, Reports for the National Occupational Health and Safety Commission, March 2004.

Short absence	A minor work-related injury or illness, involving less than 5 working days absence from normal duties, where the worker was able to resume full duties.
Long absence	A minor work-related injury or illness, involving 5 or more working days and less than 6 months off work, where the worker was able to resume full duties.
Partial incapacity	A work-related injury or illness which results in the worker returning to work more than 6 months after first leaving work.
Full incapacity	A work-related injury or disease which results in the individual being permanently unable to return to work.
Fatality	A work-related injury or disease which results in death.

The average cost of a work-related incident was estimated by calculating the average cost associated with each relevant indirect cost item. These costs were then aggregated over each cost item to derive an overall estimate. The total average cost was estimated at AUD 75,400 for injuries and AUD 223,600 for diseases.

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Table 1.9: Average costs ($ per incident) for work-related incidents, Australia, 2012–13[a]

		Short absence	Long absence	Partial incapacity	Full incapacity	Fatality	Average
Employer	Injury	700	8 800	16 400	13 400	26 600	**4 400**
	Disease	700	11 200	12 100	31 900	72 400	**9 600**
Worker	Injury	300	4 500	696 900	2 154 200	1 728 700	**52 000**
	Disease	400	4 200	681 800	1 912 000	1 185 500	**189 200**
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	Disease	6 300	30 600	738 700	2 899 900	1 470 600	**223 600**
	All cases	**4 500**	**34 100**	**766 300**	**3 496 100**	**1 597 100**	**116 600**

Source: ASCC Estimation of indirect cost items (see Appendix 1 for more detail)
[a] Unit costs are rounded to the nearest $100.

[Source https://www.safeworkaustralia.gov.au/system/files/documents/1702/cost-of-work-related-injury-and-disease-2012-13.docx.pdf]

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3.8.8 The European Agency for Safety and Health at Work's (EU-OSHA) report

"The Costs of Occupational Safety and Health in the EU Member States" estimates that the average cost of a workplace injury or illness in the EU in 2019 was €1,910 per 2019.

Table 2.1.6a: Model parameters for sensitivity analysis for Finland

Scenarios	Baseline	Lower limit	Upper limit	Source [1] refers to the baseline value, [2] to the lower limit and [3] to the upper limit
A) High-level economic assumptions				
A.1. Discount rate (%)	3	1	5	[1,2,3]Drummond (2015)
A.2. Productivity growth rate (%)	1	0	2	[1]Tompa et al. (2017), [2,3]this study
B) Incidence inclusion and underreporting rate				
B.1. Injury underreporting rate (more than 3 days lost category) (%)	0	10	20	[1,2,3]This study
B.2. Injuries with more than 3 lost days (% of all)	26	26	26	[1,2,3]Eurostat (2018b)
B.3. Injuries with 1-3 lost days (%)	13	13	13	[1,2,3]Eurostat (2018b)
B.4. Injuries with no lost days (% of all)	Not included	Not included	61	[3]Eurostat (2018b)
B.5. Injury (more than 3 lost days) severity distribution	Finland	Austria	Belgium	[1,2,3]Eurostat (2018a)
B.6. Disease incidence scenarios				[1]Compensated cases, [2]compensated + non-compensated + selected AF cases, [3]only AF cases
Fatal	629	115	629	
Non-fatal diseases	67,797	1,776	484,966	
B.7. Injury and disease incidence (both)	B.4 + B.6	B.4 + B.6	B.4 + B.6	
C) Healthcare costs				
C.1. Healthcare costs of injuries and diseases (% change)	0	-82	81	[1,2,3]This study
D) Productivity losses				
D.1. Fringe/payroll benefit rate (%)	22	20	24	[1]Eurostat lc_lci_lev (2015)
D.2. Annual working days (for productivity/output loss)	205	170	174	[1]OECD, (2015)
D.3. Productivity loss until the age of	65	60	70	[1,2,3]This study
D.4. Wage-replacement rate (%)	80	70	90	[1,2,3]This study
D.5. Consider presenteeism effect for x % of cases	90	80	100	[1]Safe Work Australia (2015), [2,3]this study
D.6. Average informal care time for permanent injuries (days)	225	183	550	[1]Safe Work Australia (2015), [2,3]this study
D.7. Average informal care time for permanent diseases (days)	190	183	550	[1]Safe Work Australia (2015), [2,3]this study
D.8. Average earnings loss of permanent disability cases (%)	35	33	38	[1,2,3]Tompa et al. (2014)
E) Administrative costs				
E.1. Healthcare insurance administration costs (%)	3	0	10	[1,2,3]This study
E.2. Other insurance administration costs (%)	10	0	15	[1]DGUV (2015), [2,3]this study
F) Intangible costs				
F.1. Monetary value of a QALY (EUR)	41,096	27,397	61,644	[1,2,3]NICE (2013)
F.2. Loss of QALY range for injuries and diseases	Median	Low	High	[1,2,3]HSE (2011), p. 45-50

[Source:https://osha.europa.eu/sites/default/files/Value%20of%20OSH_and_societal_cost_workrelated%20injuries_and_diseases.pdf.]

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3.8.9 Analysis

VBA's approach focuses on deriving valuation factors based on severity categories of occupational health and safety incidents, as determined by the Safe Work Australia report. They consider total costs to workers and the community, excluding employers' costs, and extrapolate these costs to respective countries using GDP per capita while adjusting for inflation.

WifOR Institute utilises a comprehensive methodology incorporating DALYs to value both fatal and non-fatal incidents of occupational injuries and illnesses. They estimate years of life lost and years lived with disability, incorporating age-weighting and disability weights, and value each category of DALYs at USD 200,000 per case, considering various sources such as ILO, Eurostat, and the Global Burden of Disease Study.

Both VBA and WifOR Institute share a common goal of assessing the societal impacts of occupational health and safety (OHS) incidents, acknowledging the broad range of costs incurred by individuals, employers, and society as a whole. They both utilise data sources such as Eurostat and global health studies to inform their valuation methodologies, reflecting a commitment to incorporating comprehensive and reliable data into their analyses. Additionally, both approaches consider the severity of OHS incidents, whether fatal or non-fatal, in their valuation frameworks, emphasising the importance of understanding the full spectrum of impacts on human health and well-being.

Scope of Valuation Factors: VBA focuses primarily on deriving valuation factors based on severity categories of incidents, with a narrower focus on costs to workers and the community, excluding employers' costs. In contrast, WifOR Institute's valuation includes a broader range of factors such as DALYs, encompassing both fatal and non-fatal incidents, and considering impacts on mental health and overall well-being.

Treatment of Employer Costs: VBA excludes direct effects on employers from their valuation scope, assuming these are already reflected in financial results. Conversely, WifOR Institute's approach considers a wider range of societal impacts, acknowledging the potential economic burden on employers as well as workers and the broader community.

Temporal Considerations: VBA adjusts its valuation data for inflation, given that the data is from 2012/2013, while WifOR Institute's approach does not explicitly mention temporal adjustments. Accounting for temporal changes in costs and societal factors could enhance the accuracy and relevance of the valuation results over time.

Monetization of Impacts: While both approaches aim to quantify the impacts of OHS incidents, VBA focuses on deriving monetary valuation factors, whereas WifOR Institute utilises a mix of monetary valuation (e.g. USD 200,000 per DALY) and non-monetary metrics (e.g. disability weights).

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3.9 Training

3.9.1 Challenge

Training generates diverse externalities affecting companies and society. Positive impacts include enhanced human capital, fostering a more skilled workforce, driving productivity, and spurring innovation, benefitting both the company and the broader economy. Well-trained employees share knowledge, enhancing team performance and potentially uplifting colleagues' skills. Conversely, inadequate training or dissatisfaction can provoke high turnover rates, resulting in lost human capital, increased recruitment costs, workflow disruptions, and decreased morale. Unequal access to training may lead to wage disparities among employees, causing reduced morale and potential social cohesion issues. Moreover, training focused on environmental or social responsibility can yield positive externalities by fostering improved practices, like sustainability, thereby reducing environmental impacts and benefiting society at large.

The challenges are addressed across various SDGs and targets. Specifically, they emphasise ensuring equal access to vocational and technical education (SDG 4: Target 4.3), promoting economic productivity through skills development (SDG 8: Target 8.2), achieving full and productive employment for all (SDG 8: Target 8.5), reducing inequalities through policy adoption (SDG 10: Target 10.4), integrating sustainability practices into corporate operations (SDG 12: Target 12.6), enhancing education on climate action (SDG 13: Target 13.3), and building capacity in developing countries (SDG 17: Target 17.9).

Several leading international documents provide valuable insights into various aspects of training and skills development worldwide. The ILO produces the annual "Global Wage Report", offering data on wages and salaries globally, while the "Skills for Employment and Productivity" report focuses on skills development and training. Additionally, the ILOSTAT database provides extensive data on labour market topics, including wages and productivity. The OECD publishes reports such as "Education at a Glance" and the "Skills Outlook", shedding light on education and skills development in OECD countries. The World Bank Group contributes to this discourse with the "Human Capital Index" and the "World Development Reports", highlighting the importance of investing in human capital and adapting to the changing nature of work. UNESCO's reports emphasise the promotion of lifelong learning, sustainability in education, and the future of education and skills. Furthermore, the European Centre for the Development of Vocational Training (Cedefop) offers insights into vocational education and training, emphasising flexibility and responsiveness to labour market needs. Lastly, the International Organization for Standardization (ISO) sets guidelines for training and quality management systems in education and training organisations, ensuring competence and quality assurance. Collectively, these documents contribute to shaping policies and practices aimed at enhancing training and skills development globally.

3.9.2 Activity Data

In assessing the impact of training within the VBA methodology, a systematic collection of primary data is imperative. This involves acquiring the total number of training hours provided to direct employees in each country during the focal year, alongside data on the average wage and age of employees. The turnover rate, calculated based on full-time equivalents (FTE), is crucial for understanding the proportion of individuals leaving the company and, subsequently, the impact of training on potential future wages. Recognising the diverse forms of training that contribute to increased productivity and potential wage growth, the methodology includes external and in-house training, online and offline training, vocational training, and dual bachelor/master programs. However, certain types of training, such as occupational health

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and safety (OHS) and safety training, as well as on-the-job and educational programmes without corporate support, are excluded from consideration. The methodology encourages reporting additional training data separately, providing clarity while acknowledging that a balance must be struck between detail and overall positive impact assessment. This comprehensive approach ensures a nuanced evaluation of the societal impact of training initiatives within the specified scope.

Company Information Measured:

Number of Training Hours in the Focal Year:	Total training hours provided by the company to employees within a specific year.
Average Wage of Employees:	The average salary or wage paid to employees in the company.
Average Age of Employees:	The average age of the company's workforce.

Turnover Rate Calculation:

Total number of employees at the beginning and end of the year.

Total number of employees leaving the company to work elsewhere within the focal year.

Granular Approach (Individual Level):

Training hours completed by each individual employee over the last year.

Individual employee information such as age, country, and wage/salary.

The data points listed above should be available in companies' human resource systems, including:

Training systems and platforms

Human resource management and administration systems

Payroll systems

3.9.3 Database

The ILO's Skills for Employment Database:	https://www.ilo.org/skills/lang--en/index.htm
The Global Alliance for Training and Education (GATE):	https://gateglobal.org/

3.9.4 WifOR Institute

3.9.4.1 Introduction

The total societal value created by corporate training is the accumulated increase in economic productivity of the person trained until her retirement through the training hours provided in a given year.

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The estimation is based on the country-specific rate of return for one year of schooling, i.e. the percentage increase in income per year of schooling. These are scaled to the rate of return for one hour of schooling. The rate of return per school hour is multiplied by country and sector-specific labour productivity, estimated by GDP per capita. Assuming that these productivity gains through training occur not only in the first but persist throughout the remaining work years, we calculate the net present value for all future income-earning years. These are estimated as the time to retirement age for a worker at the median age of employees in a country. The net present value of the absolute return per hour can then be multiplied by the number of training hours provided.

By training its employees, a company increases its stock of human capital. This stock will be used in the following years, whether employees leave or stay at the company; it thus has the form of its own work capitalised. It is similar to material stocks of capital created for the company's own use, for example, a machine or building constructed and used for production. The net present value of future productivity of such material capital stocks is accounted for in balance sheets and discounted in future years as it is used up. The same logic can be applied to the stock of immaterial capital, like human capital through training.

3.9.4.2 Activity Data Source

- Psacharopoulos & Patrinos (2018): Provides the income returns to a year of schooling. This source is essential for estimating the returns to one year of schooling using the Mincerian method and full discounting method.
- OECD (2019a, 2019b): Offers information on average hours per year of intended instruction time in lower secondary education and data on retirement ages for a person who entered the labour force at age 22.
- WifOR Institute Input Output Table: Provides data on productivity, which is crucial for calculating the societal value of one hour of training for each country/sector.
- ILO (2019), International Social Security Association, Pension Watch, WDI Indicators Database: These sources collectively provide data on the median age of the labour force, statutory pensionable age, age of eligibility for social pension schemes, and life expectancy at birth. These data are necessary for estimating the remaining work years until retirement for an employee at the median age of the workforce and for approximating the end of the working life for countries with retirement ages below life expectancy.
- Nationmaster (2000): Provides intended hours of instruction per year for 13-year-olds in public educational institutions, used when OECD data is unavailable.

3.9.4.3 Formula

Formula

$$monetary\ effects\ of\ one\ hour\ training = \sum_{j=1}^{n}\sum_{i=0}^{m}\frac{\frac{\alpha_j}{h_j} * t_j}{(1+\beta)^i} v_{j,s}$$

with $m = min(p_j - a_j)\left(l_{j,a_j} - 5 - a_j\right)$

j = is the country

θj = $training\ coefficient$ ($estimated\ return\ rate\ to$ 1 $hour\ of\ training$); refers to the work of Psacharopoulos & Patrinos (2018)

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αj = $return\ rate\ to$ 1 $year\ of\ schooling\ in\ country\ j$

hj = $school\ hours\ per\ school\ year\ in\ country\ j$

tj = $number\ of\ training\ hours\ provided\ in\ country\ j$

m = $average\ work\ years\ after\ training$

pj = $official\ retirement\ age\ in\ country\ j$

aj = $average\ age\ of\ employees\ in\ country\ j$

lj, αj = $life\ expectancy\ at\ average\ age\ of\ employees\ in\ country\ j$

vj,s = $GVA\ per\ employee\ (upstream:\ in\ sector\ s\ of\ country\ j)$

i = [0; m] $time\ periods\ during\ which\ training\ benefits\ occur$

j = $countries\ in\ which\ training\ is\ conducted$

β = *social* $discount\ rate$ (SDR) set by the reporting entity

3.9.4.4 Impact Pathway

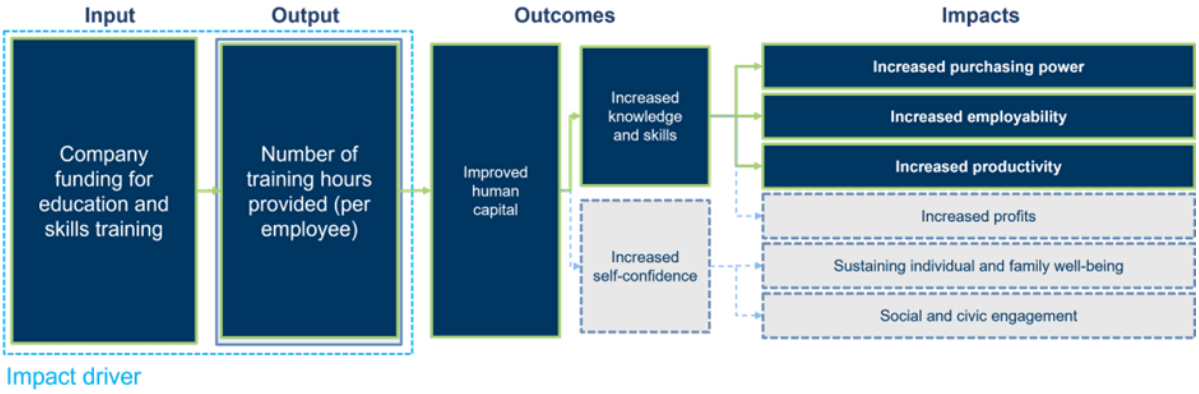

Figure 2: Simplified impact pathway of training

[Source: Training / WifOR Institute]

3.9.4.5 Valuation Method

Returns to Schooling Calculation:

Utilises data from Psacharopoulos & Patrinos (2018) to estimate the rate of return to one year of schooling using the Mincerian method or full discounting method. This is scaled to the rate of return for one hour of schooling using OECD data on intended hours of instruction per year.

Productivity Estimation:

Data from the WifOR Institute Input Output Table (WIOD and EORA multiregional input-output databases) is employed to determine country-specific labour productivity. This productivity value is crucial for calculating the societal value of one hour of training for each country/sector.

Remaining Work Life Calculation:

ILO data on the median age of the labour force and retirement ages sourced from OECD, International Social Security Association, Pension Watch, and WDI Indicators Database is

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utilised. This helps estimate the number of remaining work years until retirement for an employee at the median age of the workforce.

Net Present Value (NPV) Calculation:
The NPV for the productivity gains from corporate training is computed by discounting the future productivity gains to present value using a 1.5% discount rate. The formula involves estimating the effects of one hour of training for each country/sector.

3.9.4.6 Geographical Differences

OECD (2019b) and Nationmaster (2000) cover the rate of return to schooling data for 53 countries. For the remaining 135 countries, we use the average of the regional and income group averages for the respective country (country categories as defined by the world bank).

3.9.4.7 Sources of Valuation Data

- Nationmaster (2000). Hours of instruction for pupils aged 12 [Online]. Available at Nationmaster - Hours of Instruction for Pupils Aged 12.
- ILO (2019). Median age of the labour force by sex – ILO modelled estimates. Indicator EAP_2MDN_SEX_NB. Estimates for 2019.
- OECD (2019b). OECD.stat Pensions at a Glance 2019 [Online]. Available at: OECD Pensions at a Glance 2019.
- International Social Security Association (2021). Country profiles – pensionable ages. ISSA - Country Profiles - Pensionable Ages.
- Pension Watch (2018). Social Pensions Database [Online]. Available at: Pension Watch - Social Pensions Database.
- WDI Indicators database (2021b). SP.DYN.LE00.IN: Life expectancy at birth, total (years). - World Development Indicators Database.

3.9.4.8 Global Value

USD 4.28 Trillion

3.9.5 VBA

3.9.5.1 Introduction

The skills and capabilities of a company's employees are essential for the company's value preservation and the development of future revenue streams. Employee development and retention are beneficial for the company, the individual, and society. Although employee training has a cost, it affects employees' employability, earnings, skills, and knowledge in key ways. It also impacts softer aspects, such as self-confidence, self-awareness, and active listening. This may, in turn, result in macro-level effects, such as greater emotional capacity, that benefit the immediate social environment, social and civic engagement, and democracy.

This methodology focuses on how to measure these social impacts of increasing employees' skills and capabilities. Note, however, that there is, as yet, no consensus on how to measure the impact of employee development, upstream or downstream. Therefore, this document focuses on the impact of employee education/training on a company's own operations only.

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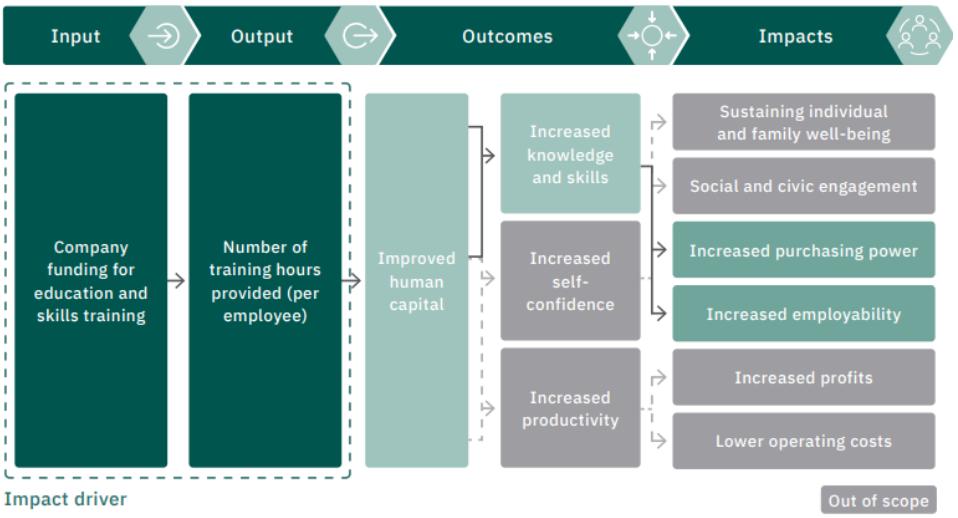

Impact Valuation Roundtable 2017 & C. Mainguet and A. Baye (2006),
3.C. Defining a framework of indicators to measure the social outcomes of learning, OECD

Figure 2: Simplified impact pathway training

[Source: Training / VBA]

3.9.5.2 Data source

- Pscharopoulos and Patrinos (2004): Returns to investment in education. https://econpapers.repec.org/article/tafedecon/v_3a12_3ay_3a2004_3ai_3a2_3ap_3a111-134.htm
- OECD retirement age statistics: https://www.oecd.org/employment/emp/average-effective-age-of-labour-market-exit.htm
- Pension Watch: http://www.pension-watch.net/

3.9.5.3 Calculation Logic

$$impact = \sum_{j=0}^{n} \sum_{i=0}^{m} \frac{\left(\alpha \frac{Tc}{Tn}\right)_{i,j}}{(1+\beta)^{i}} w_j w_j$$

Figure 3 aspects considered in the valuation approach

where:
α = training coefficient in country j
β = social discount rate
γ = turnover rate
Tc = training hours
Tn = training norm
i = time periods
j = countries in which training is conducted
m = pension age – average age of employees in country j
n = total number of countries
w = average wage

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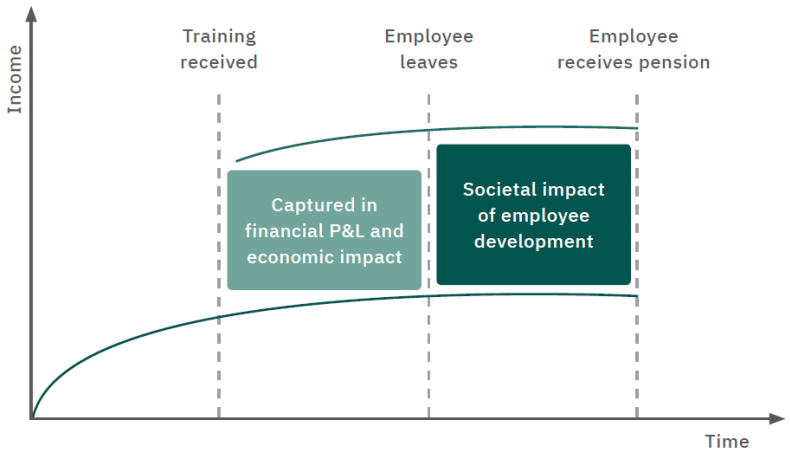
Value factors are based on:

- Estimations of return to investments in education – training coefficient (Psacharopoulos & Patrinos, 2004[Error! Bookmark not defined.])
- Adjustments by training hours in a specific country (instruction time from OECD), extrapolated for non-OECD countries
- Considering wage increase up to the point of retirement (retirement data from OECD)

Formula rationale:
Psacharopoulos and Patrinos (2004) provide insights into the returns on investments in education. These returns are used as training coefficients per country. As these factors assume a return based on a further year of education, we correct the outcomes by dividing the actual hours spent on training by the training norm hours in that country. These country norms are obtained from an OECD database. In the case of non-OECD countries, extrapolations can be made from the available country-level data based on common characteristics between countries. The wage increase is determined using the formula above, in which the years that the individual derives benefits from increased earnings are calculated up to the point of retirement. The retirement age per country is based on data from OECD and Pension Watch.



Activity data considerations:
The approach is pertinent for own operations only (no consensus yet on upstream & downstream impacts). The turnover rate should be calculated based on the number of FTEs, since it is expected that individuals who work less are also expected to be trained proportionally less. If the training costs are shared with others, e.g. training partly covered by governments, the impact should be distributed proportionally.

3.9.6 Analysis

VBA underscores the significance of specific impacts such as increased purchasing power and employability. The inclusion of sources from reputable entities such as Pscharopoulos and Patrinos (2004), OECD adds credibility to the analysis, contributing to a comprehensive understanding of the effects of training activities. VBA's approach also encompasses adjustments based on education and socioeconomic parameters, further enriching the valuation process and ensuring a more nuanced evaluation of societal impacts.

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WifOR Institute focuses on economic benefits, highlighting pathways such as higher wages and productivity resulting from training activities. The emphasis on economic outcomes provides valuable insights. WifOR Institute's approach offers a clear perspective on the financial implications of training initiatives, catering to stakeholders interested in economic returns.

Both VBA and WifOR Institute emphasise the importance of training activities in generating positive outcomes, albeit with different focuses. They both recognise the significance of impacts such as increased purchasing power and employability, albeit with differing valuation techniques. While VBA incorporates adjustments based on education and socioeconomic parameters, WifOR Institute concentrates more on economic benefits like higher wages and productivity, providing distinct but complementary perspectives on the broader implications of training initiatives.

While both VBA and WifOR Institute recognise the significance of training activities and identify similar impacts like increased purchasing power and employability, there are noticeable differences in their approaches. VBA offers a more comprehensive analysis by considering adjustments based on education and socioeconomic parameters, which enriches the depth of the VBA valuation process. On the other hand, WifOR Institute's emphasis on economic impacts may integrate critical factors influencing the overall societal impact of training programmes

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3.10 Wages

3.10.1 Challenge

Corporates enable workers to meet their basic needs for housing, food, healthcare, and education. Wages below the living wage threshold have negative societal impacts. Workers and their families may struggle to afford basic necessities, which can lead to poorer health outcomes, increased stress, and social problems. In addition, lower wages can contribute to economic inequality and instability.

The challenge with encouraging fair wages is reflected in SDG: 8, in particular to achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value (SDG Target: 8.5).

A collection of leading international documents delves into the crucial issue of fair wages and its broader implications for social progress and development. The United Nations Development Programme (UNDP) contributes with reports such as “The Rise of the Working Poor in Developing Countries”, shedding light on challenges faced by workers in low-income settings. Additionally, the UNDP's “Transforming the Social Contract for Gender Equality and Sustainable Development” underscores the importance of fair wages in advancing gender equality and sustainable development. The ILO offers valuable insights through reports like “World Employment and Social Outlook”, highlighting trends in employment and social conditions, while “The Minimum Wage and Decent Work” examines the role of minimum wages in ensuring decent work conditions. The World Bank's “World Development Report 2023” emphasises the significance of fair wages in promoting prosperity and inclusive growth, complemented by the “World Bank Group Gender Action Plan 2023-2027”, which addresses gender disparities in wages. The International Trade Union Confederation (ITUC) contributes with reports such as “The Global Wage Report”, focusing on wage inequality and sustainable development, while advocating for the protection of workers’ rights, including the right to strike. Finally, the WHO examines the impact of fair wages on health outcomes through reports like “Health in the Workplace”, underscoring the interconnectedness between fair wages, social determinants of health, and health equity. Collectively, these documents provide comprehensive insights into the multifaceted dimensions of fair wages and their implications for broader social and economic development agendas.

3.10.2 Activity Data

In the assessment of the impact of adequate wages within the VBA methodology, the systematic collection of primary data is crucial. This involves obtaining detailed information on base salaries paid to employees throughout the value chain, with a focus on securely paid components, excluding bonuses and performance-based payments, and incorporating taxes and social contributions following country-specific requirements. For own operations, individual-level data from HR departments provides a granular perspective on paid wages, though salary bands/ranges can be utilised if individual data is unavailable. The differentiation between average wages below and above the living wage, capped at four times the living wage, is vital, along with the corresponding number of employees in each category, to ensure a nuanced understanding of earning levels. The scope of employees considered aligns with financial reporting practices, encompassing contractors and non-permanent staff. For assessing upstream impacts, EEIO databases like Exiobase offer a valuable resource to calculate the average paid wages for employees per country. In estimating the impact, consideration of emission factors related to both downstream and upstream impacts, adjusted

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for country-specific nuances, enhances the accuracy and relevance of the assessment. This comprehensive approach ensures a thorough evaluation of the societal impact of wages within the specified scope, fostering transparency and alignment with sustainability goals.

3.10.3 Databases

The Global Living Wage Coalition's Living Wage Database:	https://www.globallivingwage.org/
The Fairtrade Foundation's Fairtrade Minimum Prices:	https://www.fairtrade.net/standard/minimum-price-info
The World Bank's Living Wage Database:	https://wageindicator.org/salary/living-wage

3.10.4 WifOR Institute

3.10.4.1 Introduction

The fair wages indicator serves as a critical evaluation tool challenging the conventional assumption that every job contributes positively to societal welfare. It focuses on assessing employment quality by scrutinising the wages provided to employees, specifically gauging their impact on individual well-being. This approach, rooted in the health utility of income, measures the influence of wages on DALYs gained. In the subsequent discussion, a modified implementation developed by Valuing Nature is elucidated, tailored and adjusted by WifOR Institute for a more comprehensive assessment of wage-related impacts on health and life expectancy.

3.10.4.2 Data Sources

- Vionnet, S. & Haut, S. (2018): Data set providing living wages for different countries.
- Vionnet, S. & Haut, S. (2018): Report or dataset containing HUI (Health Utility of Income) factors for different countries.
- Valuing Nature or Valuing Impact: Data source for HUI factors for 2018 per country (if different from the previous source).
- World Bank: Information on income groups for countries (to estimate missing living wage and HUI data).

3.10.4.3 Subcategories

Positive (above living wage): high-skilled, medium-skilled, low-skilled

Negative (below living wage): high-skilled, medium-skilled, low-skilled

3.10.4.4 Calculation Logic

$$(wages\ paid - living\ wage) * HUI\ factor = DALYs\ gained\ or\ lost$$

$$DALYs\ gained\ or\ lost * 200{,}000 \frac{USD}{DALY} = social\ value\ created\ or\ lost$$

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3.10.4.5 Impact Pathway

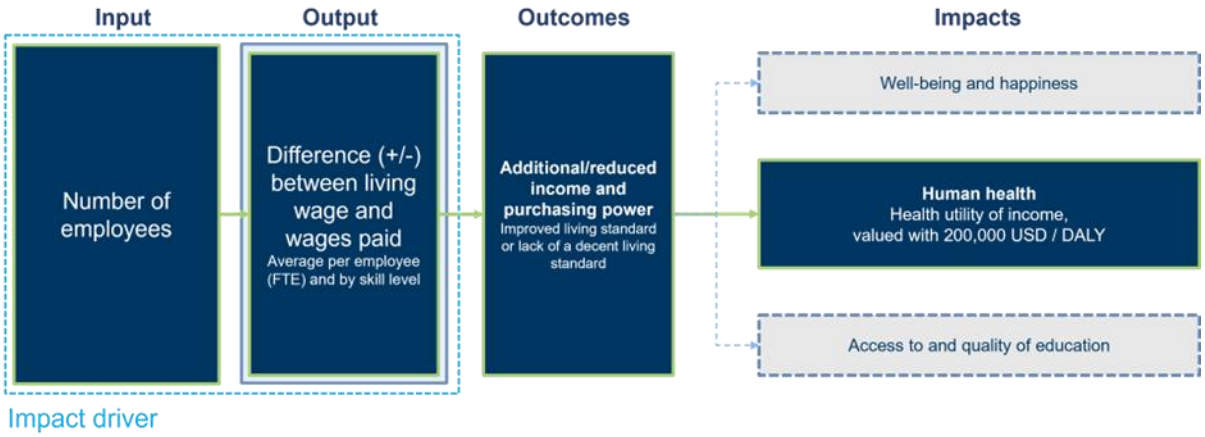

Figure: Simplified impact pathway fair wages

[Source: Fair Wages / WifOR Institute]

3.10.4.6 Valuation Method

See formulas above. The income gap is valued with the HUI. We apply a cut-off at wages higher than 4x the living wage (we apply the same HUI as 4x LW for them). We apply marginal declining utility of income for five different income groups (below living wage living wage, living wage- 2x living wage, 2x living wage – 3x living wage, 3x living wage – 4x living wage).

Wage level	Below LW	LW	Up to 2 LW	Up to 3 LW	Up to 4 LW	Up to 5 LW
% of HUI to consider	-100%	baseline	100%	50%	30%	20%

Table: HUI values following Vionnet & Haut (2018)

3.10.4.7 Sources of Valuation Data

- Vionnet, S. & Haut, S. (2018): Measuring and valuing the Social Impact of Wages – The Living Wages Global Dataset And The Health Utility Of Income. Working Paper.
- Vionnet, S.; Adhikari, R.; Haut, S. (2021): The Health Utility of Income and Taxes. Part A - Health Utility of Income. Impact valuation methodology, global assessment and application to businesses. Whitepaper, Valuing Impact. https://www.valuingnature.ch/post/the-utility-of-income-and-taxes-social-impact

3.10.4.8 Geographical Differences

Country-specific living wage, different HUI factors (greater HUI in developing countries).

3.10.4.9 Transfer Mechanism

Regional averages are used for missing countries (30 countries where estimated).

3.10.4.10 Global Damage

USD 11.5 Trillion

3.10.5 Valuing Impact (formerly Valuing Nature)

3.10.5.1 Introduction

The Health Utility of Income and Tax methodology outlines how to measure the impact of income on health and focuses on understanding the direct and indirect effects of income on health outcomes. Based on internationally established data sources from the OECD and World Bank, the methodology aims to identify how income influences health through access to resources, lifestyle choices, and overall well-being.

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3.10.5.2 Data Sources

Health GAP

The Human Capital Index serves as a pivotal tool within the Health GAP dataset. This index is specifically designed to gauge the impact of income on human capital. It provides a structured framework for evaluating how varying income levels influence and correlate with aspects of human capital, offering valuable insights into the relationship between economic status and overall well-being. The Health GAP's utilisation of the Human Capital Index underscores its focus on comprehensively assessing the interplay between financial resources and their impact on the broader aspects of human development and health.

WageIndicator Foundation

The WageIndicator Foundation stands as a significant contributor to wage-related data. This foundation focuses on gathering, analysing, and disseminating information related to wages and employment conditions worldwide. It compiles data from various sources, including surveys and other statistical information, to provide a comprehensive understanding of wage structures, trends, and disparities. Through its extensive datasets and research, the WageIndicator Foundation contributes to informed decision-making processes by shedding light on wage-related issues and employment dynamics across different regions and sectors.

OECD

The OECD is a prominent international organisation that conducts comprehensive research and analysis across various policy domains, including health and environmental policies. The OECD's report titled “The Value of Statistical Life: a meta-analysis”, conducted by the Working Party on National Environmental Policies, offers valuable insights into life valuation methodologies. Additionally, the “Health at a Glance: Europe 2018” report, a collaborative effort between the OECD and the European Union, serves as a significant data source. This report provides an in-depth analysis of health indicators in European countries, offering a comparative overview of health systems, outcomes, and determinants, thereby facilitating evidence-based policy decisions.

Eurostat

Eurostat, the statistical office of the European Union, is a primary source for comprehensive statistical information across various domains, including health and socioeconomic aspects. It gathers, organises, and disseminates statistical data from European countries, providing a wide array of indicators and analyses. Eurostat's datasets cover diverse topics such as health expenditure, demographics, employment, and social conditions, allowing for detailed cross-country comparisons and trend analysis within the European context. Through its extensive datasets and reports, Eurostat plays a crucial role in providing reliable and standardised statistical information to support evidence-based policymaking and research initiatives in Europe.

3.10.5.3 Calculation Logic

Human capital impact DALY * VSL

$$Human\ capital\ impact\ DALY = \min\left[HUI * \left(income_{employee} - baseline\right), HUI * \left(income_{employee} - baseline\right)\right]$$

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where

income max Is the income value at the top of the income gap, which we define as four times the living wage.

income employee Is the income of the employee assessed.

$$HUI_l = \frac{Change\ in\ well-being_l}{Income\ gap_l}$$

where

HUI Health Utility of Income (QALY/DALY). The HUI factors are used as direct multipliers to an income or income change. When a baseline of 0 is used, any wage contributes positively to human capital. When using a baseline of the living wage, all the wages paid below the living wage will harm human capital. The choice of the baseline is context-dependent and based on subjective choices, and it should be made in line with the objective and context of the study.

Location

Change in well-being Life quality (e.g. YLD) and expectancy (e.g. YLL) differences that are explained by income inequalities (also called the "health gap"), reported per year of life or – more precisely – year of work.

Income gap: The gap of income within which the health inequity (or gap) is experienced, expressed in a chosen currency.

Heath Utility of Income (HUI)

Health utility = f (income, taxes, lifestyle factors, health outcomes)

f is a function that weights the different factors according to their importance for health.

income is a measure of income adjusted for purchasing power parity.

taxes is a measure of taxes adjusted for purchasing power parity.

lifestyle factors are measures of lifestyle factors that are known to affect health.

health outcomes are measures of health outcomes, such as mortality rates, morbidity rates, and self-reported health status.

Income

The measure of income, adjusted for purchasing power parity. This means that the formula takes into account the fact that the cost of living varies from country to country.

Taxes

Measure of taxes, also adjusted for purchasing power parity. This means that the formula takes into account the fact that the tax burden varies from country to country.

Lifestyle factors

Measures of lifestyle factors known to affect health, such as smoking, alcohol consumption, and physical activity.

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Health outcomes

Measures of health outcomes, such as mortality rates, morbidity rates, and self-reported health status.

3.10.6 VBA

Disclaimer: The VBA methodology will evolve in the context of the IFVI-VBA partnership. The new draft will be subject to a public exposure process in the coming months. A limited description of VBA methodology v0.2 is included here.

3.10.6.1 Introduction

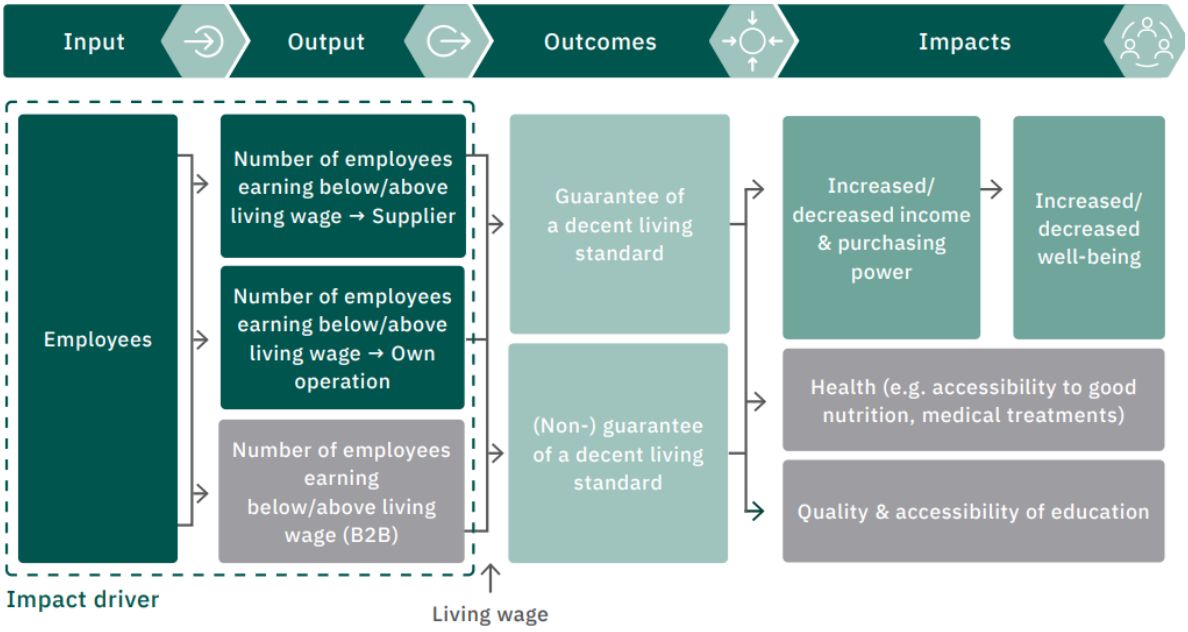

Figure 7: Simplified impact pathway Living Wages

[Source: Fair Wages / VBA]

3.10.6.2 Data Sources

- HUI values: Valuing impacts database: Vionnet, S. & Haut, S. (2018): Measuring and valuing the social impact of wages – The living wages global dataset and the Health Utility of Income. Available from: https://www.valuingnature.ch/post/2018/07/20/valuing-the-impact-of-wages-on-human-capital
- OECD VSL: OECD (2012): Mortality risk valuation in environment, health and transport policies. Available from: http://dx.doi.org/10.1787/9789264130807-en

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In this methodology, the living wage benchmarks used by the country are also key:

Table 4: "Review of main initiatives providing living wage data worldwide (review done end of 2019)", Vionnet, 2020

	Geo. coverage	Granularity	Updates frequency	Data sources	Availability
Valuing Impact	World	Country	N/A	Primary + WageIndicator + model	Public
BSR	World	Country (+US/ Brazil cities)	N/A	US + Model	Private
WageIndicator	76 countries	Country + regions + cities	Quarterly	Primary	Public / private
Asian Floor Wage	10 countries (Asia)	Country	> 3-year period	Model + primary for food	Public
Global Living Wage Coalition	21 countries / 26 locations	Regional or city	N/A	Primary	Public
Fair Wage Network	World	Sub-national	N/A	Model + WageIndicator + Secondary	Private
Others	1 or a few countries	Sub-national	N/A	Primary / model	Public

[Source Vionnet, Valuing Impact, 2020]

3.10.6.3 Calculation Logic

Wages above living wage formula:

- Sum by country ((income-living wage)*HUI*DALY)

If the income is above a satiation level ("income max"), the satiation threshold would substitute the income in the formula. As a rule of thumb, satiation can be calculated as living wage*4.

Wages below living wage formula:

- Sum by country ((income-living wage)*HUI*DALY)

In both formulas:

- HUI expresses the well-being gains of an additional unit of income and is country-specific (in countries with fewer resources per capita, income tends to be more important than in high income countries with social safety nets).
- DALY's are monetized based on the OECD's VSL.

3.10.7 Impact Weighted Account (Wage, DEI elements)

3.10.7.1 Introduction

Four impact dimensions (wage quality, diversity, opportunity, and location) are combined to calculate a measure of employment impact intensity for each firm, which is defined as total employment impact scaled by the number of employees. Employment impact intensity can be interpreted as "impact per employee".

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3.10.7.2 Activity Data

- From the employer directly (group, location, sector/job-specific data)
- Primary data on workforce composition, location, and wages are from Revelio Labs
- MIT Living Wage Calculator, the Bureau of Labour Statistics, the United States Census Bureau, and other official government sources for information, such as State-level minimum wages

3.10.7.3 Formula

Employment impact = Sum (wage quality impact, diversity impact, opportunity across jobs impact, opportunity across seniorities impact, location impact)

3.10.7.4 Valuation Technique

Wage Quality Impact

Wage quality impact calculates the wage quality impact of a firm by considering the living wage and the marginal utility of income. The living wage adjustment accounts for employees earning below the living wage, while the marginal utility adjustment accounts for employees earning above the income satiation level. The total wage quality impact is the sum of the adjustments for all firm locations.

The sum for each location of the firm results from following steps:

a. Total Unadjusted Wages Paid: Sum up the total wages paid in location for each firm-year observation.
b. Living Wage Adjustment: Determine the living wage benchmark for location. Identify employees earning below the living wage benchmark. Calculate the living wage gap and minimum wage credit. Find the living wage adjustment by adding the living wage gap and minimum wage credit.
c. Marginal Utility Adjustment: Determine the local income satiation level for location. Identify employees earning above the income satiation level. Calculate marginal utility adjusted salaries paid. Find the total marginal utility adjustment.

Diversity Impact

The diversity impact measures the diversity impact of a firm by comparing the actual number of employees from each demographic group to the expected number based on local population demographics. The "missing" employees are then multiplied by the average firm salary to calculate the monetized diversity impact for each demographic group. The total firm diversity impact is the sum of the monetized diversity impacts for all demographic groups.

Sum for each demographic group at each firm location results from the following steps:

a. Total Number of Employees: Determine the total number of employees at the firm.
b. Actual Number of Employees in Each Gender and Race/Ethnic Group: Break down the total number of employees into gender and race/ethnic groups.
c. Expected Number of Employees: Calculate the expected number of employees in each group based on local demographics.
d. Missing Employees: Find the difference between the expected and actual number of employees to identify missing employees in each group.
e. Monetized Diversity Impact: Multiply the missing employees in each group by the average firm salary to calculate the diversity impact for each group.

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Opportunity Across Job Category Impact

The opportunity across job category impact measures the opportunity across job category impact by examining the distribution of employees across job categories and their associated salaries. It identifies the median job category and splits employees into a “high salary group” and “low salary group” based on their average salary. Then, for each demographic group, it calculates the expected number of employees in the high salary group based on their percentage representation in the firm, compares it to the actual number of employees in the group, and identifies any “missing” employees. The monetized opportunity across job category impact is calculated by multiplying the number of “missing” employees by the difference in average salary between the high and low salary groups. The total firm opportunity across job category impact is the sum of these impacts for all demographic groups and firm locations.

Sum for each demographic group at each location results from the following steps:

a. Average Annual Salary in Each Job Category: Calculate the average annual salary in each job category by dividing the total unadjusted salaries paid in that category by the total employees in that category.
b. Ranking and Median Category: Rank each job category based on average salary. Determine the median category.
c. High and Low Salary Groups: Establish a “high salary group” consisting of employees in job categories earning above the median. Establish a “low salary group” consisting of employees in job categories earning below the median.
d. Percentage of Employees in Demographic Group: Determine the percentage of employees in each demographic group at the firm.
e. Expected Employees in High Salary Group: Multiply the percentage of employees in group1 by the total employees in the high salary group to find the expected number of employees in group1 in the high salary group.
f. Actual Employees in High Salary Group: Determine the actual number of employees in group1 in the high salary group.
g. Missing Employees in High Salary Group: Find the difference between the expected and actual number of employees in group1 in the high salary group to identify missing employees.
h. Monetized Opportunity Across Job Category Impact: Multiply the missing employees in each group in the high salary group by the difference between the average salary in the high salary group and the average salary in the low salary group to calculate the monetized opportunity across job category impact for group.

Opportunity Across Seniorities Impact

The opportunity across seniorities impact formula measures the distribution of employees across seniority levels and the associated salaries. It calculates the expected number of employees in each seniority level for each demographic group based on the percentage representation of the group in the firm. The formula then compares the expected number of employees to the actual number of employees and identifies any “missing” employees. The monetized opportunity penalty for each seniority level is calculated by multiplying the number of missing employees by the difference in average salary between the level and the next lower level. The total firm opportunity across seniority impact is the sum of these impacts for all demographic groups and firm locations.

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Sum up the opportunity across seniorities impact values for each seniority level 2, 3, 4 in each demographic group in each location of the firm:

a. Total Employees in Seniority Level 2: Count the total number of employees in seniority level 2.
b. Employees in Group1 at Seniority Level 2: Determine the number of employees in group1 at seniority level 2.
c. Percentage of Employees in Group1 at the Firm: Calculate the percentage of employees in group1 at the firm.
d. Expected Employees in Group1 at Seniority Level 2: Multiply the total employees at seniority level 2 by the percentage of employees in group1 at the firm.
e. Missing Employees from Group1 at Seniority Level 2: Find the difference between the expected and actual number of employees in group1 at seniority level 2.
f. Monetized Opportunity Penalty for Seniority Level 2: Multiply the missing employees from group1 at seniority level 2 by the difference in average salary between seniority level 2 and seniority level 1.

Location Impact

Location impact covers how to calculate the employment impact of a firm. It considers the number of employees at each firm location, the total number of employed individuals from local unemployment statistics, the total number of unemployed individuals, the incremental wages received due to firm employment, the hypothesised unemployment rate without firm job creation, and the monetized location impact.

Sum for each location of the firm results from the following steps:

a. Number of Employees at Each Firm Location: Determine the number of employees at each firm location.
b. Total Employed Individuals from Local Unemployment Statistics: Identify the total employed individuals from local unemployment statistics for each firm location.
c. Total Unemployed Individuals from Local Unemployment Statistics: Identify the total unemployed individuals from local unemployment statistics for each firm location.
d. Incremental Wages Received due to Firm Employment: Calculate the incremental wages received by subtracting the average annual salary at minimum wage from the average annual salary for firm employees.
e. Hypothesised Unemployment Rate without Firm Job Creation: Calculate the hypothesised unemployment rate without firm job creation using the formula provided.
f. Monetized Location Impact: Multiply the incremental wages received due to firm employment by the hypothesised unemployment rate without firm job creation and the number of employees at each firm location.

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3.10.8 VBA/ IFVI

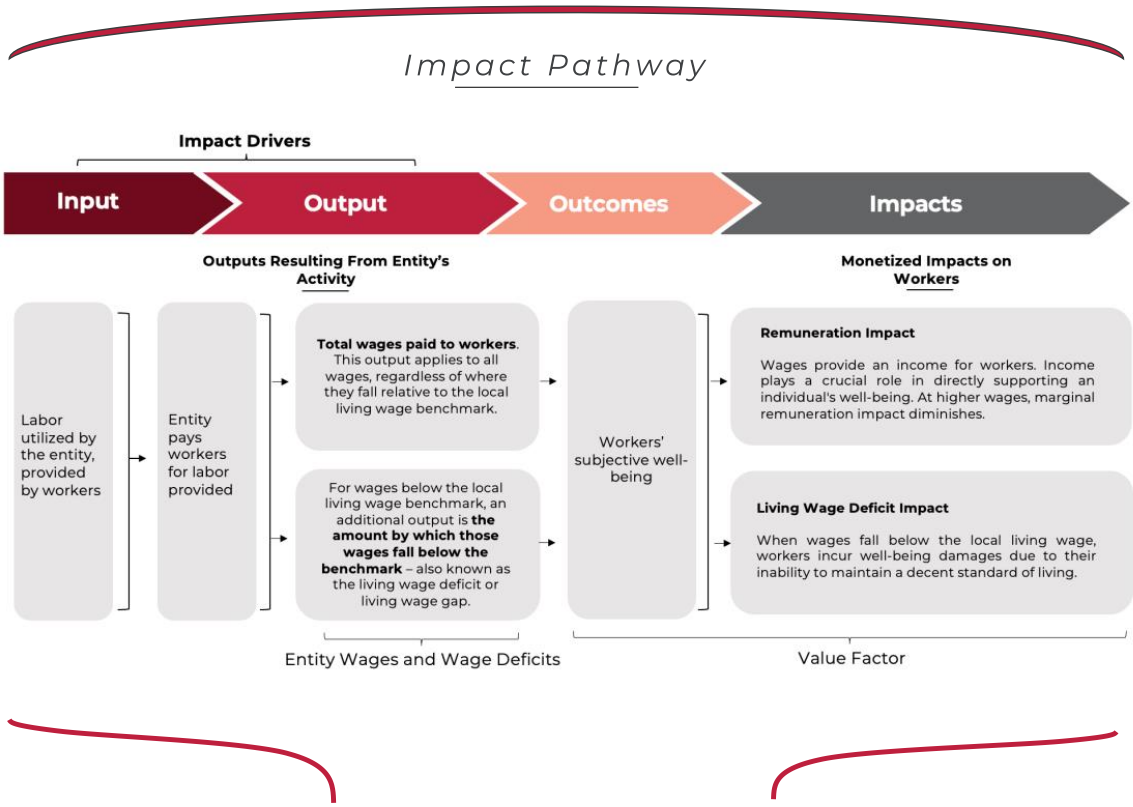
Disclaimer: The IFVI-VBA methodology will be subject to a public exposure process in the coming months. A limited description is included here.

3.10.8.1 Introduction

The VBA methodology places a significant emphasis on the concept of “adequate wages”, previously referred to as “living wages”, in alignment with the EU’s ESRS. This term signifies a wage that enables a basic yet decent standard of living, encompassing factors such as nutrition, housing, health, and education for households. The measurement of adequate wages serves as an indicator of employment quality, valuing the compensation provided to employees.

The methodology focuses on two distinct well-being effects:

1. “Remuneration impact” is the positive impact of wages on workers’ well-being, since wages of any amount provide income to a worker. The remuneration impact of each additional $1 of wage gets smaller and smaller at higher wages, reflecting the diminishing marginal utility of income.
2. The Adequate Wages Methodology also includes “living wage deficit impact” as a second impact. Earning a wage does not guarantee that that wage is adequate for an individual and their family. As of 2020, over one billion working people worldwide earn wages that are inadequate for a decent standard of living. Therefore, “living wage deficit impact” is the negative impact on workers’ well-being of being paid less than the living wage.



[Source: Adequate Wages / IFVI / VBA]

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3.10.8.2 Data Source

World Happiness Report: The SDNS's report, an organisation backed by the UN, is one of the leading publications assessing subjective well-being across the globe.

- Helliwell, J. F., Layard, R., Sachs, J. D., De Neve, J., Aknin, L. B., & Wang, S. (2023). *World Happiness Report 2023*. Sustainable Development Solutions Network. https://happiness-report.s3.amazonaws.com/2023/WHR+23.pdf

Own estimates: Following a similar approach to HUI estimates, the calculation of each country's WUI factor involves assessing the well-being gap in relation to the income gap, both quantified from the WHR dataset. The well-being gap is the disparity in well-being explained by GDP per capita between a given country and the reference country, while the income gap is the difference in GDP per capita between the countries.

The value of a WELLBY is set at USD 17,663 for 2022 and USD 19,524 for 2023, based on recommendations from the UK Treasury. These figures are derived from the UK Treasury's central estimate for a WELLBY in 2019 values and converted to USD for 2022 and 2023 using inflation rates and exchange rates.

- MacLennan, S., Stead, I., & Little, A. (2021). *Wellbeing Guidance for Appraisal: Supplementary Green Book Guidance*. HM Treasury, Social Impacts Task Force. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005388/Wellbeing_guidance_for_appraisal_supplementary_Green_Book_guidance.pdf
  Satiation level: The regional thresholds have been obtained from Jebb et al. (2018)
- Jebb et al. (2018): Happiness, Income Satiation and Turning Points around the World.

Example living wage databases that can be used

Benchmark Meets Required Criteria	- Benchmark Additionally Meets Preferred Criteria
Valuing Impact Typical Family Methodology	- No
Valuing Impact Single Working Parent Typical Family Methodology	- Yes, because: - Includes approach for one wage earner
Anker Full Methodology	- Yes, because: - Relies on data sources besides online cost-of-living surveys - Sub-national geographic specificity
Anker Reference Values	- Yes, because: - Relies on data sources besides online cost-of-living surveys - Sub-national geographic specificity

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WageIndicator Foundation Typical Family Methodology	- Yes, because: - Relies on data sources besides online cost-of-living surveys - Sub-national geographic specificity
Fair Wage Network Typical Family Methodology	- Yes, because: - Includes childcare costs - Sub-national geographic specificity

3.10.8.3 Calculation Logic

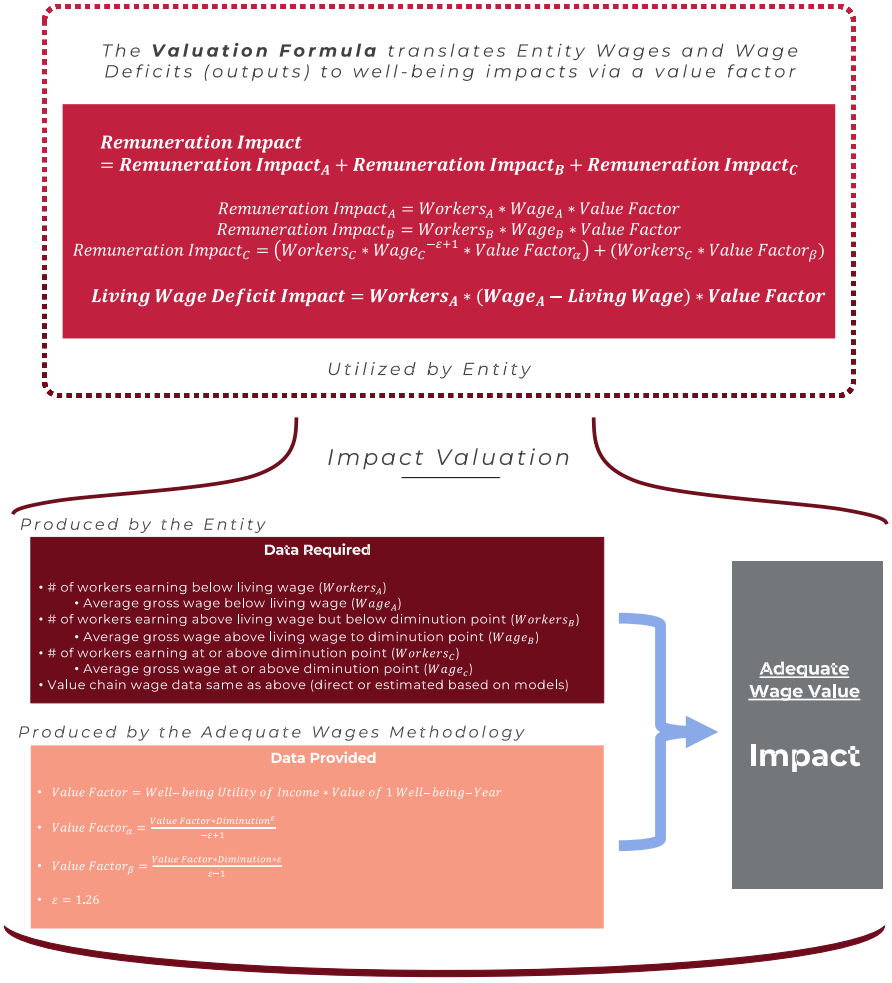

Figure 1: Impact Pathway and Valuation for Adequate Wages

[Source: Adequate Wages / IFVI / VBA]

These equations describe how the remuneration impact for different worker categories and the impact of living wage deficits on worker well-being are calculated. The values of workers, wages, value factor, satiation, and living wage are used in these equations to compute the respective impacts. There are three main categories:

- Workers A: Earning below a living wage
- Workers B: Earning above a living wage, but below the satiation threshold
- Workers C: Earning above the satiation threshold*

The workers C impact could vary its valuation formula in the coming weeks.

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3.10.9 Analysis

WifOR Institute's approach to evaluating fair wages focuses on assessing employment quality through the lens of HUI and DALYs gained or lost. They utilise data from various sources such as the World Bank, Valuing Nature, and Vionnet & Haut (2018) to determine living wages, HUI factors, and income groups. Their calculation logic involves measuring the social value created or lost due to wage disparities, considering factors like income gaps and marginal utility of income. They also emphasise the importance of geographical differences and transfer mechanisms to ensure a comprehensive assessment of fair wages globally.

Valuing Impact emphasises the Health Utility of Income and Tax methodology to measure the impact of income on health outcomes. Their data sources include Health GAP and WageIndicator Foundation, among others. They utilise the Human Capital Index and OECD data for their assessment. Their calculation logic involves evaluating the impact of income on human capital through factors like access to resources and lifestyle choices. They emphasise the importance of understanding the direct and indirect effects of income on overall well-being, offering insights into the relationship between economic status and health outcomes.

VBA's methodology revolves around the concept of adequate wages and their impact on workers' well-being. They utilise data from the World Happiness Report and their own estimates to assess subjective well-being and income gaps. Their calculation logic involves considering the remuneration impact and living wage deficit impact on worker well-being, categorising workers into different groups based on wage levels. They emphasise the importance of addressing inadequate wages to ensure a decent standard of living for workers worldwide.

Impact Weighted Account combines four impact dimensions (wage quality, diversity, opportunity, and location) to calculate the employment impact intensity for each firm. They gather primary data on workforce composition, location, and wages from various sources such as Revelio Labs, MIT Living Wage Calculator, and government sources. Their valuation technique involves assessing wage quality, diversity impact, opportunity across job category impact, opportunity across seniorities impact, and location impact to measure the overall impact of employment practices on societal welfare.

VBA / IFVI methodology also focuses on evaluating adequate wages but places a significant emphasis on living wage benchmarks and their impact on worker well-being. They utilise data from the World Happiness Report and their own estimates to calculate the well-being gap and income gap. Their calculation logic involves considering the remuneration impact for different worker categories and the impact of living wage deficits on worker well-being. They highlight the importance of addressing wage disparities to promote equitable economic development and improve overall societal welfare.

Focus on Well-being: All methodologies prioritise the assessment of well-being, whether through HUI, human capital impact, or subjective well-being indicators. They recognise that fair wages not only impact economic outcomes but also have significant implications for individuals' overall welfare and quality of life.

Data Utilisation: Each methodology relies on a combination of data sources to inform their assessments. These sources include reports, datasets, and statistical information from organisations such as the World Bank, OECD, Eurostat, and various research institutions.

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They draw upon living wage benchmarks, HUI factors, income levels, and health indicators to gauge the impact of wages on societal welfare comprehensively.

Calculation Logic: While the specific formulas and calculations may vary, there's a shared logic underlying the assessment of fair wages. They consider factors such as wage differentials, living wage thresholds, marginal utility of income, and location-specific variables to quantify the social value created or lost due to wage disparities.

Emphasis on Equity: Across the methodologies, there's a common emphasis on equity and fairness in employment practices. They seek to identify and address wage inequalities, ensuring that workers are adequately compensated for their contributions and that disparities in income do not disproportionately impact individuals' well-being.

Global Perspective: Recognising the global nature of labour markets and economic interdependencies, these methodologies adopt a global perspective in their assessments. They account for geographical differences, transfer mechanisms, and regional averages to provide a comprehensive evaluation of fair wages on a global scale.

Policy Implications: Importantly, these methodologies offer insights with significant policy implications. By quantifying the impacts of fair wages on societal welfare, they provide valuable information for policymakers, businesses, and other stakeholders to enact policies and practices that promote equitable economic development and improve overall well-being.

Data Availability and Quality: Despite relying on various data sources, there may be gaps in data availability, especially for certain regions or demographic groups. Inconsistencies in data quality and coverage across different sources can also pose challenges to the accuracy and reliability of assessments.

Subjectivity in Metrics: Some methodologies involve subjective judgments in defining metrics such as living wages, marginal utility of income, and well-being indicators. These subjective decisions can introduce biases and uncertainties into the assessment process, potentially impacting the validity of results.

Limited Scope: While methodologies aim to capture the multidimensional aspects of fair wages and employment quality, there may be limitations in the scope of factors considered.

Geographical Disparities: Despite efforts to adopt a global perspective, methodologies may struggle to adequately address geographical disparities in living standards, wage levels, and access to resources. This can result in unequal treatment of regions and populations in the assessment of fair wages.

Incomplete Impact Assessment: While methodologies assess the impact of fair wages on individual well-being and societal welfare, there may be gaps in capturing indirect or long-term effects.

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3.11 Child Labour

3.11.1 Challenge

The VBA methodology addresses the complex issue of child labour, defining it as the engagement of children in work beyond legal limits, often involving mentally, socially, or morally hazardous activities that impede their education. This definition varies based on factors such as age, local regulations, and working conditions. The methodology considers all forms of child labour, excluding domestic work, and emphasises the societal impact of such practices. Child labour deprives children of their childhood, potential, and dignity, leading to a reduction in years of education. This, in turn, results in lower future wages, diminished family income, and reduced purchasing power, thereby influencing the well-being of societies in the long term. The methodology aims to comprehensively address this issue within own operations and throughout the value chain, promoting a holistic understanding of the impacts associated with child labour. For a more detailed insight, refer to the accompanying methodology documents.

The challenge with ending child labour and protecting children from exploitation and abuse is reflected within the framework of the SDGs. Specifically, they underscore the goal of eradicating all forms of child labour, including forced labour and human trafficking (SDG 8: Target 8.7), and ending abuse, exploitation, and violence against children (SDG 16: Target 16.2).

The ILO has been at the forefront of efforts to combat child labour through various seminal reports. “Worst Forms of Child Labour: Global Estimates 2020” provides critical insights into the prevalence and nature of the most egregious forms of child labour worldwide, helping to inform targeted interventions and policies. Complementing this, “Ending Child Labour: A Global Childhood Guarantee” outlines a comprehensive framework for eradicating child labour and ensuring a protective environment for all children, emphasising the need for concerted global action and investment in education and social protection. Additionally, the “Global Child Labour Index 2022”, developed by the International Institute for Labour Studies (IILS) in collaboration with the ILO, serves as a vital tool for monitoring progress and identifying priority areas for intervention, facilitating evidence-based decision making and advocacy efforts. Together, these reports provide invaluable insights and tools for stakeholders to address the complex challenges posed by child labour and work towards the realisation of children's rights and well-being worldwide.

3.11.2 Activity Data

In assessing the negative impact of child labour within the methodologies, companies have two practical options for data collection and estimation. The first involves a direct measurement approach, encompassing on-site visits or adherence to a code of conduct, with a keen focus on compliance with country-specific regulations governing the minimum age for employment. Alternatively, the second option employs modelling based on low-skilled employees. This approach entails estimating child labour cases using UNICEF statistics on a country level and distributing the data across sectors according to the global average distribution. In cases where specific country data is lacking, a predefined global distribution allocates percentages to agriculture, hospitality, and manufacturing sectors. Importantly, the child labour share is specifically applied to low-skilled employees within each sector. To obtain the number of low-skilled workers, ILOSTAT serves as a valuable resource, with corrections made for outliers exceeding the median value. The methodology ensures transparency, encourages documentation of sources, calculations, and assumptions, and emphasises the importance of regular updates to reflect changes in child labour statistics and sector-specific

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distributions. Through these methods, companies can navigate a comprehensive and informed approach to assessing the societal impact of child labour, aligning with regulatory requirements and fostering continuous improvement in addressing this critical issue.

3.11.3 Databases

The International Labour Organization's (ILO)'s Forced Labour Statistics Database:	https://www.ilo.org/global/topics/forced-labour/statistics/lang--en/index.htm
The Walk Free Foundation's Modern Slavery Index:	https://www.walkfree.org/
The International Organization for Migration (IOM)'s Migration Data Portal:	https://gmdac.iom.int/global-migration-data-portal

3.11.4 WifOR Institute

3.11.4.1 Introduction

Child labour, besides its immediate implications, casts a long shadow on both the affected children and the society at large. The deprivation of educational opportunities for children not only compromises their prospects but also diminishes the potential productivity and income-earning capabilities of the workforce. In attempting to comprehend the economic ramifications of child labour, a prevailing method involves approximating the income and productivity forfeited concerning GDP per capita in PPP for each year of labour lost. This approach, rooted in assessing returns to education, aids in estimating the net present value of future losses across an individual's working life. Such an approach is a recurrent practice in the existing literature, ultimately culminating in a country-specific estimation of the economic costs incurred due to instances of child labour.

3.11.4.2 Activity Data Sources

- Psacharopoulos, G. & Patrinos, H.A. (2018): Returns to Investment in Education. A Decennial Review of the Global Literature. World Bank Policy Research Working Paper 8402.
- WDI Indicators database (2021a): NY.GDP.PCAP.PP.CD: GDP per capita, PPP (current international $).
- WDI Indicators database (2021b): SP.DYN.LE00.IN: Life expectancy at birth, total (years).
- OECD, provides the current retirement ages for a person who entered the labour force at age 22 (general or men if differentiated by gender).
- International Social Security Association, collecting the statutory pensionable age.
- The Social Pensions Database by Pension Watch, providing the age of eligibility for social pension schemes.

3.11.4.3 Formula

Simple multiplicative: Monetized impact = Sum of activity data (per subindicator and specification) x value factor

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3.11.4.4 Impact Pathway

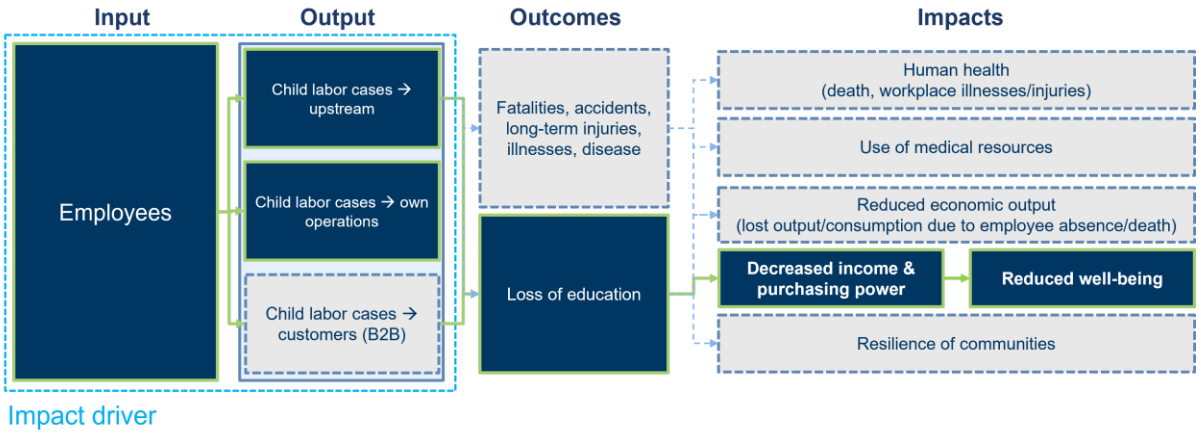

Figure 4: Simplified impact pathway of Child labour

[Source: Child Labour / WifOR Institute]

3.11.4.5 Valuation Method

WifOR uses the overall returns to schooling, estimated by the Mincerian rate of return. Returns to education over all grades are chosen as we are interested in returns to education across all age groups. There are estimates for 103 countries. For the remaining countries, we take the average of the world region and income region averages following the World Bank classifications.

The absolute productivity loss per year is the ratwe of return to schooling in percent multiplied by the average income in the country. We use the 2020 per capita values for gross domestic product (GDP) expressed in current international dollars converted by PPP conversion factor[14] to reflect both impacts on individual income and the productivity potential losses incurred by the society.

3.11.4.6 Sources of Valuation Data

- ILO (2019): What is child labour. International Labour Organization. Retrieved from: ILO Child Labour Facts.
- ILO & UNICEF (2021): Child Labour: Global estimates 2020, trends and the road forward. ILO & UNICEF Child Labour Global Estimates.
- Edmonds, E.V. (2008): Economic Growth and Child labour in Low Income Economies. GLM|LIC Working Paper No. 11, April 2016.
- Gordon, J. (2008): The Economic Implications of Child labour. A Comprehensive Approach to labour Policy. Gordon's Paper on Economic Implications of Child labour.
- Vionnet, S.; Friot, D.; Haut, S.; Adhikari, R. (2021): Screening for human rights impact in corporate supply chains. A methodological proposal for quantitative assessment and valuation — Novartis case study. Working Paper. Quantitative Assessment on Human Rights Impact in Corporate Supply Chains.
- Pereznieto, P.; Montes, A.; Langston, L.; Routier, S. (2014): The costs and economic impact of violence against children. Economic Impact of Violence Against Children.

[14] WDI Indicators database (2021a): NY.GDP.PCAP.PP.CD: GDP per capita, PPP (current international $).

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- World Vision (2016): Eliminating child labour, achieving inclusive economic growth. Policy Paper, October 2016.

3.11.4.7 Geographical Differences

To estimate income and productivity losses over a lifetime, the adult working life in the country is considered, taking the difference between the age 18 and the official retirement age.

3.11.4.8 Global Damage

USD 1.1 Trillion

3.11.5 VBA

3.11.5.1 Introduction

Child labour is defined as “work that deprives children of their childhood, their potential and their dignity, and that is harmful to physical and mental development.”[15] Child labour refers to the participation of children in work beyond what is permissible by law. Whether work done by children should be considered child labour depends on the age, local minimum working age regulations, the type and environment of work, working hours, and work relations.

At this point, this indicator concentrates on the societal impacts arising from children performing labour in upstream and own operations. As seen in Figure 4, various impacts can be related to child labour. The presented approach currently focuses on the impact of decreased income and purchasing power as a consequence of loss of education.

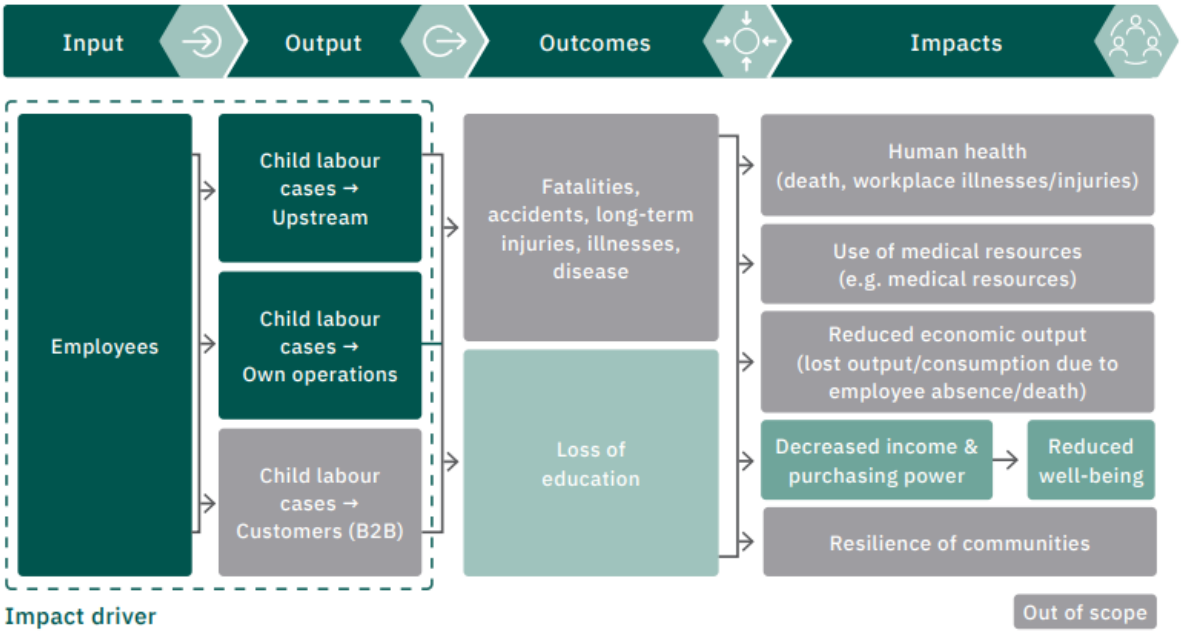

Figure 4: Simplified impact pathway Child Labour

[Source: Child Labour / VBA]

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3.11.5.2 Data Source

To measure impact drivers (cases): https://www.unicef.org/protection/child-labour

3.11.5.3 Calculation Logic

Total impact = Loss of education + illnesses and injuries

The impact of child labour is calculated based on the number of child labour cases in upstream and own operations. While data for child labour at own operations may be accessible (country-specific regulations on the minimum age for employment should apply for the assessment), obtaining data for the whole of upstream activities can be challenging for companies. To estimate the child labour rate by sector, the absolute number of cases is set about the number of employees in the sectors. It is assumed that children perform only low-skill labour.

Recommended approach: Track the number of child labour cases for own operations;
→ For the number of child labour cases in upstream activities, use the statistic from UNICEF on estimated child labour cases at country level for all countries in which upstream activities are located. Further guidance is presented publicly in the VBA methodology documentation.

- Loss of education: Per child labour case, the assumption of one year of missed education should be used. Regarding the income, the Gross National Income (GNI) per capita per country from the World Bank should be taken. A time period of 20 years is assumed to derive the net present value (NPV) of the lost income, with a discount rate of 3.5% (see General Method paper) which is then transferred to the change of well-being through the use of the HUI method. The DALYs lost are monetized taking into account the OECD's VSL (USD 185,990 per DALY in 2011 USD).
- Illnesses and injuries, even if part of the methodology, have not yet been implemented into the valuation approach due to a lack of data on the severity of cases occurring from child labour.

3.11.6 Analysis

VBA's methodology for assessing the impact of child labour emphasises the consequences of lost education and decreased income, particularly focusing on cases in both own operations and upstream activities. They recommend tracking child labour instances internally and estimating cases in upstream activities using UNICEF data, employing a net present value approach to quantify the long-term effects.

WifOR Institute's approach to understanding the economic implications of child labour involves estimating productivity and income losses over a lifetime, drawing from various data sources such as GDP per capita and life expectancy. Their method utilises returns to schooling and GDP per capita to calculate monetized impacts, estimating global damages at USD 1.1 trillion and highlighting the importance of addressing child labour for both individual and societal well-being.

Both VBA and WifOR Institute methodologies share a common focus on understanding and quantifying the impacts of child labour, particularly in terms of lost education and decreased income. They both rely on data from reputable sources such as UNICEF, the World Bank, and the OECD to inform their calculations and assessments. Additionally, both methodologies highlight the importance of addressing child labour not only for the well-being of affected children but also for broader societal and economic development.

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While both the VBA and WifOR Institute methodologies provide comprehensive frameworks for evaluating the impacts of child labour, they exhibit some gaps. Firstly, neither methodology fully addresses the complexities of measuring and valuing the non-economic consequences of child labour, such as its psychological and social effects on children and communities. Secondly, there's a lack of emphasis on incorporating qualitative data or perspectives from affected communities, potentially limiting the holistic understanding of the issue. Lastly, both approaches acknowledge challenges in obtaining comprehensive data for upstream activities, suggesting potential limitations in accurately assessing the full extent of child labour in supply chains.

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3.12 Forced Labour

3.12.1 Challenges

Forced labour is a serious human rights violation that occurs when individuals are compelled to work against their will. It is often accompanied by exploitative conditions, such as limited pay, restricted freedom, and dangerous working environments. The VBA methodology defines forced labour as involuntary work conducted under the threat of penalties, excluding state-imposed forced labour. This assessment aligns with the broader commitment to address the societal impact of forced labour, recognising its contribution to injuries and illnesses. Forced labour restricts freedom and alternative work opportunities, leading to a decrease in future income and purchasing power.

The challenge outlined emphasises the eradication of forced labour and the protection of labour rights within the context of the Sustainable Development Goals. They highlight the goal of ending all forms of child labour, including forced labour and human trafficking (SDG 8: Target 8.7, Target 8.8), and ending abuse, exploitation, trafficking, and violence against children (SDG 16: Target 16.2). Additionally, they stress the promotion of the rule of law and equal access to justice for all (SDG 16: Target 16.3).

3.12.2 Activity Data

To assess the negative impact of forced labour within the methodologies, companies have two main approaches for data collection and estimation. The first method involves direct measurement, such as information obtained from random site visits or adherence to a code of conduct. The second approach utilises a modelling technique based on the number of low-skilled employees. In this method, forced labour cases are estimated using statistical data on the prevalence of forced labour incidents and the number of low-skilled employees reported in the respective country. For modelling purposes, the number of forced labour incidents on a country level is derived from the Global Slavery Index Initiative. It is assumed that individuals in forced labour typically engage in low-skilled work. Therefore, the estimated forced labour cases are allocated specifically to low-skilled employees within the country and sector. Data on the total number of employees and the number of low-skilled employees per country are obtained from ILOSTAT. The forced labour share relative to the number of low-skilled workers in each country is then computed. Due to a lack of available data, there is no further breakdown of forced labour cases per sector. This modelling approach ensures transparency and allows for documentation of sources, calculations, and assumptions, providing a comprehensive understanding of the societal impact of forced labour. Regular updates to reflect changes in forced labour statistics and sector-specific distributions are recommended to enhance accuracy and relevance over time.

3.12.3 Databases

The ILO's Forced Labour Statistics Database:	https://www.ilo.org/global/topics/forced-labour/statistics/lang--en/index.htm
The Walk Free Foundation's Modern Slavery Index:	https://www.walkfree.org/
The International Organization for Migration (IOM)'s Migration Data Portal:	https://gmdac.iom.int/global-migration-data-portal

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3.12.4 WifOR Institute

3.12.4.1 Introduction

The phenomenon of forced labour represents a stark violation of human rights, entailing work that is coercively imposed by private agents and often linked to modern-day forms of slavery. This form of exploitation encompasses various labour conditions, including bonded labour, forced domestic work, and practices that echo historical remnants of slavery. However, within this scope, forced sexual exploitation and state-imposed forced labour are excluded from consideration. The impacts on the victims of forced labour are multifaceted, encompassing heightened risks of injury or fatality, compromised life quality due to the inability to make autonomous life decisions, mental stress arising from threats, and the financial exploitation endured. This approach seeks to quantify the combined effects of mental health repercussions, which are relatively uniform globally, and financial exploitation, contingent upon specific income levels within countries and sectors. The resulting assessment aims to delineate the country and sector-specific impacts in terms of USD per victim of forced labour.

3.12.4.2 Activity Data Sources

- Walk Free Foundation (2018): “Global Slavery Index 2018 Dataset”. Perth, Australia. www.globalslaveryindex.org.
- ILO and Walk Free Foundation (2017): Global Estimates of Modern Slavery: Forced Labour and Forced Marriage

3.12.4.3 Subcategories

None

3.12.4.4 Calculation Logic

Simple multiplicative: Monetized impact = Activity data x value factor

Calculates the share of income withheld from victims and the societal cost per victim in different sectors (agriculture, other sectors, domestic labour).

Assumptions: Assumes similar rates across sectors and regions for lack of sectoral differentiation and data.

Formula

$$regular\ income = profit\ per\ victim + 12 * monthly\ average\ earning$$

$$withheld\ income\ share = profit\ per\ victim\ regular\ income$$

$$withheld\ income\ of\ a\ forced\ labor\ victim = withheld\ income\ share * average\ sectoral\ labor\ compensation\ per\ employee$$

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3.12.4.5 Impact Pathway

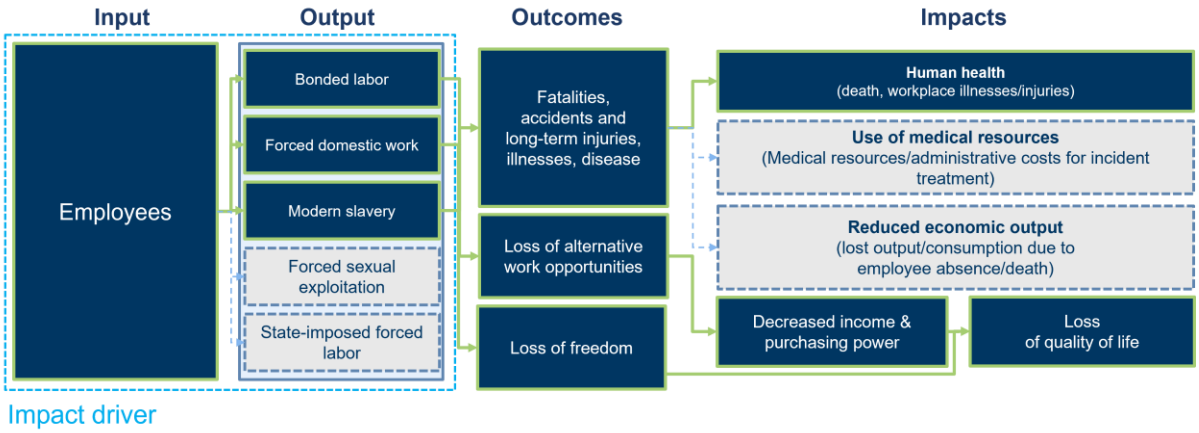

Figure: Impact pathway of Forced labour

[Source: Forced Labour / WifOR Institute]

3.12.4.6 Valuation Method

Mental Health Impacts: To value the mental health impact of forced labour, we evaluate the quality-of-life reduction through the experience of psychological distress by translating it into DALYs. The Global Burden of Disease Collaborative Network[15] provides standardised "disability weights" that reflect the relative severity of a health state. The disability weight of a moderate episode of a major depressive disorder is chosen as the comparative impact on the quality of life as life in forced labour.

This results in the following equation for the valuation of the mental health impacts per person in forced labour:

$$\frac{0.4 * DALY}{case} * 200{,}000 \frac{USD}{DALY} = 80{,}000 \frac{USD}{case}$$

Unduly withheld income:

- **Non-domestic Forced Labour:**
  The International Labour Organization (ILO) provides estimates for annual profits per victim in non-domestic private forced labour. It distinguishes the sectors "Agriculture" and "Other Sectors" and by world region.
  It also provides monthly average earnings per victim in these categories, allowing to calculate the share of income that is withheld from the victim:
  regular income = profit per victim + 12 * monthly average earning
  withheld income share = (profit per victim)/(regular income)

$$withheld\ income\ of\ a\ forced\ labor\ victim = withheld\ income\ share\ * average\ sectoral\ labor\ compensation\ per\ employee$$

[15] Global Burden of Disease Collaborative Network (2020): Global Burden of Disease Study 2019 (GBD 2019) Disability Weights. Seattle, United States of America: Institute for Health Metrics and Evaluation (IHME), 2020.

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- **Domestic Labour:**
  "The economic data stored in the 2012 Global Estimate database of reported cases of forced labour show that, on average, domestic workers in forced labour are deprived of 60 per cent of their due wages," i.e. wages they should or would earn if working freely in the corresponding regions. Therefore, the societal cost per victim in the sector covering households as employers is estimated as 60% of the per capita labour compensation in the sector, given by the reference Input-Output table.

3.12.4.7 Sources of Valuation Data

- ILO (2014): Profits and Poverty: The Economics of Forced Labour. ILO Working Paper. https://www.ilo.org/wcmsp5/groups/public/---ed_norm/---declaration/documents/publication/wcms_243391.pdf.
- Oram, S.; Abas, M.; Bick, D.; Boyle, A.; French, R.; Jakobowitz, S.; Khondoker, M.; Stanley, N.; Trevillion, K.; Howard, L.; Zimmerman, C. (2016): Human Trafficking and Health: A Survey of Male and Female Survivors in England, in: American Journal of Public Health (AJPH), Vol. 106, Nr. 6, pp. 1073- 1078.
- The Freedom Fund (2017): Understanding the psychosocial and mental health needs of bonded labourers in south-eastern Nepal, Evidence in Practice (2).
- Global Burden of Disease Collaborative Network (2020): Global Burden of Disease Study 2019 (GBD 2019) Disability Weights. Seattle, United States of America: Institute for Health Metrics and Evaluation (IHME), 2020.

3.12.4.8 Geographical Differences

Differences among countries due to income differences.

3.12.4.9 Global Damage

USD 1.6 Trillion

3.12.5 VBA

3.12.5.1 Introduction

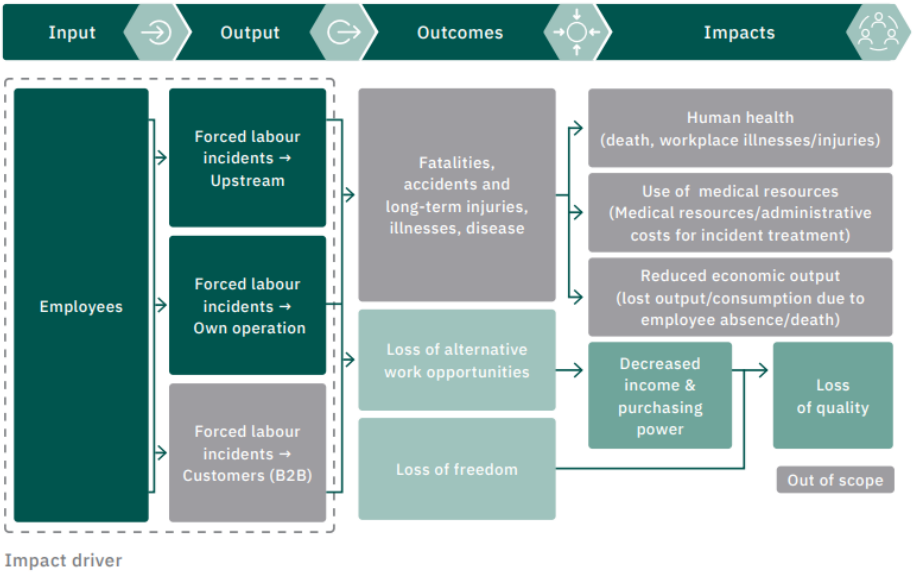

Figure 6: Simplified impact pathway Forced Labour

[Source: Forced Labour / VBA]

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With this indicator, we currently concentrate on the societal impacts arising from employees being forced to perform the work in upstream and own operations. As seen in Figure 6, this approach focuses on the impacts on life quality resulting from forced labour. However, there may be additional impact categories which have not yet been implemented in this valuation approach but might be added in future versions.

3.12.5.2 Data Sources

Data sources for the valuation factor:

- Value of a DALY: VSL OECD
- 50% assumption: Vionnet et al., 2021

Data sources for the impact driver:

- Described in VBA methodology paper. If no direct data is available, some of the data sources used are the Global Slavery Index Initiative.

3.12.5.3 Calculation Logic

The VBA approach is to:

→ Collect the number of forced labour incidents across upstream and own operations – if no data is available, follow the instructions for calculating the number as described in (i) and (ii) in the VBA methodology guidelines;

→ Value the outcome of loss of life quality assuming a loss of 50% DALY per forced labour incident (comparable to a severe anxiety disorder) and a universal value of USD 185,900 per DALY.

Users should: → Apply the rules outlined in the General Method paper (e.g. include all relevant value chain levels); → Select appropriate data sources to calculate an estimation of forced labour for upstream activities.

In practice, you either (1) use the number of forced labour cases, or (2) estimate the cases from the number of low-skilled employees.

The models propose to exclude illnesses/injuries effects of forced labour due to missing data on the severity of cases and only focus on forced labour's effect on loss of life quality.

3.12.6 Analysis

WifOR Institute: Defines forced labour, focusing on mental health and financial exploitation while excluding sexual exploitation and state-imposed labour; relies on data from sources like the Walk Free Foundation and ILO to quantify forced labour incidents and assess financial impacts; values mental health impacts using disability weights and estimates financial exploitation based on withheld income shares, applying a simple multiplicative calculation logic.

VBA: Focuses on societal impacts of forced labour in upstream operations, valuing life quality impacts and excluding other categories; utilises data sources such as the Global Slavery Index Initiative for valuation factors and impact drivers; estimates forced labour incidents, values the loss of life quality per incident using DALYs and a universal value, and compares impacts across different value chain levels and regions.

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Scope and Exclusions: Both methodologies define forced labour and focus on assessing its societal impacts, particularly in terms of mental health repercussions and financial exploitation. They exclude certain aspects such as forced sexual exploitation and state-imposed labour from their analyses.

Data Sources: Both methodologies rely on data from reputable sources like the Walk Free Foundation, ILO, and other relevant organisations to quantify forced labour incidents and understand their financial implications.

Analysis Approach: They employ valuation methods to assess the impact of forced labour, with the WifOR Institute methodology focusing on quantifying mental health impacts and financial exploitation through simple multiplicative calculation logic, while the VBA methodology concentrates on valuing the loss of life quality per incident using DALYs and a universal value.

Geographical Considerations: Both methodologies consider geographical differences, recognising variations in income levels and sectoral differences globally when evaluating the impacts of forced labour.

Scope Variation: WifOR Institute focuses primarily on mental health repercussions and financial exploitation, while VBA concentrates specifically on life quality impacts, excluding other potential consequences such as physical health issues or broader societal implications.

Valuation Methods: WifOR Institute utilises disability weights and income withholding calculations to quantify impacts, while VBA relies heavily on DALYs and a universal monetary value per DALY, potentially overlooking nuances in valuation approaches.

Data Sources and Estimation: While both methodologies use reputable data sources, VBA's estimation methods for forced labour incidents are less clearly defined, potentially leading to inconsistencies in data interpretation and analysis compared to the more transparent approach outlined by WifOR Institute.

Geographical Considerations: While both methodologies consider geographical differences, there may be discrepancies in how these differences are accounted for, potentially leading to variations in the assessment of forced labour impacts across regions.

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3.13 Human Capital

3.13.1 Challenge

Human capital addresses living wages, inequality, and occupational health and safety based on demography, sector, and region.

The SDGs related to human capital underscore the importance of investing in human capital. They emphasise targets aimed at promoting good health and well-being (SDG 3: Target 3.3, Target 3.8, Target 3.9), fostering decent work and economic growth (SDG 8: Target 8.2, Target 8.5), and reducing inequality (SDG 10: Target 10.1, Target 10.2, Target 10.3). These targets prioritise initiatives such as halving premature deaths from non-communicable diseases, achieving universal health coverage, promoting full and productive employment, reducing poverty, and ensuring equal opportunity and access to essential goods and services for all individuals, regardless of gender or socioeconomic status.

The "Global Goals Report 2022" provides a comprehensive assessment of progress towards achieving the SDGs, highlighting the interconnected nature of global challenges and the urgent need for coordinated action. Central to the SDGs is the concept of human capital, which encompasses the knowledge, skills, health, and well-being of individuals. The report underscores the critical role of investing in human capital to address inequalities, promote inclusive growth, and advance sustainable development worldwide. Complementing this, the "World Inequality Report 2022" sheds light on the persistent disparities in income and wealth distribution, emphasising the importance of equitable access to resources and opportunities in fostering human capital development. Meanwhile, the "World Happiness Report 2023" offers insights into subjective well-being and life satisfaction, providing a holistic perspective on human capital that encompasses not only material wealth but also social connections, mental health, and overall quality of life. Together, these reports underscore the multidimensional nature of human capital and the imperative of prioritising investments in education, health, and social protection to foster sustainable and inclusive development for all.

3.13.2 Activity Data

The activity data requires association of individuals with demographic characteristics, regions, sectors, and income.

3.13.3 Databases

ILOSTAT	https://ilostat.ilo.org/
OECD Employment and Labour Market Statistics	https://stats.oecd.org/
OECD Education and Skills Database	https://data.oecd.org/education.htm
OECD Social Expenditure Database	https://www.oecd.org/social/expenditure.htm
OECD Labour Market Flexibility Database	https://stats.oecd.org/index.aspx?queryid=35253
OECD Productivity Database	https://www.oecd.org/sdd/productivity-stats/
World Bank Open Data	https://data.worldbank.org/

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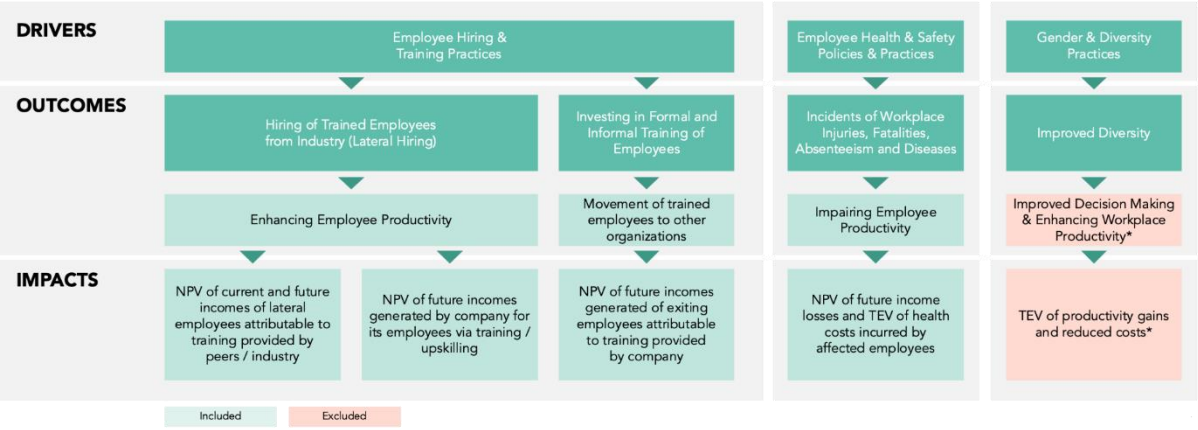
3.13.4 GIST Impact (Human Capital)

3.13.4.1 Evaluation Framework and Methodology

An overview of the framework adopted for the valuation of human capital is shown below.



[Source: Human Capital / GIST Impact]

“Human Capital” represents the economic value embodied in individuals, including their knowledge, skills, and health. In synergy with this concept, training plays a vital role, concentrating on providing education to employees through dedicated training hours for skill development and retention. This employee education not only enhances productivity but also increases the future wages of the trained workforce, thereby contributing to the overall enrichment of human capital. GIST Impact's Human Capital Externality valuation framework utilises an income-based approach to assess human capital creation, externalities, and the impacts on employee health and safety generated by businesses. This approach aligns with the neoclassical economic theory of investment from a business perspective, effectively capturing factors that influence human capital formation based on values, volumes, and prices.

Our framework diverges from Lev & Schwartz (1971) by adopting a gate-to-grave approach, considering individuals’ economic life until retirement and accounting for the flow of human capital via hiring and attrition, while measuring the economic impact of employee health & safety (EHS) practices on employee well-being. Incorporating insights from Jorgenson & Fraumeni (1989), we include the role of non-market activities in the formation of human capital. For the same, we start by identifying initial employee numbers and estimating yearly exits based on attrition rates. We project future compensation using provided salary growth rates, calculate the yearly increase for exiting employees, and determine per capita human capital externalities (HCX) using specified discount rates. The annual HCX value results from multiplying per capita HCX with exits, covering both exits and lateral hires.

Moreover, the total economic value of HCX from occupational health and safety practices covers permanent and temporary disability, occupational health problems, fatalities, parental leave, overwork, and absenteeism. Avoided costs for fatalities use the value of statistical life (VSL), and absenteeism costs are calculated based on wage loss. Also, we take account of diversity, equity, and inclusion (DEI) outcomes in the workforce and its impact on human capital. This module is grounded in thorough research on the gender pay gap and women's labour force participation. Utilising gender and ethnicity-specific data from a trusted workforce intelligence provider, we meticulously examine indicators essential for human capital, segmented across 6 ethnic groups (White, Asian, Hispanic, Black, Native, and Multiple), 7 seniority levels (Entry, Junior, Associate, Manager, Vice President, Director, and

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C-Suite), 7 roles (Sales, Engineer, Admin, Operations, Scientist, Marketing, and Finance), and 15 geographic regions.

3.13.4.2 Calculation Logic

Human Capital Creation (HCC): Human capital creation emanates from employee training and skilling focusing on the gate-to-grave model.

HCC/per employee = Increase in compensation/Discount Rate(1/1+Discount Rate-1)^Years to retirement*

Human Capital Externalities (HCX): Human capital externality flowing from attrition takes into account the discounted increase in compensation for the number of years HCX accrues post the exit of the employee (we assume this to be five years).

HCX Attrition/person = Increase in compensation/Discount Rate(1/1+Discount Rate-1)^ No of*

years HCX accrues post-exit

Employee Health & Safety (EHS): Workplace injuries and accidents, affecting employees' effectiveness and efficiency, contribute to human capital losses and a diminished quality of life measured in life years.

Employee Health Safety Impact = Total economic cost due to permanent disability/temporary disability + Economic cost of occupational health diseases/fatalities + Economic cost of parental care + Economic cost of overwork and absenteeism

Diversity, Equity, and Inclusion (DEI): For the assessment of DEI, we consider workforce diversity in terms of gender and ethnicity. The calculation of the labour force participation rate (LFPR) represents diversity, while the pay gap represents inclusion.

Gender Pay Gap (GPG) = {(Average remenuration of men - Average remenuration of women) / Average remenuration of men}× 100

Women LFPR (LFPRw) = (Women in the labour force / Working-age women) × 100

Both are expressed as percentages. The pay gap and LFPR can also be measured for ethnicity using the same calculation logic.

3.13.4.3 Data Sources

- European Agency for Safety and Health at Work. (2024). Retrieved from: https://osha.europa.eu/en
- Health and Safety Executive. (2024). Retrieved from: https://www.hse.gov.uk/
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- Organisation for Economic Co-operation and Development. (2024). Retrieved from: https://stats.oecd.org/Index.aspx?DataSetCode=rmw
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3.13.5 Impact Weighted Account (Human Capital)

3.13.5.1 Introduction

Four impact dimensions (wage quality, diversity, opportunity, and location) are combined to calculate a measure of employment impact intensity for each firm, which is defined as total employment impact scaled by the number of employees. Employment impact intensity can be interpreted as “impact per employee”.

3.13.5.2 Activity Data

- From the employer directly (group, location, sector/job-specific data)
- Primary data on workforce composition, location, and wages are from Revelio Labs
- MIT Living Wage Calculator, the Bureau of labour Statistics, the United States Census Bureau, and other official government sources for information such as State-level minimum wages

3.13.5.3 Formula

Employment impact = Sum (wage quality impact, diversity impact, opportunity across jobs impact, opportunity across seniorities impact, location impact)

3.13.5.4 Valuation Technique

3.13.5.4.1 Wage Quality Impact

Wage quality impact calculates the wage quality impact of a firm by considering the living wage and the marginal utility of income. The living wage adjustment accounts for employees earning below the living wage, while the marginal utility adjustment accounts for employees earning above the income satiation level. The total wage quality impact is the sum of the adjustments for all firm locations.

The sum for each location of the firm is the result of the following steps:

a. Total Unadjusted Wages Paid: Sum up the total wages paid in location for each firm-year observation.
b. Living Wage Adjustment: Determine the living wage benchmark for location. Identify employees earning below the living wage benchmark. Calculate the living wage gap and minimum wage credit. Find the living wage adjustment by adding the living wage gap and minimum wage credit.
c. Marginal Utility Adjustment: Determine the local income satiation level for location. Identify employees earning above the income satiation level. Calculate marginal utility-adjusted salaries paid. Find the total marginal utility adjustment.

3.13.5.4.2 Diversity Impact

The diversity impact measures the diversity impact of a firm by comparing the actual number of employees from each demographic group to the expected number based on local population demographics. The “missing” employees are then multiplied by the average firm

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salary to calculate the monetized diversity impact for each demographic group. The total firm diversity impact is the sum of the monetized diversity impacts for all demographic groups.

The sum for each demographic group at each firm location is the result of the following steps:

a. Total Number of Employees: Determine the total number of employees at the firm.
b. Actual Number of Employees in Each Gender and Race/Ethnic Group: Break down the total number of employees into gender and race/ethnic groups.
c. Expected Number of Employees: Calculate the expected number of employees in each group based on local demographics.
d. Missing Employees: Find the difference between the expected and actual number of employees to identify missing employees in each group.
e. Monetized Diversity Impact: Multiply the missing employees in each group by the average firm salary to calculate the diversity impact for each group.

3.13.5.4.3 Opportunity Across Job Category Impact

The opportunity across job category impact measures the opportunity across job category impact by examining the distribution of employees across job categories and their associated salaries. It identifies the median job category and splits employees into a “high salary group” and “low salary group” based on their average salary. Then, for each demographic group, it calculates the expected number of employees in the high salary group based on their percentage representation in the firm, compares it to the actual number of employees in the group, and identifies any “missing” employees. The monetized opportunity across job category impact is calculated by multiplying the number of “missing” employees by the difference in average salary between the high and low salary groups. The total firm opportunity across job category impact is the sum of these impacts for all demographic groups and firm locations.

Sum for each demographic group at each location results from the following steps:

a. Average Annual Salary in Each Job Category: Calculate the average annual salary in each job category by dividing the total unadjusted salaries paid in that category by the total employees in that category.
b. Ranking and Median Category: Rank each job category based on average salary. Determine the median category.
c. High and Low Salary Groups: Establish a “high salary group” consisting of employees in job categories earning above the median. Establish a “low salary group” consisting of employees in job categories earning below the median.
d. Percentage of Employees in Demographic Group: Determine the percentage of employees in each demographic group at the firm.
e. Expected Employees in High Salary Group: Multiply the percentage of employees in group1 by the total employees in the “high salary group” to find the expected number of employees in group1 in the high salary group.
f. Actual Employees in High Salary Group: Determine the actual number of employees in group1 in the high salary group.
g. Missing Employees in High Salary Group: Find the difference between the expected and actual number of employees in group1 in the high salary group to identify missing employees.

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h. Monetized Opportunity Across Job Category Impact: Multiply the missing employees in group1 in the high salary group by the difference between the average salary in the high salary group and the average salary in the low salary group to calculate the monetized opportunity across job category impact for group1.

3.13.5.4.4 Opportunity Across Seniorities Impact

The opportunity across seniority impact formula measures the distribution of employees across seniority levels and the associated salaries. It calculates the expected number of employees in each seniority level for each demographic group based on the percentage representation of the group in the firm. The formula then compares the expected number of employees to the actual number of employees and identifies any "missing" employees. The monetized opportunity penalty for each seniority level is calculated by multiplying the number of missing employees by the difference in average salary between the level and the next lower level. The total firm opportunity across seniority impact is the sum of these impacts for all demographic groups and firm locations.

Sum up the opportunity across seniorities impact values for each seniority level 2, 3, 4 in each demographic group in each location of firm:

a. Total Employees in seniority level 2: Count the total number of employees in seniority level 2.
b. Employees in Group1 at Seniority Level 2: Determine the number of employees in group1 at seniority level 2.
c. Percentage of Employees in Group1 at the Firm: Calculate the percentage of employees in group1 at the firm.
d. Expected Employees in Group1 at Seniority Level 2: Multiply the total employees at seniority level 2 by the percentage of employees in group1 at the firm.
e. Missing Employees from Group1 at Seniority Level 2: Find the difference between the expected and actual number of employees in group1 at seniority level 2.
f. Monetized Opportunity Penalty for Seniority Level 2: Multiply the missing employees from group1 at seniority level 2 by the difference in average salary between seniority level 2 and seniority level 1.

3.13.5.4.5 Location Impact

Location impact covers how to calculate the employment impact of a firm. It considers the number of employees at each firm location, the total number of employed individuals from local unemployment statistics, the total number of unemployed individuals, the incremental wages received due to firm employment, the hypothesised unemployment rate without firm job creation, and the monetized location impact.

Sum for each location of firm results from following steps:

a. Number of Employees at Each Firm Location: Determine the number of employees at each firm location.
b. Total Employed Individuals from Local Unemployment Statistics: Identify the total employed individuals from local unemployment statistics for each firm location.

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c. Total Unemployed Individuals from Local Unemployment Statistics: Identify the total unemployed individuals from local unemployment statistics for each firm location.
d. Incremental Wages Received due to Firm Employment: Calculate the incremental wages received by subtracting the average annual salary at minimum wage from the average annual salary for firm employees.
e. Hypothesised Unemployment Rate without Firm Job Creation: Calculate the hypothesised unemployment rate without firm job creation using the formula provided.
f. Monetized Location Impact: Multiply the incremental wages received due to firm employment by the hypothesised unemployment rate without firm job creation and the number of employees at each firm location.

3.13.6 Analysis

The IWA framework evaluates a firm's impact on human capital through metrics such as wage quality, diversity, opportunity across job categories and seniorities, and location impact to provide insights into how the firm's practices affect employee well-being and economic opportunity within and across demographic groups and locations.

GIST Impact assesses human capital by focusing on human capital creation, externalities, employee health and safety, and diversity, equity, and inclusion (DEI) outcomes. It provides a comprehensive evaluation of how businesses contribute to the economic value embodied in individuals, considering factors such as training, attrition, workplace safety, and workforce diversity.

Both the Impact Weighted Account (IWA) and GIST Impact frameworks share a common goal of assessing the impact of businesses on human capital. They both consider various dimensions such as wage quality, diversity, opportunity, and location to understand how firms affect employee well-being and economic opportunity. Additionally, both frameworks emphasise the importance of analysing workforce demographics and practices to comprehensively evaluate a firm's contribution to human capital development and societal well-being.

While both the Impact Weighted Account (IWA) and GIST Impact frameworks provide comprehensive assessments of businesses' impacts on human capital, there are notable gaps between them. The IWA framework primarily focuses on quantitative metrics such as wage quality, diversity, and location impact, which may overlook qualitative aspects of human capital development such as training and skill enhancement. On the other hand, while GIST Impact incorporates factors like human capital creation, health and safety, and diversity, it may lack the same level of granularity in quantifying impacts across different dimensions compared to the IWA framework. Bridging these gaps could involve integrating qualitative aspects of human capital development into the IWA framework and enhancing the quantitative analysis of impacts within the GIST Impact framework to provide a more holistic assessment of businesses' contributions to human capital.

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3.14 Diversity, Equity, and Inclusion

3.14.1 Challenge

Diversity, equity, and inclusion revolves around achieving gender equality and promoting diversity, equity, and inclusion across various sectors to address disparities in pay, equal employment opportunities, and health outcomes based on gender, ethnicity, and socioeconomic status. To tackle these challenges effectively, comprehensive strategies and interventions are required to end discrimination, ensure equal opportunities, and promote inclusive growth and development worldwide.

The challenge emphasises the importance of diversity, equity, and inclusion within the Sustainable Development Goals framework, which focus on targets aimed at promoting gender equality (SDG 5: Target 5.1, Target 5.5), reducing inequalities (SDG 10: Target 10.2), and ensuring decent work and economic growth for all (SDG 8: Target 8.5, Target 8.8). These targets underscore the need to end discrimination against women and girls, ensure their equal participation in decision-making processes, empower marginalised groups, promote equal opportunities in employment, and create safe and inclusive work environments for all individuals, including woman migrants and those in precarious employment.

The “Global Gender Gap Report” by the World Economic Forum, The “Global Diversity Management Outlook” by The Economist Intelligence Unit, and “The Inclusive Growth and Development Report” by the World Bank collectively provide valuable insights into diversity, equity, and inclusion (DEI) across various sectors and regions. These reports highlight the importance of addressing disparities and promoting inclusivity to achieve sustainable development and shared prosperity globally. The Global Gender Gap Report assesses gender disparities in economic participation, education, health, and political empowerment, emphasising the need for concerted efforts to close gender gaps and promote gender equality. Similarly, The Global Diversity Management Outlook sheds light on organisational practices and strategies for fostering diversity and inclusion in workplaces, recognising the benefits of diverse teams and inclusive cultures for innovation and business performance. Complementing these, The Inclusive Growth and Development Report underscores the significance of inclusive policies and investments in reducing poverty and promoting equitable economic opportunities for all individuals, regardless of their background or identity. Together, these reports contribute to the broader conversation on DEI, highlighting the imperative of creating environments where everyone can thrive and contribute to shared prosperity.

3.14.2 Activity Data

The activity data requires association of individuals with demographic characteristics, regions, sectors, and income.

3.14.3 Databases

ILOLEX	https://www.ilo.org/global/standards/lang--en/index.htm
Skills for Employment Database	https://www.ilo.org/skills/lang--en/index.htm
Global Alliance for Training and Education (GATE)	https://gateglobal.org/
Occupational Safety and Health (OSH) Data Portal	https://osha.europa.eu/en
Forced Labour Statistics Database	https://www.ilo.org/global/topics/forced-labour/statistics/lang--en/index.htm

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Global Living Wage Coalition's Living Wage Database	https://www.globallivingwage.org/
Fairtrade Foundation's Fairtrade Minimum Prices	https://www.fairtrade.net/standard/minimum-price-info
World Bank's Living Wage Database	https://wageindicator.org/salary/living-wage/database-access

3.14.4 VBA

Disclaimer: Some VBA members are currently piloting a pre-test methodology based on the work of Deloitte. The main impacts quantified are related to gender pay and gender balance. More information on this topic may be shared after the piloting (May 2024).

3.14.5 WifOR Institute

3.14.5.1 Introduction

In societies worldwide, the persistence of gender pay disparities casts a long shadow on the fabric of equality. The indicator assessing the impacts of gender inequality, particularly in the form of earnings differences between men and women (known as the gender pay-gap), holds a critical mirror to societal dynamics. The ramifications extend beyond mere economic discrepancies; they echo profoundly in the social landscape. In countries where this imbalance is pronounced, it often signals a systemic issue, where women face barriers to achieving parity in societal status. This unequal distribution of income not only affects economic prosperity but also crucially impedes access to essential healthcare. The resulting health consequences are quantified and expressed through DALYs, offering a stark numerical representation of the toll exacted by these disparities on overall well-being.

3.14.5.2 Activity Data Sources

WIOD database: The WIOD provides detailed information on the global economy's input-output structure, including the interrelationships between industries and sectors. It offers data on production, trade, and consumption across various countries and regions, enabling the analysis of economic activities and their impacts on different sectors and countries.

ILO database: The ILO database offers comprehensive data on labour-related indicators, including employment rates, wages, working conditions, and labour market trends worldwide. It provides valuable insights into labour market dynamics, helping policymakers, researchers, and practitioners understand employment patterns and labour market challenges.

Eurostat (Table "nama_10_a64e"): Eurostat, the statistical office of the European Union, offers a wide range of economic data, including the "nama_10_a64e" table, which provides information on employment and economic activities across EU member states. This dataset covers key indicators such as employment by economic activity, allowing for detailed analysis of employment trends and structures within the EU.

OECD (Table "SNA_TABLE7A"): The OECD provides data on various economic aspects, including national accounts and input-output tables. The "SNA_TABLE7A" table likely contains information related to economic activities, such as production, consumption, and investment, allowing for cross-country comparisons and analysis of economic performance and structure among OECD member countries.

3.14.5.3 Subcategories

None

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3.14.5.4 Calculation logic

Compute the gender pay gap as a percentage difference between the mean earnings of men and women.

Monetized impact = Gender pay gap x value factor

3.14.5.5 Impact Pathway

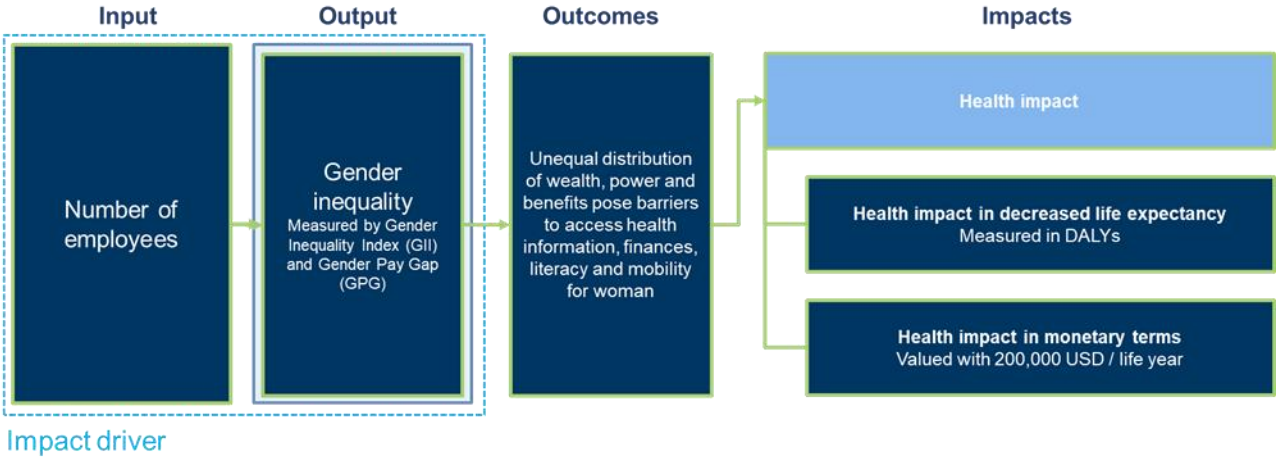

Figure: Impact pathway gender pay gap

[Source: DEI / WifOR Institute]

3.14.5.6 Valuation Method

Gender inequality is commonly expressed using the gender inequality index (GII). Vaes et al. analysed the link between gender inequality (GII) and health indicators (e.g. DALYs) between 1990 and 2017 for 36 OECD countries. The study concluded that a 0.1 unit increase in GII, leads to 0.05 years decrease in life expectancy of a person. The relationship between the GII and the GPG was calculated using GII and GPD data of 48 countries. The analysis concludes that a 0.1 unit increase in GPG (10%) correlates with a 0.04 unit increase in the GII. By bringing the above together it can be concluded that a 10% GPG is correlated with a 0.2 years decrease in the total life expectancy of a person and a GPG of 15% to a 0.3 years life expectancy decrease, respectively. The decrease in life expectancy is translated into DALYs with 1 DALY being valued at USD 200,000.

3.14.5.7 Geographical Differences

Country-specific wage data.

3.14.5.8 Global Damage

USD 7.3 billion

Use the findings to propose policy changes or interventions aimed at reducing the gender pay gap and achieving pay equity.

Sources

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A. de Koning and A. Tukker. (2018): EXIOBASE 3: Developing a time series of detailed Environmentally Extended Multi-Regional Input-Output tables. Journal of Industrial Ecology.
- Vaes et al. (2021): Association between gender inequality and population-level health outcomes: Panel data analysis of organization for OECD countries. The Lancet, Volume 39, 101051.
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- Vionnet, S.; Adhikari, R.; Haut, S. (2021): The Health Utility of Income and Taxes. Part A - Health Utility of Income. Impact valuation methodology, global assessment and application to businesses. Whitepaper, Valuing Impact.
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- Pinho-Gomes A, Vassallo A, Carcel C, et al. (2022): Gender equality and the gender gap in life expectancy in the European Union, BMJ Global Health 2022;7:e008278.
- Vaes et al. (2021): Association between gender inequality and population-level health outcomes: Panel data analysis of organization for OECD countries. The Lancet, Volume 39, 101051.
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3.14.6 GIST Impact

GIST Impact is currently in the pre-testing phase of incorporating diversity, equity, and inclusion (DEI) as an indicator, along with the corresponding value factor.

3.14.7 Conclusion / Analysis

WifOR Institute's approach focuses on quantifying the impacts of gender pay disparities on societal well-being, particularly through the lens of health outcomes measured in DALYs. Utilising data from various sources, including the WIOD and studies such as Vaes et al. (2021), they establish a correlation between the GPG and decreases in life expectancy, translating

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these health effects into monetary terms to highlight the substantial economic costs associated with gender inequality. Their analysis underscores the urgent need for policy interventions aimed at reducing the gender pay gap to mitigate its detrimental effects on both economic prosperity and public health.

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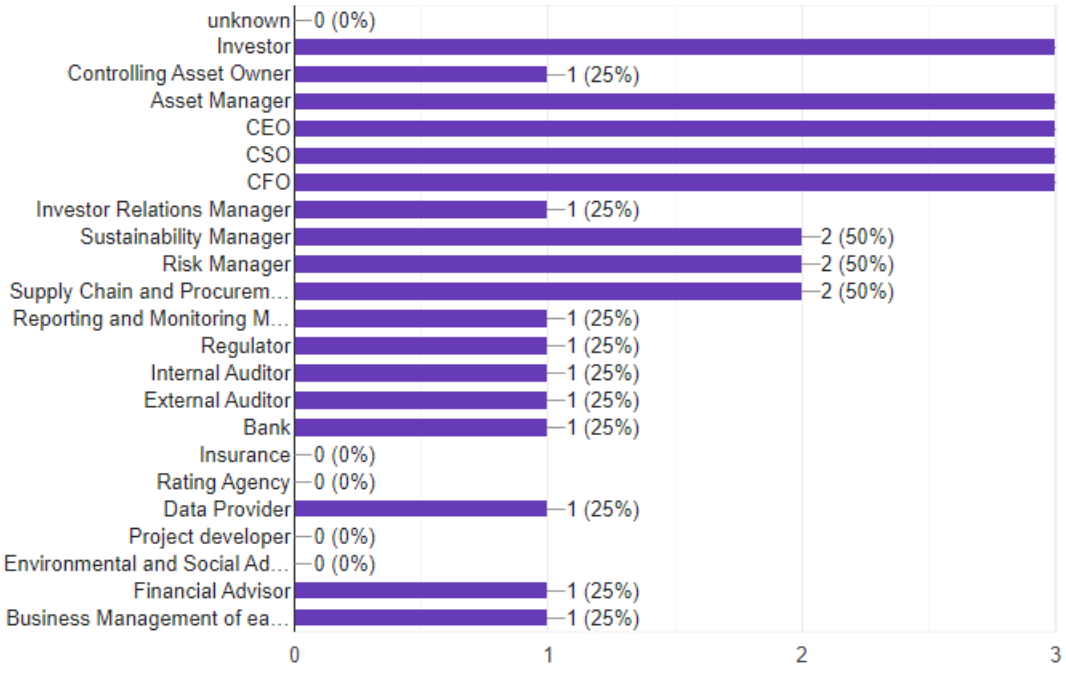
Annex

Annex "Invitation to the Sprint"

Dear [Name]
You will find agenda items for our discussion scheduled today directly in the invitation (https://teams.microsoft.com/link).
Agenda suggested as follows:

- Discuss the outline for the Impact Valuation Sprint ('Sprint') – 5 minutes
- Potential application of the outcomes of the Sprint ('Potential Applications') – 5 minutes
- Envisage impact metrics and valuation techniques used in the analysis (Identify Impact Metrics and Valuation Techniques Sources) – 10 minutes
- Suggest and discuss a structure to organise each (Impact) Driver – 5 minutes
- Coverage of the Drivers in the Sprint based on data availability and methodological transparency (organisation of (Impact) Driver / deliberately not using KPI) – 10 minutes

Additionally, I want to draw your attention to the brief 5-question survey (https://forms.link). The early responses have been enlightening, especially in addressing queries such as "Who are the intended users of your impact valuation solution?" (if you are developing a software tool and/or management process for yourself or for third-parties)



Your insights and contributions to these topics, incorporating previously raised comments, will be invaluable to our progress. I look forward to seeing you today!
Best regards,

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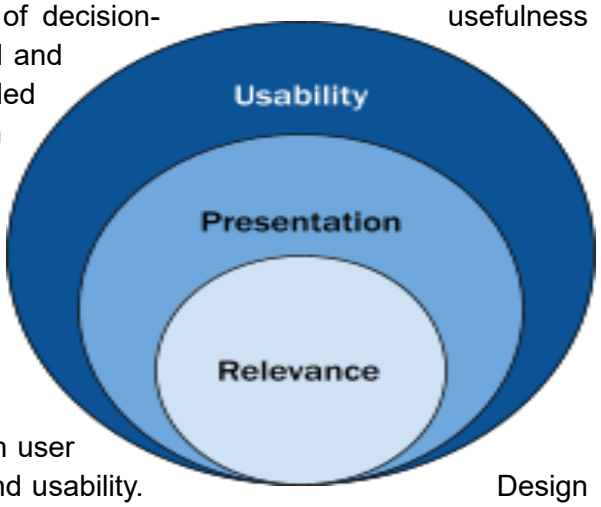
Annex "Integration of Impact Valuation in Decision-Making"

Presentation Summary held by Dennis West, University of Oxford – Session 3 and 7 and as discussed

What is Information User Experience?

The working paper presented by co-author Dennis West explored impact valuation from the perspective of users and user cases. The stated aim of any accounting standard is decision-usefulness. Standard setters and methodology developers contain general guidance on primary information users but explicitly leave the analysis and identification of information needs to the preparer entities. The principle of decision-usefulness is conceptually and normatively underspecified and requires more understanding and clarity provided by the presented working paper. Information User Experience operationalises the principle of decision-usefulness. The core elements of user experience for impact measurement and valuation are divided into relevance, presentation, and usability.



Why is it important?

Different user groups have different information user needs in relation to relevance, presentation, and usability. Design choices include the inputs to the valuation model, i.e. the operators and data that are wrapped up in the underlying valuation factor equation. Valuation approaches such as mitigation cost, damage cost, health utility, and others are only to a certain degree compatible and depend on the purpose and information user needs. Scientific studies ensure transparency and soundness of the evidence base and the mathematical operation in relation to the purpose of and user needs for impact valuation. Examples are the IPCC and IPBES as authoritative sources from climate science. Physical measurement and monetary valuation of social-environmental impacts follow the behaviours and preferences of information users. Impact valuation methodologies quantify and monetize positive and negative impacts, and they vary in their qualitative characteristics but are all based on three common elements: 1) corporate activity data in a physical unit based on original measurement and modelling of physical stock and flow dynamics; 2) impact valuation factors in a currency unit based on valuation techniques dependent on logic model/impact pathways; 3) adjustment of the two aforementioned factors for their risks and opportunities to social and environmental systems based on the harm/benefit potential of the impact driver in specific geographical and sectoral contexts. Each of those elements are based on the purpose and dynamics of the evaluative system as well as the preferences and behaviours of information users within. The final output is numerical result in monetary units that acts as a financial unit of account for positive or negative impact of an organisation.

How is it used?

The ongoing and future academic research and professional work on information user experience will involve further analysis of decision journeys and user personas. The outcomes of this work will be a better understanding of the preferences regarding measurement

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uncertainty and error propagation. It is expected that in other arenas, such as the Global Value Commission, a more user-centric approach will be adopted in the near future.

For the original working paper:

- West, Dennis and Euler, Dimitrij, Agile Sustainable Development: A Primer on Corporate Impact Indicators and Valuation Factors via Agile Models (August 2023). Available at SSRN: https://ssrn.com/abstract=4545204 or http://dx.doi.org/10.2139/ssrn.4545204.

Annex "OECD Wellbeing framework"

Presentation held by Fabrice Murtin, OECD on [DATE] – Session 4

Introduction

In economic terms, a shadow price represents the monetary value assigned to one unit of a non-monetary good. This valuation is based on the concept of equal preference among individuals, denoted by the utility function $U(y,m)$, where y signifies the quantity of a non-monetary good and m represents monetary wealth. The shadow price is calculated through the equation $w=\delta/(m-m*)$, emphasising the willingness to pay for an incremental unit of the non-monetary good. The equivalent income, $y*$, associated with the (y,m) situation is expressed as $y*=y+\delta=y+w.(m-m*)$. This framework provides a means to assess the monetary value attributed to non-monetary goods within the context of equal individual preference and utility.

Data Sources

- Longevity:
  - Murtin, F., et al. (2017), "Inequalities in longevity by education in OECD countries: Insights from new OECD estimates", OECD Statistics Working Papers, No. 2017/02, OECD Publishing, Paris (hereinafter Murtin et al. (2017))
- (Un)employment:
  - Murtin et al. (2017)
  - Boarini, Romina, et al. "Well-being during the Great Recession: new evidence from a measure of multi-dimensional living standards with heterogeneous preferences." The Scandinavian Journal of Economics 124.1 (2022): 104-138
- Working conditions:
  - Murtin, Fabrice, and Vincent Siegerink. "Valuing business impacts in the areas of wage inequality and employee well-being." (2023)
- Leisure, home production, any human activity:
  - Derived from the shadow price of time (Alpman-Balestra-Murtin, 2019)
- Education (through income, employment, and health):

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- Diaz-Murtin (2020)

- Air pollution (through health):
  - De Serres-Murtin (2015)

Calculation Logic

The concept of a shadow price, representing marginal utility, necessitates the inference of a utility function, and two prevalent approaches have been employed for this purpose.

Calibrate a theoretical utility function

The first approach involves the calibration of a theoretical utility function, as demonstrated by studies such as Becker et al. (2005) and Jones-Klenow (2019).

Assume that instantaneous utility is proxied by life satisfaction

The second approach assumes that instantaneous utility can be approximated by life satisfaction, drawing upon the hedonic regression literature.

Reconciliation of both approaches in a complex utility function

Murtin et al. (2016) have shown a degree of reconciliation between these approaches, revealing the complexity of the utility function.

Fusion of both approaches

The hybrid methodology, Boarini et al. (2019) adopt a hybrid methodology by combining both approaches. They develop a model to price longevity, recognising its nuanced nature not well captured by life satisfaction.

Additionally, they employ hedonic regressions to assess the value of unemployment, considering both individual and country-level incomes and acknowledging the existence of heterogeneous preferences across distinct groups.

This integrated approach contributes to a more comprehensive understanding of shadow pricing in the context of diverse well-being dimensions.

The framework for lifetime utility is structured as separable, denoted by $V(y_i,T,X_i)$, where instantaneous utility incorporates group-specific coefficients (Γ_i) on the externality X_i. The equation $u(y_i,X_i)$ encapsulates both income (y_i) and the externality, where ω drives the Value of a Statistical Life, calibrated based on the US value. Parameters (α, Γ_i) are estimated from Gallup micro-data, utilising a regression model that considers a variety of factors. Unemployment's impact on well-being is assessed directly and indirectly through the unemployment rate.

The closed-form formulas for shadow prices account for preferences heterogeneity within and between countries, incorporating factors such as income, unemployment, and externalities. The mixed approach, as demonstrated by Boarini et al. (2019), proves more robust than a purely subjective approach, given that life expectancy is a less reliable determinant of life satisfaction.

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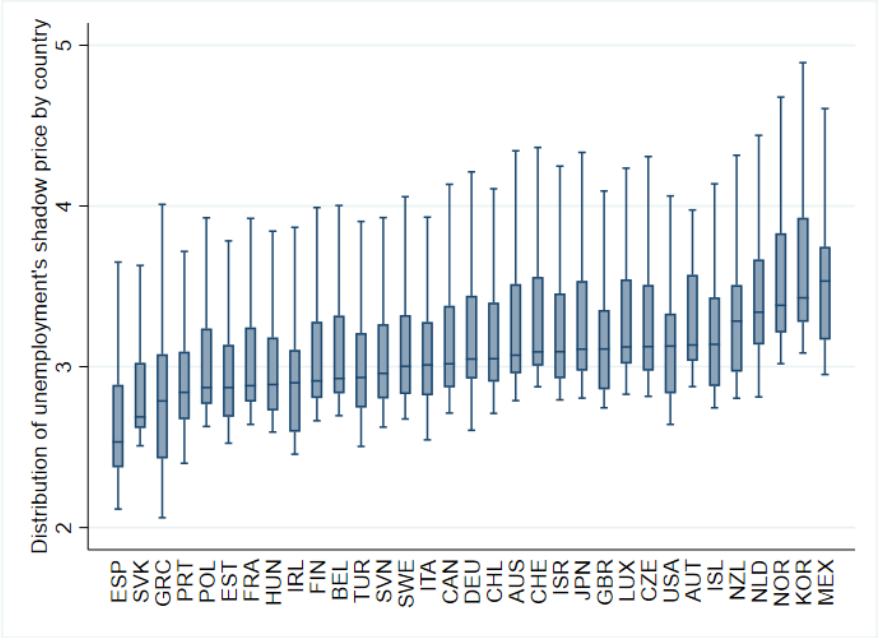
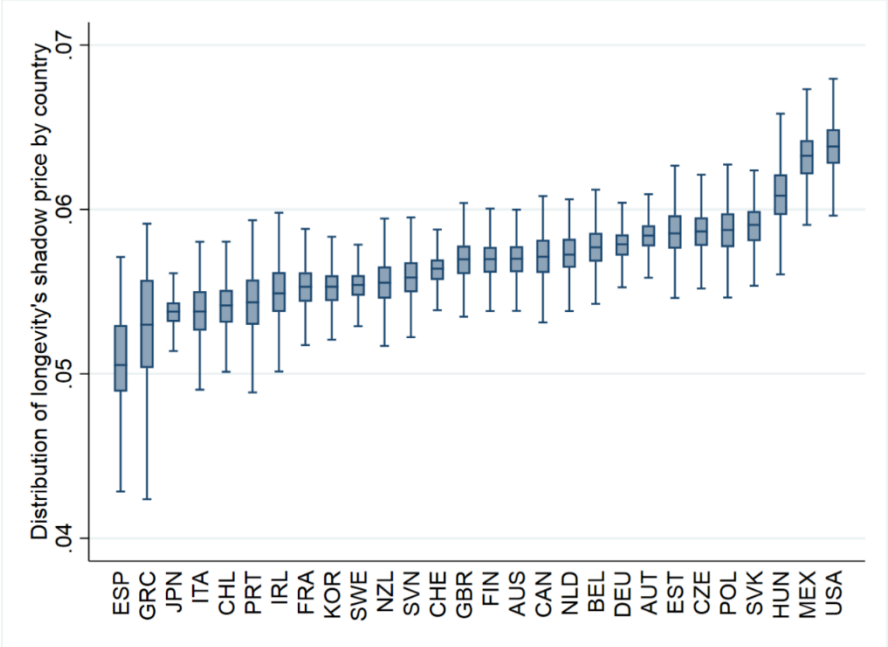
Simultaneously, it offers greater richness compared to a model-based approach, acknowledging and accommodating preferences heterogeneity across diverse populations. This comprehensive methodology contributes to a nuanced understanding of well-being dimensions.





The equation $〖MDLS〗_c=y_c-w\text{^}U\ U_c-w\text{^}T\ 〖\Delta T〗_c-I_c\ (\tau)$ represents the Measure of Discretionary Leisure Spending (MDLS) for an individual or a household in context c. Here, y_c signifies the income, while $w\text{^}U$ and $w\text{^}T$ denote the wage rates for work and leisure, respectively. The term U_c represents the utility derived from discretionary leisure, and $〖\Delta T〗_c$ represents the change in leisure time. Additionally, $I_c\ (\tau)$ accounts for the impact of taxes (τ) on discretionary leisure spending. In essence, this equation captures the discretionary spending capacity available to individuals or households after considering income, wage rates, and the influence of taxes on leisure activities. It provides a quantitative measure of the

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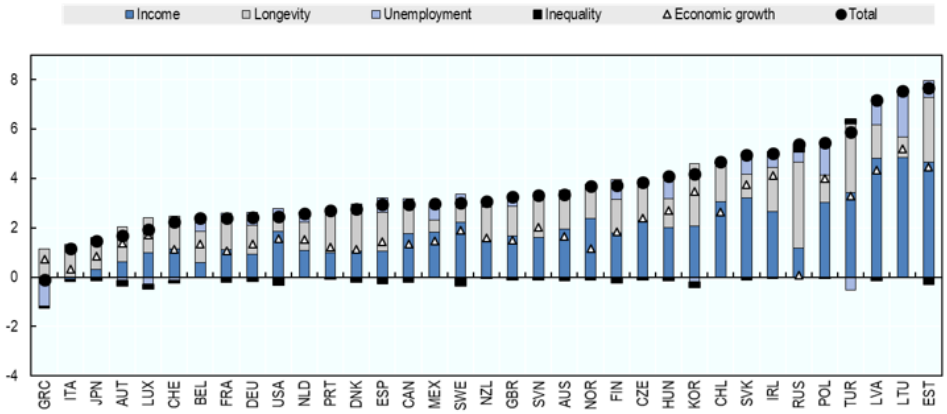
$$MDLS_c = y_c - w^U U_c - w^T \Delta T_c - I_c(\tau)$$



Economic growth	MDLS	Income	Longevity	Unemployment	Inequality
1.6	2.9	1.5	1.3	0.2	-0.1

financial resources available for non-essential leisure pursuits, shedding light on the discretionary aspect of leisure-related expenditures in a given context.

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