INTERIM METHODOLOGY

Waste

Environmental Topic Methodology

The International Foundation for Valuing Impacts, Inc. (IFVI) is a section 501(c)(3) public charity dedicated to building and scaling the practice of impact accounting to promote decision-making based on risk, return, and impact.

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Executive Summary

- The Interim Waste Topic Methodology can be used by preparers of impact accounts to measure and value the impact of waste on people and the natural environment. The Interim Waste Methodology can also be applied by users of impact information to manage the sustainability-related risks, opportunities, and impacts of an entity and inform decision-making regarding an entity's contribution to sustainability.

- To use this methodology, preparers should:

    - develop a full accounting of waste in an entity's own operations as well as upstream and downstream in the value chain, considered separately;

    - organize waste data by type, hazardous or non-hazardous, the method of disposal, either landfill or incineration, at the geographical location that data is available;

    - utilize the impact pathway and value factors developed in this methodology to convert waste into impact accounts;

    - present any related impact information with supplemental notes and qualitative commentary necessary to meet the qualitative characteristics of impact information.[1]

- **Section 1** introduces the purpose of the document, outlines key concepts and definitions, and defines the scope for the Methodology. As an interim methodology, the Interim Waste Methodology complements official impact accounting methodologies produced by IFVI in partnership with the Value Balancing Alliance and will be revised as part of the official Due Process Protocol with oversight from the Valuation Technical Practitioner Committee.

- **Section 2** develops the impact pathway for the Methodology, consisting of inputs, activities, outputs, outcomes, and impacts. The main impacts of waste production included in the methodology are reduced human health and well-being, disamenity, agricultural losses, and related impacts produced through greenhouse gas emissions and air pollution.

- **Section 3** establishes the data required from the entity to implement the Methodology. This includes waste produced in metric tons by location, organized by hazardous and non-hazardous, and whether waste is incinerated, sent to landfill, or unspecified.

[1] See General Methodology 1: Conceptual Framework for Impact Accounting.

- **Section 4** outlines the approach of the Methodology for measuring and valuing the impacts, focusing on four main drivers of impacts: leachate, disamenity, greenhouse gas impacts, and air pollution impacts.

- **Section 5** articulates potential opportunities for further development of the Methodology as it proceeds through the Due Process Protocol.

- This methodology builds on frameworks and protocols published by leading organizations in the impact management ecosystem and sustainability-related disclosures required by governing jurisdictions and international standard setters, including:

    - Capitals Coalition;
    - Ecosystem Service Valuation Database (ESVD);
    - European Sustainability Reporting Standards (ESRS);
    - Global Reporting Initiative (GRI);
    - Intergovernmental Panel on Climate Change (IPCC);
    - National Institute for Public Health and Environment, Netherlands;
    - The Transparent Project;
    - Value Balancing Alliance;
    - World Resources Institute (WRI); and
    - World Wide Fund for Nature (WWF).

1 Introduction

1.1 Document purpose

1. The purpose of this document is to outline the Interim Topic Methodology for Waste (henceforth, the Interim Waste Methodology or the Methodology).

2. Interim methodologies have been released by the International Foundation for Valuing Impacts as complements to the official *impact accounting methodology* being developed by the International Foundation for Valuing Impacts and the Value Balance Alliance. The content of the Interim Waste Methodology builds on the General Methodology and is intended for use alongside other Interim, Topic, and Industry-specific Methodologies.

3. The impact accounting methodology measures and values the *impacts* of corporate entities (entities or an entity) in monetary terms for the purposes of preparing impact accounts and generating impact information. The Interim Waste Methodology can be used to inform internal decision-making, investment decisions, and understand the significance of waste impacts of an entity.

4. Interim methodologies have undergone a detailed research and development process but have not gone through the Due Process Protocol or been approved by the Valuation Technical and Practitioner Committee (VTPC). Interim methodologies will be further developed and revised through the Due Process Protocol according to the established annual VTPC work plan.

5. The Interim Waste Methodology can apply via this document and the Global Value Factors Database. Supporting resources include the Interim Waste Methodology Model and the Interim Waste Model Technical Manual for users interested in understanding and expanding the interim methodology at a more technical level.

6. Preparers of impact accounts should adhere to the Interim Waste Methodology to the fullest extent possible and should disclose any deviations from it when shared with users of impact information.

1.2 Topic description

7. Over 2 billion metric tons of solid waste are generated globally every year, with at least 33 percent (as a conservative estimate) not disposed of in an environmentally safe

manner.[2] By 2050, it is expected this will increase drastically to 3.4 billion tons disposed of globally, outpacing population growth.[3]

8. Corporate activities in all sectors result in some level of solid waste generation across their value chains. The disposal of this waste can lead to a range of environmental outcomes that adversely affect human wellbeing, thereby carrying a societal cost. These impacts include those related to air pollution, disamenity, greenhouse gases, and leachate.

9. Each of these changes to the environment affects society by increasing human morbidity and mortality, negatively impacting agricultural output, reducing enjoyment of the environment, and contributing to climate change, which in turn increases incidence of extreme weather events.

10. The Interim Waste Methodology takes a societal perspective and not of a discrete affected stakeholder group by considering the impacts of all of society. By measuring and valuing the impacts on society, waste impact accounts can provide guidance to entities to manage and mitigate risks related to the impacts they have on stakeholders.

1.3 Scope and assumptions

11. For the purposes of the Interim Waste Methodology, only solid waste is included. Fluid waste is considered in the Water Pollution Methodology and gaseous waste is considered in the Air Pollution Methodology.

12. Most material impacts associated with solid waste are covered in this paper, but two classes of impact draw from other methodologies.

    a) For GHG and air pollution outcomes, waste disposal is an intermediate step (e.g., waste disposal then generates these outcomes).

    b) The approaches to quantifying these outcomes as they relate to waste disposal are hence defined in this Methodology but valued according to their respective Methodologies (*Greenhouse Gas Methodology* and *Air Pollution Methodology).*

13. The Interim Waste Methodology is concerned with the direct impacts of waste disposal, rather than related topics like inefficiencies in product design.

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[2] See The World Bank (2018): What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050.

[3] See The World Bank (2018): What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 in the Foreword.

14. The Interim Waste Methodology focuses on impacts associated with treating solid waste through incineration and landfill, including unmanaged dumpsites (sites where solid waste is left but which are not managed in ways that reduce their environmental impact). For most entities, these two methods will capture the vast majority of the associated environmental outcomes of waste disposal.

15. Waste impacts are local, thereby requiring the geographic location of waste for proper valuation. Value factors for the interim methodology are presented at the country level, while the same models can be utilized to produce more geographically precise value factors as well.

16. The impacts of recycling are not covered in the Interim Waste Methodology. The impact of a company recycling materials or using recycled materials as inputs will likely indirectly affect other waste flows captured in the methodology, but the resources used in the processing of recycling are not currently included.

17. The scope and boundaries of the Interim Methodology includes full value chain waste production. This includes upstream, direct operations, and downstream as defined in General Methodology 1. An entities' own operations should be the same scope used for financial statements to ensure comparability. Value chain waste production may be based on models and not directly measured due to the challenges of measuring upstream and downstream waste productions.

18. The Interim Waste Methodology recognizes full responsibility of an entity for its upstream and downstream waste production. Waste production is attributed to an entity through physical or economic relationships by portioning the inputs or outputs of waste production and determining the portion that is linked to the entity. The inclusion of value chain waste production means that double counting will occur if aggregating across entities in the same value chain. However, this will not lead to double counting within an individual entity's impact statement.

19. The impacts of specialist waste processing are highly dependent on the impact materiality of such waste disposal to the business in question. For most value chains, specialist processing is not relevant, and given the potential range of processes and contexts the methodology does not attempt to present a generalized approach.

20. This methodology does not cover the impacts caused by littering, ocean waste or persistent plastics. Whilst impacts of these could include disamenity, ecosystem degradation and ecotoxicity, more work is required to understand the causal links in these impact pathways.

1.4 Key concepts and definitions

21. For the purposes of applying the Interim Waste Methodology, the following terms are defined as:

    a) **Hazardous waste:** Waste that is defined as particularly dangerous or damaging to the environment. Entities may wish to utilize their relevant regulator's official listings as to what types of waste are included under this definition.

    b) **Non-hazardous waste:** This covers all types of waste not classified as hazardous. In other contexts, it may cover all other waste not otherwise classified.

    c) **Incineration:** The combustion of solid waste. This produces various flue gases, residual fly ash and disamenity from the aesthetic qualities of incinerators. The heat produced by incineration may be recovered to produce electricity, known as energy recovery.

    d) **Landfill:** The disposal of solid waste in specially designated areas. Waste, excluding inert waste, decomposes in landfill sites, producing GHGs, leachate and disamenity effects. This methodology uses the term to cover everything from unmanaged dumpsites, where GHGs and leachate can escape into the environment; to impermeable lined, sanitary landfills, where methane is collected and, in some cases, combusted for to produce electricity, also known as energy recovery.

2 Impact Pathway

2.1 Summary

22. The impact pathway is the analytical framework adopted to identify series of consecutive, causal relationships, ultimately starting at an input for an entity's activities and linking its actions with related changes in people's well-being. It serves as the foundation of the impact accounting methodology.

23. Detailed components of the impact pathway are outlined in subsequent sections, leading to the valuation of an entity's waste in *Section 4: Outcomes, Impacts, Valuation.*

24. The impact pathway for waste is as follows:

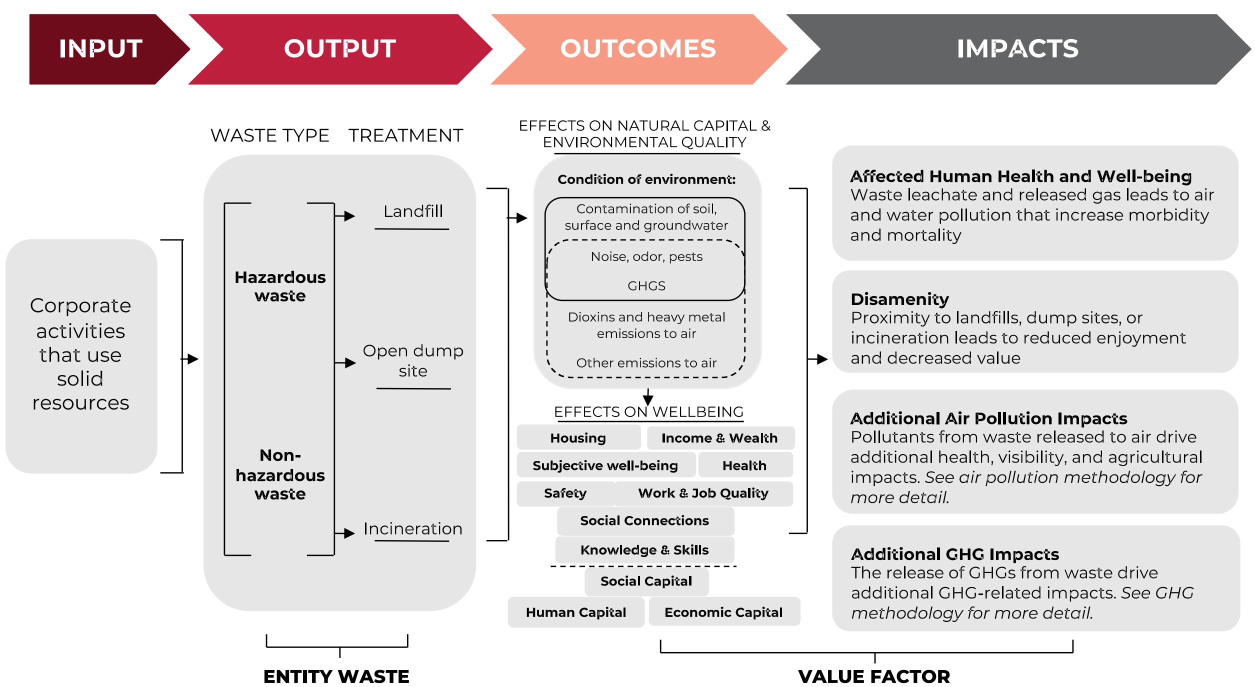

Figure 1: Waste impact pathway

2.2 Description and notes

25. The primary input for the waste impact pathway are corporate activities that generate solid waste output. This could include general municipal waste, biodegradable waste, sanitary waste, and / or clinical waste.

26. The output from the entity can then be categorized as hazardous or non-hazardous waste. This can then be further refined by the treatment with which the two types of waste receive (or, in other words, where the waste is sent to); landfill, open dump site,

or incinerator. These outputs would be expressed in units which can be measured at the corporate level.

27. The disposal and accumulation of waste has consequent effects that alter environmental quality and natural capital:

a) **Air pollution:** As a by-product of waste incineration, where pollutants released reduce air quality and can cause health impacts, reduce visibility, and affect agriculture. The pollutants accounted for in this Methodology include particulate matter (PM2.5 and PM10), nitrogen oxides (NOx), sulfurous oxides (SOx), and heavy metals and dioxins.

b) **Disamenity:** A wide range of impacts on local environmental quality, for example in terms of visual intrusion, odor, noise and pests.[4]

c) **Greenhouse gases** (GHGs): Where waste disposal from both landfill and incineration release GHGs that contribute to climate change. The majority of GHGs from incinerators are in the form of carbon dioxide (CO_2) whilst those from landfill sites are methane (CH_4).

d) **Leachate:** Where the release of liquid from solid waste disposed of in landfill sites, principally through the infiltration of rainwater, breaks waste down and the liquid produced contaminates the soil and local ground and surface water.

28. The extent of these impacts depends on how the waste is treated and disposed of – in particular, whether it is disposed of in a landfill site or an incinerator, as well as the specific characteristics of that waste disposal facility. For example, the contamination of soil, surface and ground water from incinerated waste is negligible and as such only landfill waste is accounted for in this specific impact pathway). The impact is also dependent on the type and composition of the waste (for example, whether it is hazardous or not, and its organic carbon content).

29. The consequential changes to the physical environment drive impacts that reduce the well-being of people. The categories of well-being affected include health, housing, income and wealth, subjective well-being, safety, work and job quality, social connections, knowledge and skills, economic capital, human capital, and social capital Specifically, the impacts include reduced human health and reduced enjoyment of the natural environment, as well as reduced agricultural output and ecosystem services due to contamination of soil and groundwater can impact agricultural output, and impacts on climate change through release of GHGs emissions.

[4] Ham et al (2013).

3 Impact Driver Measurements

30. Impact drivers consider inputs and outputs and reflect the data needs expected of a preparer to provide an impact account for solid waste.

31. Data requirements for the Interim Waste Methodology are aligned with and expand upon waste related sustainability reporting standards, which primarily captures the waste of non-hazardous and hazardous waste produced.

3.1 Data Requirements

32. The Interim Waste Methodology requires the total metric tons of waste generated by an entity. This should be separated into waste composition, specifically metric tons of hazardous and non-hazardous waste, and the waste disposal method, where known, as shown in Table 1.

33. If known, providing the waste treatments — either landfill or incineration — offers greater accuracy in choosing the value factors to apply to the waste generated. If waste disposal method is not known, an 'Unspecified treatment' value factor can be used.

Data input		Country 1	Country 2	Country 3
Waste Production in Own Operations				
Hazardous waste (metric tons), by location of disposal	Landfill			
	Incineration			
	Unspecified			
Non-hazardous waste (metric tons), by location of disposal	Landfill			
	Incineration			
	Unspecified			
Waste Production in Upstream Value Chain				
Hazardous waste (metric tons), by location of disposal	Landfill			
	Incineration			
	Unspecified			

Non-hazardous waste (metric tons), by location of disposal	Landfill			
	Incineration			
	Unspecified			
Waste Production in Downstream Value Chain				
Hazardous waste (metric tons), by location of disposal	Landfill			
	Unspecified			
	Incineration			
Non-hazardous waste (metric tons), by location of disposal	Landfill			
	Unspecified			
	Incineration			

Table 1: Waste data requirements

34. Further data on specific waste characteristics, such as fossil carbon percentage, or composition, such as principal materials, can be added into the Interim Waste Methodology Model for even greater precision.

35. Different types of waste, particularly hazardous and non-hazardous waste, will have different environmental outcomes in certain circumstances, and so they are often recorded separately. This distinction is particularly relevant to the impact on GHGs and leachate from landfill, as well as GHGs and air pollution from incineration. Despite inconsistencies in the definition of the two categories between countries, the approaches that we have developed or adapted from the literature in each of these areas take this distinction into account.

36. The most influential factor in determining the environmental outcomes associated with the disposal of solid waste is the mode of treatment. It is therefore important to understand how much waste is disposed of through landfill or incineration. If mode of treatment is not known, an 'unspecified' value factor is provided which gives whichever is larger of the landfill and incineration value factors per country. IFVI recognizes that this will only provide a picture of the average impacts in a given country.

37. The data requirements of the Interim Waste Methodology are aligned with and expand upon disclosure requirements established by relevant standard setters including European Sustainability Reporting Standards E5: Resource Use and Circular Economy

and the Global Reporting Initiative 306: Effluents and Waste 2016. Additional alignment may exist with other regional or topic specific reporting standards as well.

Metric	ESRS	GRI
Hazardous and Non-Hazardous Waste Production – own operations	Fully aligned with E5-5, paragraph 37 (c), page 150	Fully aligned with Disclosure 306-3 (a) and 306-5 (a)
Hazardous and Non-Hazardous Waste Production – value chain	Expands upon E5-5, paragraph 37 (c), page 150	Expands upon Disclosure 306-3 (a) and 306-5 (b)
Location of waste production	Expands upon E5-5, paragraph 37 (c), page 150	Expands upon Disclosure 306-5 (b)
Method of disposal	Expands upon E5-5, paragraph 38 (b), page 150	Expands upon Disclosure 306-3 (a)

Table 2: Alignment with reporting standards[5]

3.2 Data sources, gaps, and uncertainty

38. Preparers should strive to measure waste impacts in a manner that is complete, neutral, and free from error. This includes faithfully representing waste creation from all parts of the value chain.

39. In practice, obtaining full value chain waste data may be challenging for entities, particularly from upstream or downstream in the value chain. Barriers such as cost, accounting methods, or availability of data may limit preparers from measuring, in their entirety, waste impacts.

40. To determine the impacts of waste, total metric tons of waste produced, and the disposal methods used, are both needed. These can be estimated directly, using data reported by the entity, or indirectly through techniques such as life-cycle assessment or environmentally extended input-output modelling. Where a direct approach is taken, waste data should be apportioned to landfill and incineration using actual data where available. Otherwise, general trends at a country or sub-national level can be used.

41. The availability of actual (rather than modelled or estimated) metric data will vary according to the company's level of control over the producers and users of this information. This is likely to vary across a company's value chain as described below:

[5]Categories of alignment include (1) fully aligned: data from reporting can be used as is for preparation of impact accounts; (2) expands upon: data from reporting conceptually aligns with the impact accounting methodology, but additional detail, context, or presentation is necessary for an accurate accounting of impact; or (3) independent: Data needed for the preparation of impact accounts are not covered by the reporting standards and would require separate data collection and analysis.

a) **Own operations:** Waste tonnage, broken down by waste type and composition, should be available from company management information. The other estimation techniques detailed for the supply chain can also be used if direct data are unavailable.

b) **Immediate suppliers:** Waste tonnage, broken down by waste type and composition, may be available from some suppliers. Where this is unavailable, gaps in metric data can be filled using modelling techniques such as EEIO.

c) **Upstream / supply chain:** Reliable metric data on waste tonnage, type and composition are unlikely to be available from indirect suppliers. Metric data can be modelled using EEIO techniques, which may be further informed from industry information.

d) **Downstream / use phase:** Reliable metric data on waste tonnage, type and composition are unlikely to be available from users. Metric data can be modelled using EEIO techniques, which may be further informed from customer surveys or industry information.

e) **End of life / re-use impacts:** Some metric data can be derived using physical production characteristics, such as the masses of constituent materials. Other metric data can be modelled using EEIO techniques, which may be further informed from customer surveys or industry information.

42. Preparers should prioritize approaches that:[6]

a) Directly measure waste produced over those that estimate waste production based on calculations from activity data,

b) Utilize primary data from specific activities within a company value chain over secondary data, and

c) Consider sources of data that are of the highest quality possible.

43. High quality data sources should consider:[7]

a) Technological representativeness. Does the data match the technology used?

b) Temporal representativeness. Does the data represent the actual time or age of the activity?

c) Geographical representativeness. Does the data reflect geographic considerations of the activity?

d) Completeness. Is the data statistically representative of the activity?

e) reliability. Are the data sets or sources dependable?

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[6]Language adapted to water consumption from the Greenhouse Gas Protocol. (2011). Corporate value chain (scope 3) accounting and reporting standard.

[7]Language adapted to water consumption from the Greenhouse Gas Protocol. (2011). Corporate value chain (scope 3) accounting and reporting standard.

44. Various estimation techniques can be used to determine waste production. While a variety of techniques exist, those recommended for waste analysis include life cycle analysis (LCA) and environmentally extended input-output (EEIO) tables. Both approaches have developed frameworks for determining waste production but may differ in levels of data specificity or considerations depending on the context of application.

45. Uncertainty will arise when quantifying waste production. Preparers should report qualitative uncertainty and, when possible, quantitative uncertainty. These may include but are not limited to propagated measured uncertainty, pedigree matrices, sensitivity analyses, or probability distributions. Reporting uncertainty and other results may be done in accordance with the Value Notes guidance produced by the Value Commission of the Capitals Coalition.[8]

[8] https://capitalscoalition.org/project/the-value-commission/

4 Outcomes, Impacts, and Valuation

46. The impacts that result from the waste production affect the environmental quality dimension of well-being and the well-being resource of natural capital. These are linked to the well-being of people through their effects on health, housing, income and wealth, subjective well-being, safety, work and job quality, social connections, knowledge and skills, economic capital, human capital, and social capital.

47. The impact pathway in this statement has been developed using a value factor that collapses the impact measurement and valuation stages into a summary value that is location-specific for each category of impact. The value factors can then be multiplied directly by entity-specific waste production consumption using the equations in section 4.1. The measurement and valuation approaches are expanded upon in sections 4.2 and 4.3 and Appendix B.

4.1 How to calculate impacts

48. To determine the monetary cost of waste production (Waste Value$_{Total}$), preparers should use the following equations:

$$\textbf{Waste Value}_{\textbf{Total}} = \sum(AP\ Impact_{ti} + DIS\ Impact_{ti} + GHG\ Impact_{ti} + LEA\ Impact_{ti}) \quad \text{(Eq. 1)}$$

for all types and treatments of waste in all countries

$$AP\ Impact_{ti} = Waste_{ti} * VF_{ti\ AP} \text{ for each country} \quad \text{(Eq. 2)}$$

$$DIS\ Impact_{ti} = Waste_{ti} * VF_{ti\ DIS} \text{ for each country} \quad \text{(Eq. 3)}$$

$$GHG\ Impact_{ti} = Waste_{ti} * VF_{ti\ GHG} \text{ for each country} \quad \text{(Eq. 4)}$$

$$LEA\ Impact_{ti} = Waste_{ti} * VF_{ti\ LEA} \text{ for each country} \quad \text{(Eq. 5)}$$

49. The variables for the equations are as follows:

$VF_{ti\ AP}$	The value factor for waste air pollution for each type of waste (hazardous or non-hazardous) and treatment type (landfill, incineration or unspecified). These values are distinct for each country where disposal occurs. The value factor should be obtained for each country where disposal occurs and can be obtained from the Global Value Factors Database.
$VF_{ti\ DIS}$	The value factor for waste disamenity for each type of waste (hazardous or non-hazardous) and treatment type (landfill, incineration or unspecified). These values are distinct for each

	country where disposal occurs. The value factor should be obtained for each country where disposal occurs and can be obtained from the Global Value Factors Database.
$VF_{ti\ GHG}$	The value factor for waste GHGs for each type of waste (hazardous or non-hazardous) and treatment type (landfill, incineration or unspecified). These values are distinct for each country where disposal occurs. The value factor should be obtained for each country where disposal occurs and can be obtained from the Global Value Factors Database.
$VF_{ti\ LEA}$	The value factor for waste leachate for each type of waste (hazardous or non-hazardous) and treatment type (landfill, incineration or unspecified). These values are distinct for each country where disposal occurs. The value factor should be obtained for each country where disposal occurs and can be obtained from the Global Value Factors Database.
$Waste_{ti}$	The kilograms of waste disposed of for each type of waste (hazardous or non-hazardous) and treatment type (landfill, incineration or unspecified)
t	type of waste (hazardous or non-hazardous)
i	treatment type (landfill, incineration or unspecified)

50. The waste production impact calculation is described below.

    a) Equations 2 - 5 calculate the monetary value of impacts for each of the four components of the waste impact pathway, including air pollution, disamenity, greenhouse gas emissions, and leachate, based on the location, waste type, and treatment type specific value factors presented as part of the Global Value Factors Database. Where waste treatment is unknown, the methodology applies an “unspecified” treatment value factor by taking a worst-case value factor, i.e. whichever is higher of the landfill or incineration value factor in a given country. The value factor for each can be multiplied by the waste produced. These equations should be calculated separately for each of the categories provided.

    b) After determining each impact, the total waste impact can be determined by summing the four impacts for each location, waste type, and treatment type.

51. Upstream value chain, downstream value chain, and own operations of waste production should always be considered separately to increase transparency, comparability, and decision-usefulness. Additional levels of detail may be useful such as

an assessment of waste production impact regionally, nationally, or within specific value chain categories.

4.2 Outcomes and impacts

52. For each impact, the approaches used to link water consumption to outcomes and impacts are described below. Additional methodological details are in Appendix B.

a) **Air pollution, *from incineration*:** the impacts for air pollution are calculated through two means.

- Country incineration emissions factors are used to estimate the kilograms of dioxin and heavy metals released per metric ton of waste incinerated. Linear dose response functions then estimate the change incidence in cancer and lost intelligence quotient (IQ) points per kilogram of heavy metal or dioxin ingested.

- For the second part of the equation, emissions of NOx, SOx, PM2.5 and PM10 are estimated using country emissions factors. Avoided emissions through energy recovery are accounted for to obtain the net metric tons of pollutant released.

b) **Disamenity, *from landfill and incineration sites:*** the total waste flow to landfills and incinerators per country is discounted over the site's remaining active years to get the present discounted waste flow to each landfill or incinerator site. Waste flows are discounted in order to reflect the higher effect of disamenity felt today than at periods in the future.

c) **GHGs, *from landfills and incineration:***

- Landfill GHGs are estimated over 90 years using the IPCC Waste Model, based on type of waste and the conditions of country landfills. The present value of associated impacts is then calculated by applying a social discount rate of 2%.

- Incineration GHGs are quantified using waste emission factors based on the fossil carbon content of the waste specified.

- Energy recovery are then accounted for both methods of disposal based on country data, to get net tons of CO_2 emitted.

d) **Leachate, *from landfills:*** countries are assigned a risk score[9] based on population density, soil permeability and percentage of sanitary landfills vs. unlined landfills or open dump sites within the country.

4.3 Monetary valuation

53. Monetary valuation uses value factors to estimate the relative importance, worth, or usefulness of changes in well-being indicators in monetary terms. The monetary valuation approach and value factors are developed individually for each impact. Each approach is described briefly below with additional methodological details in Appendix B.

a) **Air pollution, *from incineration*:** the valued impacts for air pollution are calculated through two means.

- Societal costs of cancer from dioxin exposure are estimated through a value of a statistical life and willingness-to-pay (WTP) studies. Cost of loss of IQ points through heavy metal exposure are estimated through WTP studies. Both are then applied as a valuation method to obtain the costs of health impacts resulting from waste incineration.

b) **Disamenity, *from landfill and incineration sites:*** The effect of the waste flow is valued by applying a hedonic transfer function, based on the national housing market, to represent the WTP to avoid disamenity.

c) **GHGs, *from landfills and incineration:*** both landfill and incineration GHGs are valued using the variety of methods described in the GHG Methodology.

d) **Leachate, *from landfills:*** A likelihood cost is used to estimate the worst-case cost scenario from a leachate incident. The worst-case cost scenario takes into account impacts on people through contaminated ground and surface water causing health impacts and reducing agricultural yields.

[9] Singh et al (2009).

5 Future Development

54. The Interim Waste Methodology represents the current state of knowledge built upon decades of rigorous scientific work. But some limitations still exist, including the ability of entities to have full visibility of their waste treatment outcomes and processing procedures. Comparable country-level waste data is also difficult to obtain, particularly for low-income countries or those with transitional waste management strategies. This limits the ability to provide robust and comparable value factors across countries.

55. There are opportunities to further advance waste impact accounting by exploring new pathways that overcome limitations and reduce uncertainty. Some of these include:

    a) New methods and tools that allow for a more complete and accurate accounting and reporting of entity waste data including added detail about the type of waste;

    b) Improvements in regulatory reporting on waste generation, which in turn may improve waste reporting;

    c) Incorporation of circular economy principles into the methodology that better capture the impacts associated with recycling and other circularity practices;

    d) Methodological updates that expand the scope of impacts included in the methodology such as topics like marine plastic waste;

    e) Improvements in waste disposal technologies, such as Landfill Gas Capture, or more stringent waste regulations, such as with open dump sites;

    f) Advancements to valuation approaches that can determine impacts at finer spatial resolution. For example, conditions at specific waste sites (e.g., climate and soil permeability) have a significant effect on the scale of waste impacts. Future work will continue to incorporate these considerations to refine water consumption valuation.

56. Further revisions based on these opportunities, among others, will be considered as the methodology is further developed and revised through the Due Process Protocol according to the established annual VTPC work plan.

Appendix A: Glossary

Term	Definition	Source
Air pollution	The presence of harmful substances or particles in the air, caused by human activities or natural processes, that can have negative effects on human health, the environment, and climate.	WHO
Anaerobic	The conditions under which decomposition occur without oxygen. For landfill waste, this is when methane is then generated.	EPA
Anthropogenic	Caused or influenced by human activity.	National Geographic Society
Avoided emissions	A reduction or prevention of greenhouse gas emissions that would have occurred without specific actions or measures.	UNFCCC
Biogenic	A product made by, or from, life forms such as plants, animals and microorganisms.	EPA
Disamenity	A feature or factor that makes a location or property less desirable or unpleasant to be in, such as landfills or waste incinerators.	European Commission
Discount factor	A factor used to adjust future costs or benefits to their present value, taking into account the time value of money.	US Council of Economic Advisors
Ecosystem	A biological community of interacting organisms and their physical environment.	National Geographic Society
Energy recovery	The process of extracting usable energy from waste materials or by-products.	US Department of Energy

Environmentally extended input-output	An analytical framework that incorporates environmental data into economic input-output models to assess the environmental impacts of economic activities.	UNEP
Fossil carbon content	Contents of products that come from fossil fuels, such as plastics or synthetic textiles.	IPCC
Greenhouse gases	Gases, such as carbon dioxide and methane, that trap heat in the Earth's atmosphere and contribute to the greenhouse effect and global warming.	IPCC
Hazardous	A substance that poses a risk to human health, safety, or the environment due to its toxic, flammable, or otherwise dangerous properties.	World Bank
Hedonic pricing factor	A factor used in hedonic pricing models to estimate the implicit value of a specific attribute or characteristic of a good or service.	Office for National Statistics
Hedonic transfer function	A mathematical equation or model used to estimate the relationship between a good's attributes and its value.	University College London
Impact	A change in one or more dimensions of people's well-being directly or through a change in the condition of the natural environment.	GM1
Impact accounting	A system for measuring and valuing the impacts of corporate entities and generating impact information to inform decisions related to an entity’s effects on sustainability.	GM1
Impact pathway	The series of consecutive, causal relationships, ultimately starting at an input for an entity's activities and linking its actions with related changes in people's well-being.	ISO 14008:2019 (GM1)

Input	The resources and business relationships that the entity draws upon for its activities.	Impact Management Platform (GM1)
Incineration	The process of burning waste materials at high temperatures, often used for waste management and energy recovery.	World Bank
Life-cycle assessment	A comprehensive analysis of the environmental impacts of a product or process throughout its entire life cycle, from raw material extraction to disposal.	EPA
Landfill	A designated area for the disposal of solid waste, where waste is buried and covered with soil.	World Bank
Leachate	Liquid that drains or leaches through waste materials and may contain pollutants.	World Bank
Monetized impact	The process of assigning monetary values to damages.	N/A
Non-hazardous	A substance that does not pose a significant risk to human health, safety, or the environment.	World Bank
Outcome	The level of well-being experienced by people or condition of the natural environment that results from the actions of the entity, as well as from external factors. Outcomes are used to describe the one or more dimensions of people's well-being that are affected by an input, activity, and/or output.	Impact Management Platform (GM1)
Output	The direct result of an entity's activities, including an entity's products, services, and any by-products.	Impact Management Platform (GM1)

Sanitary landfill	A landfill designed to minimize environmental impacts and prevent contamination of groundwater and soil with the presence of a liner.	EPA
Unlined landfill	A landfill without a protective liner to prevent leachate from contaminating the surrounding environment.	EPA
Valuation method	A technique or approach used to assign a monetary value to goods, services, or impacts for economic analysis or decision-making.	Office for National Statistics
Willingness to pay	A valuation method to assess the value of a good or service by how much people are willing to pay to experience it.	World Bank

Appendix B: Methodological Details

Introduction

B1. Defining waste management is a complex issue, covering a wide variety of materials, product types, and sources, yet all falling under the same umbrella as the 'unintended by-product of consumption and production'[10]. This lack of clarity as to what should be defined as 'waste', along with differing national conditions and data collection methods, make it difficult to arrive at clear definitions or easily comparable waste generation or treatment data[11]. The consequence is that the impact of waste is still largely not well reported, understood, or valued.

B2. However, as the awareness and reporting on climate change has improved globally, the recognition that waste plays a significant role in the triple planetary crisis of climate change, pollution and biodiversity loss has also grown. As such, the impacts of waste are starting to be better analyzed. Specifically, measuring and reducing the GHGs released from incinerated or decomposing waste are now priority regulations in many countries, along with reducing the amount of waste disposed in unsanitary or open dump sites[12]. Yet this means approaches for estimating the monetized impacts of waste vary in robustness for different impact pathways. The methodology therefore uses a variety of valuation method approaches for each of the impact pathways within the Interim Waste Model.

B3. The waste value factor is determined by summing the monetized impacts across four pathways:

$$WVF_{ti} = AP_{ti} + Dis_{ti} + GHG_{ti} + L_{ti}$$

Where AP = air pollution, Dis = disamenity, GHG = greenhouse gases and L= leachate. The specific calculations of these modules are set out below (each module calculates the impacts associated with a specific impact pathway).

Air pollution module

B4. This module values the impacts associated with air pollution from incineration. As landfills produce trivial volumes of non-GHG emissions they are not addressed here. The air pollutants from incineration fall into two categories within the Interim Waste Model: heavy metals and dioxins, and traditional air pollutants (NOx, SOx, PM2.5 and PM10).

[10] UNEP – Beyond an Age of Waste – Global Waste Management Outlook, 2024.

[11] UNEP – Beyond an Age of Waste – Global Waste Management Outlook (2024).

[12] EU Landfill Directive (2018), South Africa Control of Waste Disposal Sites By-Law (2007).

B5. The air pollution valuation formula is as follows:

$$AP_{ti} = (health\ incindences\ per\ kg\ heavy\ metal_{ti} \times kg\ heavy\ metal\ per\ pollutant_{ti}) + (Gross\ pollutant\ emissions_{ti} - avoided\ emissions_{ti})$$

a) The impact of heavy metals and dioxins is valued through health impacts: the majority are highly damaging to health and, if inhaled, can cause cancer or neurotoxicity, reducing IQ. First, heavy metal and dioxin emissions released per metric ton of waste incinerated are calculated using regional emissions limits on waste incineration[13]. Dose response functions then describe how many health effects are likely to be associated with a given level of emissions. Dose response functions in terms of cancers per kg of dioxin, and neurotoxicity per kg of heavy metal are taken from ExternE (2004). These incidences of health impact are then valued through two methods:

- Of the cancers caused, a proportion are assumed to be fatal and non-fatal cancers[14]. For fatal cancers, the value of a statistical life[15] is used to estimate the impact value. For non-fatal cancers, a median WTP from studies to avoid non-fatal cancer is applied.[16]

- For neurotoxicity, a median WTP is taken from studies to avoid a loss of 1 IQ point.[17]

These provide a single global value for health impacts, with the option to adjust values for country income. This represents the total monetized impact of heavy metals and dioxins.

b) For traditional air pollutants, the methodology calculates the total emissions released before subtracting any avoided emissions from energy recovery. Total emissions are estimated using global emissions factors[18] for 1 metric ton of industrial waste incinerated. Avoided emissions through energy recovery are then estimated using the emissions intensity of the national grid for the relevant

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[13] See EMEP/EEA Air Pollutant Emission Inventory Guidebook (2023).

[14] Cancer survival statistics, Cancer Research UK (2024).

[15] IFVI VoSL value.

[16] See OECD (2011).

[17] Spadaro, J. and Rabl, A. (2004).

[18] See EMEP/EEA Air Pollutant Emission Inventory Guidebook (2023).

pollutant in each country. Once the net volumes of these air pollutants are calculated, the Interim Air Pollution Methodology value factors are applied to calculate the social cost of the impact.

c) These valuation of these two impacts are added together to generate the total monetized impact of air pollution from waste incineration.

Disamenity module

B6. This module values the disamenity associated with waste disposal, including visual intrusion, noise, odor, and pests. The approach for valuing disamenity through hedonic pricing is well established and as such is the method followed here. In this approach, disamenity impacts are valued based on the impact of proximity to a landfill or incineration site on observed house prices.

B7. The disamenity valuation formula is as follows:

$$Dis_{ti} = \frac{Fn}{\sum_{1}^{T} W/(1-DR)^{y}}$$

Where:

F = hedonic function transfer

n = number of waste sites per country

W = annual national waste to landfill / incinerator

DR = discount rate

y = remaining site lifetime (years)

a) This module uses a linear hedonic price function (HPF, or F in the valuation formula), reflecting that the change in house price as a function of its distance from a waste management facility. This was derived from the results of a meta-analysis of hedonic pricing studies from Schutt et al (2021),[19] using the hedonic pricing function approach as described by Eunomia (2002).[20]

b) The HPF is adjusted for country differences by accounting for country-specific factors, such as average property price and household density, along with total number of disposal sites within the country. This function represents the WTP to

[19] Schutt et al (2021).

[20] Eunomia (2002).

avoid all disamenity effects of disposal sites adjusted for country-specific socio-economic factors.

c) Finally, to get the disamenity impact per metric ton of waste, the disamenity impact is apportioned across each metric ton of waste entering the disposal site over its remaining lifetime. The total metric tons of waste entering landfills or incinerators per country is discounted over the remaining lifetime of those sites at a rate of 2%. Waste flows are discounted in order to reflect the higher effect of disamenity felt today than at periods in the future. The disamenity associated with each metric ton of waste is therefore the total WTP to avoid disamenity from waste disposal sites in a country, divided by the discounted waste flow to that site.

GHGs module

B8. The Intergovernmental Panel on Climate Change's (IPCC) National Greenhouse Gas Inventories[21] provides a global standard for calculating and reporting on entity GHGs. Chapter 5 of the Inventories provides methodologies for estimating the emissions from incineration and decomposition (in landfills) of waste. As such, these methodologies are used to calculate landfill and incineration GHGs from waste disposal.

B9. Both the incineration and landfill GHGs calculations follow the same methodology format: the total emissions released from the respective waste treatment are calculated along with the avoided emissions through energy recovery programs within the country. Total emissions and avoided emissions can then be summed to quantify the net emissions released. These net emissions are then valued with the Social Cost of Carbon (see further details on the SCC in the *Greenhouse Gas Emissions Topic Methodology*).

B10. The GHG valuation formula for both landfill and incineration is as follows:

$$GHG_{ti} = gross\ emissions\ released_{ti} - avoided\ emissions_{ti}$$

a) The IPCC Waste Model[22] is used to estimate the total amount of GHGs released from 1 metric ton of waste being disposed in a landfill, designed for use in calculating country GHG emission's inventories. Landfill GHGs are generated through the degradation and decomposition of waste under the anaerobic conditions that prevail in landfill sites. The primary gas released from this decomposition is methane (CH_4), which is emitted over the lifetime of the landfill – the IPCC recommends calculating this over 90 years as beyond this, emissions are insignificant.[23] The IPCC

[21] IPCC Guidelines for National Greenhouse Gas Inventories

[22] IPCC Guidelines for National Greenhouse Gas Inventories, IPCC Waste Model.

[23] IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 5: Waste.

Model used in this methodology allows for adjustments depending on the conditions present in the landfill (e.g. different climatic conditions), as well as the characteristics of waste, to generate total methane released per metric ton of waste disposed in a landfill per country. Once total methane generated has been calculated, it is converted into CO2e and the avoided emissions from energy recovery programs within individual countries is subtracted from this to yield the net CO2e released over the landfill lifetime.

b) Incineration GHGs are generated through the CO2 released from the burning of waste. Some of this CO2 is biogenic, such as wood or plant matter, which forms part of the carbon cycle. However, this module is concerned with the anthropogenic emissions released when fossil carbon, or carbon that would otherwise stay out of the carbon cycle, is released. Fossil carbon released per metric ton of incinerated waste is estimated as a product of the carbon content of waste, of which what percentage is fossil carbon, and the efficiency of combustion of such waste. The IPCC default values for calculating national GHG emission inventories are taken for these variables[24], however if these variables are known then these figures should be used instead (see the Waste User Guide).

c) For both landfill and incineration GHGs, once the total amount of CO2/CO2e released is known, the impacts are valued using the SCC. For Landfill GHGs, the SCC is inflated at a rate of 1.5%[25] over 90 years and then discounted at a rate of 2% to get the net present valued impact of Landfill GHGs. For Incineration GHGs, where the emissions are instantaneous and not emitted over many years, the net tons of CO2 emitted are multiplied by the year of emission's SCC.

Leachate module

B11. This module values the societal impacts of leachate release. As leachate is a by-product only from landfill, incineration treatment is not considered here.

B12. As with other areas in this methodology, a methodology ideally would apply a specific impact pathway approach to the causal links between disposal of waste and impacts of leachate on, say, drinking water and agriculture via groundwater. However, there is no credible generalizable approach to do this given that occurrence of leachate is highly site-

[24] IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 5: Waste – Table 5.6.

[25] UK Department for Business, Energy and Industrial Strategy, Policy Paper: Valuation of greenhouse gas emissions: for policy appraisal and evaluation, September 2021.

specific and typically occurs over a long period of time. This module instead uses a risk-based approach typically used in valuation approaches[26].

B13. The leachate module valuation formula is as follows:

$$L_{ti} = \ worst\ case\ cost \times country\ risk\ factor_{ti}$$

a) A risk-adjusted estimate of the likelihood of a leachate incident occurring in a country is estimated using the HARAS model[27]. This leachate risk factor is based on three characteristic ratings: source of waste (hazardous vs. non-hazardous), pathway (soil permeability of site), and receptor (population density around site), along with whether the landfill is sanitary or unlined. This represents the likelihood and severity of a leachate incident per country, ranked on a scale from 0 (no risk) to 1000 (high risk).

b) To then estimate the monetized value of leachate impacts, clean-up costs are used as a proxy for societal costs. Clean-up cost is the chosen valuation approach as estimating the impacts of leachate in a given location is subject to high uncertainty. The Onalaska Municipal Landfill in Wisconsin is likely to be a good proxy of the worst case societal impact as over the period the landfill was active (1969-1980) a mixture of municipal and hazardous wastes were disposed of, including a relatively high proportion of chemical wastes. The site was unlined, in an area of high soil permeability, and affected a relatively large population. This chosen cost represents a ‘worst case’ scenario, given per metric ton of waste disposed, as defined in the HARAS model with a score of 1000. This is then applied to country-specific HARAS rankings and adjusted for country PPP.

Combining all monetized impacts

Once all impact pathways have been monetized, these are combined to create value factors for each waste type (hazardous or non-hazardous) and treatment type (landfill or incineration), for every country. Where waste treatment is unknown, the methodology applies an “unspecified” treatment value factor by taking a worst-case value factor, i.e. whichever is higher of the landfill or incineration value factor in a given country.

[26] Miranda and Hale (1997).

[27] Singh et al (2009).

Appendix C: Value Accountability Framework – Value Factors

This Appendix presents the Interim Waste Methodology summarized in the form of the Transparency Report proposed by the Value Commission of the Capitals Coalition. Minor adaptations have been made to the report structure to align with the impact accounting methodology.

<table>
<tr><th colspan="3">Transparency Report – Value factors</th></tr>
<tr><td colspan="3">Title and version #: Interim Waste Topic Methodology Value Factor, Version 1

Developed by: International Foundation for Valuing Impacts

Published and updated date: October 2024</td></tr>
<tr><td colspan="3">Unit: The impact in dollars per metric ton ($/metric ton) of waste, hazardous or non-hazardous, being sent to landfill, incineration or unspecified, per country.</td></tr>
<tr><td colspan="3">Linkages to other value factors: This value factor is a complement to the public good, independent, impact accounting methodology developed by IFVI in partnership with the Value Balancing Alliance and can be combined or complemented with value factors from other topic methodologies.</td></tr>
<tr><th colspan="3">SCOPE OF VALUE FACTOR</th></tr>
<tr><td>Impact pathway scope</td><td colspan="2">1. The scope of the value factor includes hazardous or non-hazardous waste being sent to landfill or incineration.

2. The value factor captures impacts associated with waste disposal including from air pollution, greenhouse gases, disamenity effects and leachate. Future work will continue to explore the valuation of additional impacts.

3. More detail about the impact pathway scope can be found in Section 1.4: Scope and Assumptions.

4. Application of the methodology by an entity is based on a materiality assessment as outlined by General Methodology 1: Conceptual Framework for Impact Accounting</td></tr>
<tr><th></th><th>ESTIMATING CHANGES IN WELL-BEING</th><th>ESTIMATING MONETARY VALUE</th></tr>
<tr><td>Approach and specificity</td><td>5. Via four impact pathway modules (air pollution, disamenity, GHGs, and leachate) changes in well-</td><td>10. For each of the changes in well-being pathways, societal impacts are estimated using different valuation methods.</td></tr>
</table>

<table>
<tr>
<td></td>
<td>being are estimated using a series of economic techniques.

6. The changes in well-being are estimated through health impacts (morbidity and mortality) from air pollution, hedonic pricing transfers from waste disposal sites for disamenity, social costs of carbon of GHGs and potential clean-up costs for leachate.

7. The Interim Waste Model has data inputs for many countries and models impacts at the national level, or regional level where national data are not available.

8. Present research has not yet captured all impacts on society and future work will continue to develop value factors for these impacts.

9. Additional details about estimating changes in well-being can be found in Section 4.2: Outcomes and Impacts and Appendix B: Methodological Details.</td>
<td>11. The approaches to convert impacts into monetary terms can be found in Appendix B: Methodological Details.

12. Where future impacts are modelled (Disamenity and Landfill GHGs), present day values are discounted at a 2% social discount rate.

13. Waste impacts can be highly localized, however as specific waste data are hard to obtain, impacts have been averaged at a national, or regional level, where needed.

14. Additional details about estimating societal impacts can be found in Appendix B: Methodological Details.</td>
</tr>
<tr>
<td>Data inputs</td>
<td colspan="2">15. Country-specific and regional-income waste data is taken from the World Bank and UNEP.

16. For further data sets see Appendix B: Methodological Details along with the primary literature sources cited in each.</td>
</tr>
<tr>
<td colspan="3">VIEWS OF AFFECTED STAKEHOLDERS</td>
</tr>
<tr>
<td>Representation of stakeholders</td>
<td colspan="2">17. As an interim methodology, these value factors have yet to undergo the Due Process Protocol of the official methodology, which includes additional stakeholder engagement and public comment.</td>
</tr>
<tr>
<td colspan="3">ETHICAL DECISIONS IN ESTIMATING SOCIETAL IMPACT</td>
</tr>
</table>

Equity weightings and income adjustments	18. The health impacts of waste disposal use a global DALY value to ensure equity in consideration of impacts regardless of their location.
Accounting for future impacts	19. Future impacts are modelled in the Disamenity discounted waste flow and Landfill GHG methane release. Both are discounted at a rate of 2%, and the SCC is assumed to grow at a rate of 1.5% per year.
Other ethical considerations	20. N/A
SENSITIVITY	
Sensitivity to key variables	21. Sensitivity analysis was carried out for hazardous and non-hazardous waste to landfill and incineration, for 3 countries (United States, China and Nigeria). For full results see Table 2.

Table 3: Sensitivity analysis

Key: HL – Hazardous waste to landfill, HI – Hazardous waste to incineration, NHL – Non-hazardous waste to landfill, NHI – Non-hazardous waste to incineration

		United States				**China**				**Nigeria**			
Variable	**Flex**	*HL*	*HI*	*NHL*	*NHI*	*HL*	*HI*	*NHL*	*NHI*	*HL*	*HI*	*NHL*	*NHI*
SCC	10%	8%	10%	9%	9%	7%	9%	8%	7%	7%	10%	8%	9%
Waste type	Textile (from industrial)	23%	0%	26%	0%	19%	0%	22%	0%	19%	0%	21%	0%
Leachate clean-up cost	10%	1%	0%	0%	0%	1%	0%	0%	0%	1%	0%	0%	0%
Lined landfill	10%	11%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%
House price	10%	1%	0%	1%	0%	2%	1%	2%	2%	0%	0%	0%	0%
Household density	10%	-1%	0%	-1%	0%	-1%	-1%	-2%	-2%	0%	0%	0%	0%
Hedonic factor	10%	1%	0%	1%	0%	2%	1%	2%	2%	2%	0%	2%	0%
Value of IQ point	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Income adjustment for health	Income adjusting health impact	0%	0%	0%	0%	0%	-1%	0%	-2%	0%	-1%	0%	-2%

Appendix D: Data Sources in the Interim Waste Methodology

Data	Source[28]	Year
ERQ Score	Esty (2002)	N/A
Sox intensity of national grid	Ember	2024
Nox intensity of national grid	Ember	2024
PM2.5 intensity of national grid	Ember	2024
PM10 intensity of national grid	Ember	2024
Average CO2e grid factor	Ember	2024
Emissions factors	EMEP/EPA	2024
Soil permeability	Gleeson 2011	2024
Household size	United Nations Population Division	Various
Total waste metric tons	World Bank	2024
Landfill waste flow	World Bank	2024
Metric tons landfill waste flow	World Bank	2024
Incineration waste flow	World Bank	2024
Metric tons incineration waste flow	World Bank	2024
Waste collection	World Bank	2024
Average property price	Finder	2022
IPCC climate zones	IPCC	2000

[28] Sources are hyperlinked for your reference.

Non-hazardous -fraction methane captured	World Bank	2024
Non-hazardous fraction captured methane then burned	World Bank	2024
Hazardous-fraction methane captured	World Bank	2024
Hazardous - fraction captured methane then burned	World Bank	2024
Dioxin EF (g I-TEQ/Mg waste)	EEA	2023
Pb EF (g I-TEQ/Mg waste)	EEA	2023
Hg EF (g I-TEQ/Mg waste)	EEA	2023
Hazardous waste incineration with energy recovery	World Bank	2024
Non-hazardous waste incineration with energy recovery	World Bank	2024
% lined landfills - Australia	Government statistics	2013
% lined landfills - Australia	Waste Management Association	2008/2010
% lined landfills - India	Delhi Pollution Control Board	2020
% lined landfills - Morocco	World Bank	2013
% lined landfills - Pakistan	Centre for Peace and Development Pakistan	2021
% lined landfills - Peru	Holland Circular Hotspot	2021
% lined landfills - Russia	World Bank	2010
% lined landfills - Tunisia	EEA	2013
% lined landfills - Turkey	EEA	2013

% lined landfills - Chile	Holland Circular Hotspot	2021
% lined landfills - Singapore	Government statistics	2021
% lined landfills - Thailand	Chiemchiasri et al	2008
% lined landfills - Vietnam	Thiemialis et al	2005
% waste to landfill - Bangladesh	Government statistics	2022
% waste to landfill - Colombia	Holland Circular Hotspot	2021
% waste to landfill - Mauritius	Government statistics	2019
% waste to landfill - Mexico	Holland Circular Hotspot	2021
% waste to landfill - Norway	Norway Statistics Centre	2018
% waste to incinerated - Brazil	da Silva et al	2020
% waste to incinerated - OECD	OECD Statistics	2022
Number of landfills- Albania	EEA	N/A
Number of landfills- Cambodia	Pheakdey et al	2022
Number of landfills- Brazil	World Bank	2004
Number of landfills- Canada	Government statistics	2020
Number of landfills- Chile	National report	2020
Number of landfills- Colombia	European Union statistics	2018
Number of landfills- Croatia	Netherlands Foreign Office	2022
Number of landfills- Denmark	Government statistics	2015
Number of landfills- Finland	EastCham Finland	2020
Number of landfills- France	Zero Waste France	2015
Number of landfills- Iceland	EEA	2016

Number of landfills- Jordan	Retech Germany	2013
Number of landfills- Malaysia	Greenpeace	2024
Number of landfills- Morocco	WWF	2019
Number of landfills- Russia	Semenova et al	2020
Number of landfills- South Africa	Government statistics	2016
Number of landfills- Thailand	Government statistics	2021
Number of landfills- Turkey	Government statistics	2020
Number of landfills- UK	Government statistics	2024
Number of landfills- US	Government statistics	2024
Number of landfills- Vietnam	Salhofer et al	2022
Number of incinerators - Albania	Policy Paper	2019
Number of incinerators - Australia	Zero Waste Australia	N/A
Number of incinerators - Canada	Government statistics	2022
Number of incinerators - Finland	Government statistics	2015
Number of incinerators - Germany	Government statistics	2019
Number of incinerators - Iceland	Oskarrson et al	2022
Number of incinerators - Japan	Government statistics	2022
Number of incinerators - Jordan	UNDP	2020
Number of incinerators - Malaysia	Yong et al	2020
Number of incinerators - Netherlands	Zero Waste Europe	2018
Number of incinerators - Russia	Shilkina et al	2018

Number of incinerators - Thailand	IPEN	2006
Number of incinerators - UK	UKWIN	2022
Number of incinerators - US	National Research Council	2000
Number of incinerators - Vietnam	Salhofer et al	2021
Cancers / IQ loss per kg of heavy metal	Spadaro & Rabl	2008
Cancers / IQ loss per kg of heavy metal	Rabl et al	2008
WTP avoid lost IQ	OECD	2023
WTP avoid of cancer	OECD	2004
Cancer survival	Cancer Research	2022
Conversion calculator	EPA	2024
IPCC Waste Model	IPCC	2000
Hedonic pricing function	Schutt et al	2021
Hazardous Waste incinerated	UN Data	2023
Carbon content of waste	IPCC	2000
HARAS scores	Singh et al	2012
SCC Annual growth rate	UK Government	2021
OECD GNI	OECD	2022
Remaining site lifetime	South Carolina State Environment Department	2019
Remaining site lifetime	Michigan Department for environment	2022
Carbon CO2 conversion	EPA	2024

Health cost elasticity	Viscusi and Masterman	2017
Onalaska Case Study	US EPA	1990
Energy potential of waste incineration	Kumar & Samadder	2022
Energy potential of waste landfill	Dadario et al	2023

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