The Lancet MedZero: Platform Methodology

Carbon analytics for healthcare, by healthcare, at scale

www.MedZeroCarbon.com

The Lancet MedZero is a global collaboration of clinicians, environmental engineers, data scientists, industrial ecologists, economists, and public health professionals working to support healthcare decarbonisation worldwide. Convened by *The Lancet*, it brings together expertise in healthcare delivery, carbon analytics, and system transformation, with contributors from across the Asia–Pacific, Europe, and North America.

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Acronyms

Acronym	Definition
API	Active Pharmaceutical Ingredient
CO_2e	Carbon dioxide equivalents
EPD	Environmental Product Declaration
GHG	Greenhouse Gas
FTIR	Fourier Transform Infrared Spectroscopy
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
MRIO	Multi-Region Input–Output
NLP	Natural Language Processing
PAS 2090	Publicly Available Specification 2090 (British Standards Institution)
PCR	Product Category Rule
PMI	Process Mass Intensity
UNSPSC	United Nations Standard Products and Services Code
USD	United States Dollar

Definitions

Term	Definition
Carbon footprint	The greenhouse gas emissions associated with a product, service, or activity, summated and expressed as carbon dioxide equivalents (CO_2e).
Cradle to factory gate	System boundary covering processes from raw material extraction up to the point a product leaves the manufacturing facility.
Environmental Product Declaration	A standardised, third-party verified document that reports the environmental impacts of a product based on life cycle assessment.
Life cycle stage	A distinct phase in a product's life cycle (e.g. materials and manufacturing, transport, use, disposal).
Life Cycle Assessment	A method to quantify environmental impacts (including carbon footprint) of a product or service across its life cycle, from raw material extraction, through manufacturing, transport, use, and disposal.
Life Cycle Inventory	Data describing inputs (e.g. materials, energy) and outputs (e.g. emissions, waste) associated with each stage of a product's life cycle.
Material and manufacturing	Processes involved in raw material extraction, processing, and product manufacture up to the factory gate. This includes upstream supply chain transport.
Multi-Region Input–Output Modelling	A top-down modelling method that estimates greenhouse gas emissions based on economic transactions between sectors and countries, linking expenditure to environmental impacts.
Parametric approach	A modelling approach that estimates emissions using key parameters (e.g. weight, energy use, transport distance) and standardised assumptions, rather than fully granular process-specific data.
Process-based	A bottom-up modelling method using process-specific life cycle inventory data to model greenhouse gas emissions for individual products or components.
Product Category Rules	Standardised rules that define how to conduct life cycle assessments and develop Environmental Product Declarations for specific product categories, ensuring consistency and comparability.

Products	In this document, ‘products’ refer to individual pharmaceuticals, medical and surgical devices, and diagnostic services. It does not include any associated packaging.
System boundary	A scope of included and excluded processes within a life cycle assessment.
Transport	Distribution of products from the factory gate to the point of use at a healthcare provider, including freight transport, while excluding upstream supply chain transport (which is included within the material and manufacturing stage).
Use	Energy and resources required during product use, including direct energy consumption for powered products and medical imaging, as well as any washing, disinfection, or sterilisation required between uses where applicable.
Waste disposal	End-of-life treatment processes such as recycling, incineration, and landfill.

Executive Summary

In 2009, *The Lancet* concluded that "climate change is the greatest global health threat of the 21st century". By 2015, the framing had shifted: "tackling climate change could be the greatest global health opportunity".

Responsible for 4-7% of global greenhouse gas emissions, if healthcare was a country, it would be the 5th largest emitter in the world. National health systems across the world are beginning to act, with over 100 countries now committed to the World Health Organization's Alliance for Transformative Action on Climate and Health. However, despite these commitments, momentum and progress risks stalling. With high-quality carbon footprints available for less than 1% of the two million medical products used globally, clinicians and health policymakers alike do not have the evidence they need to act. Whether it's a surgeon designing new surgical care pathways, a pharmacist reviewing prescribing patterns, a hospital procurement lead redesigning supply contracts, or a health system's Chief Sustainability Officer setting out a new national strategy – all of them require product-level carbon data at pace and scale to move forward.

In 2026, *The Lancet* is tackling this challenge head on. The Lancet MedZero is a new, open-access, independent, and global database platform to provide carbon data for pharmaceuticals, medical and surgical devices, pathology and imaging services, and broader clinical pathways.

The platform integrates a wide diversity of methodological approaches – process-based assessments, parametric modelling, and bespoke multi-region input-output analysis – deployed hierarchically, always drawing on the best-available science and data for each entry. Every estimate is accompanied by a transparent quality rating, and all outputs customisable to the user's individual clinical context. It is built to deliver results at the pace and scale that health system decision-making requires.

By design, the Lancet MedZero is a continuously evolving collaboration that depends on the support and expertise of a thriving community of sustainable healthcare professionals from across the world and from every discipline. The collaboration is actively seeking contributions from clinicians, researchers, health systems, and industry partners who wish to contribute expertise, data, or methodological improvements. With thousands of products already captured, the Lancet MedZero is committed to covering 80% of all health system emissions across all major pathways and care settings, over the next five years.

This document describes how the platform works, its underlying methodologies and data sources, and crucially – how to get involved.

Introduction

Key points

- The Lancet MedZero is an open-access, independent global database providing carbon analytics for pharmaceuticals, medical and surgical devices, pathology and imaging services, and broader clinical pathways to support decision-making across healthcare systems.
- It uses an iterative, hierarchical modelling approach to generate high-quality carbon estimates across thousands of products, combining best available data with transparent quality indicators to support informed decisions. The platform integrates process-based, parametric, and Multi-Regional Input Output modelling to ensure comprehensive lifecycle coverage.
- A user-focused design enables intuitive search and configurable assumptions (e.g., country of use, transport, energy, and disposal), allowing outputs to be tailored to specific contexts.
- The platform is constantly evolving, always looking to incorporate new data and methods as the field evolves. At all times, the platform aims to transparently communicate the underlying data, methodologies, and quality. To that end, the collaboration welcomes higher quality methods and data where available, and strongly encourages engagement from technical experts, clinicians, health systems, and industry to provide this.

Overview of the Lancet MedZero's approach

The Lancet MedZero is a new open, dynamic and collaborative global database that delivers carbon analytics for pharmaceuticals, medical and surgical devices, pathology and imaging services, and broader clinical pathways to support decision-making across healthcare systems.

With over two million distinct products found in the average healthcare system, and an average of 6-9 months of work required for a high-quality process-based carbon footprint, over 333,000 person-years worth of analytical capacity would be required to assess the footprint of everything. Clinicians and national procurement teams alike require estimates at speed, and at scale.

The Lancet MedZero is built to overcome this exact issue. As a foundational principle, it combines the best-available methodologies and data available to provide actionable carbon analytics at scale, supporting sustainable healthcare decisions for frontline clinicians to system-wide policymaking. It achieves this through four complementary approaches:

- **Building on decades of work from a dedicated community:** All available high-quality life cycle inventory data for healthcare products are harmonised and remodelled using a standardised approach, ensuring that existing knowledge is fully utilised rather than duplicated.
- **Bespoke commissioned audits of high-priority products:** For the highest-volume products (those that account for the greatest share of procurement and clinical use), the collaboration has undertaken direct and bespoke audits using direct material composition analysis, with a variety of new clinical settings soon to follow.
- **Novel parametric and hybrid input-output methods:** Purpose-built parametric models and a bespoke multi-regional input-output approaches provide scalable, evidence-informed estimates across a range of additional products.
- **Open submission from industry and external data providers:** The platform is designed to incorporate higher-quality data as it becomes available, with a structured submission pathway for manufacturers, health systems, and research groups planned for the near-future.

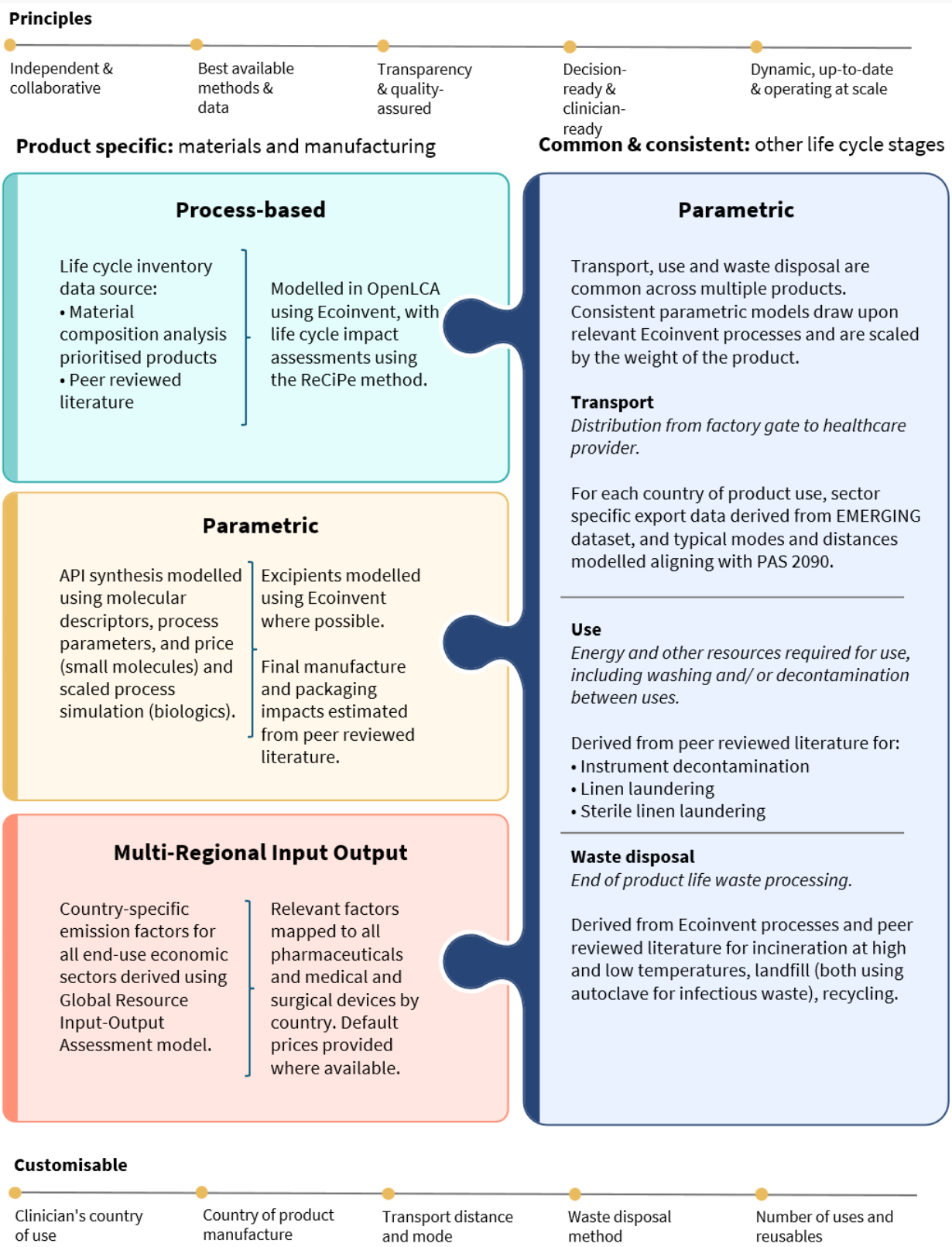
A diversity of methods and approaches are deployed across the platform, with an iterative hierarchical modelling approach to generating high-quality carbon estimates across thousands of healthcare products using best available data from a variety of sources. Process-based life cycle assessment provides the highest-resolution estimates, drawing on detailed material and manufacturing inventory data from the peer reviewed and grey literature. All process-based modelling was undertaken in openLCA, using Ecoinvent version 3.11[1], with life cycle impact assessments characterised using the ReCiPe 2016 (Hierarchist) method.[2] This approach is then replicated with high-quality commissioned audits which are prioritised for the highest-volume products in clinical use.

A bespoke parametric model has been developed for prioritised pharmaceuticals to estimate emissions based on key emissions drivers, informed by established standards, including the British Standards Institution *PAS 2090: Product Category Rules for Life Cycle Assessments*, ensuring consistency in the treatment of lifecycle stages and emissions boundaries.[3] A purpose-built MRIO model provides system-wide coverage, capturing specific materials and manufacturing emissions specific to the user's individual health system context, drawing upon the Global Resource Input–Output Assessment (GLORIA) MRIO model. Across all methodological approaches, material and manufacturing data were combined with further bespoke parametric modelling of product transport, use, and disposal to ensure full lifecycle representation and to provide higher-quality data for each individual user (Figure 1).

A clear traffic light quality rating system, alongside transparent reporting of data provenance, supports informed and proportionate decision-making by helping users identify where emissions arise and where reduction efforts can be most effective. For each individual product, users are provided with examples of how the data can responsibly be used, and are always directed towards higher-quality data where it exists within the platform.

Taken together, the approach embraces five core principles: **independent and collaborative**, convening expertise across the clinical, environmental, and data sciences from world-class institutions across the world, and free from commercial influence; deploying the **best available methods and data**, always applying the most rigorous methodology the underlying data supports, and continuously iterating as better data and approaches emerge; **transparent**, with full reporting of data provenance, methodological assumptions, and evidence quality for every product in the database; **decision-ready and clinician-ready**, designed for busy clinicians, health systems leaders and policymakers who need actionable analytics at the point of care and across health systems, not for specialist researchers alone; and **dynamic, up-to-date, and operating at scale**.

Figure 1: The Lancet MedZero's approach



Designed for clinicians, health system leaders and policymakers

The Lancet MedZero is designed for busy clinicians, health systems leaders, and policymakers who require accessible, centralised carbon analytics, with transparent reporting of data quality and provenance. Designed for ease of use, the Lancet MedZero features an optimised search engine and intuitive interface, with pre-configured assumptions tailored to users while allowing further customisation as needed.

An optimised search engine

To optimise the ability to search for products, all entries in the Lancet MedZero database are matched to United Nations Standard Products and Services Codes (UNSPSC),[4] which provides comprehensive classification of medical products and pharmaceuticals using a hierarchical four-level taxonomy. Products are given a title using generic (non-brand specific) names, capturing detail provided by the original source (e.g. volume of a syringe) where available.

Each product in the Lancet MedZero database is then converted into a semantic vector using a text-embedding large language model.[5] A semantic vector is a numerical representation that captures the meaning of the product and its classification, rather than just the exact words. This includes the product's title, simplified name, and UNSPSC classification details. When a user searches for a product, their query is converted into the same kind of vector, and the Lancet MedZero identifies entries that are closest in meaning. Results are then filtered using the Lancet MedZero quality indicators (see Quality rating) to help users find the most relevant and reliable data. When a user searches for a product with multiple matches in the Lancet MedZero, results are prioritised by the closest matches. Related, similar products for which higher-quality methodologies and data are available, are also suggested to the user.

Customised for users

The majority of carbon footprints in the existing peer reviewed literature are static results, specific to a single time, country of manufacture and use, sometimes with limited sensitivity analysis or generalisability. In contrast, the Lancet MedZero is built with dynamic, location-specific assumptions that are tailored to the user's location and the product type, while still allowing users to modify key parameters.

By default, the Lancet MedZero determines a country of use based on the user's location, automatically updating several linked assumptions. These include the likely transport mode and distance (based on typical import patterns for that product category), the carbon intensity of electricity used during the use phase, and country-specific emissions associated with waste disposal where available (see Other life cycle stages). The country of use can be further manually updated by the user, or a global default can be selected which draws upon global averages.

For products modelled using process-based approaches, the default country of manufacture is extracted from the relevant peer reviewed literature, or where it is not reported, global averages are taken, with transport modelled based on the most likely countries of import for a given user's location. Users can also specify the country of manufacture of their specific product if this

information is known, allowing for more accurate representation of material and manufacturing-related emissions.

Across all products, users can override default assumptions where more specific information is available. This includes defining transport modes, selecting waste disposal methods, and adjusting parameters such as the number of uses for reusable products.

An evolving platform

The Lancet MedZero is a continuously evolving platform. While it currently incorporates the highest-quality data available for healthcare products at the time of release, the platform will actively seek to integrate new data sources and innovative methodologies as they emerge. To accelerate data collection and analysis, the Lancet MedZero will explore cutting-edge approaches in material analysis, artificial intelligence, and automation, while also enabling submissions from industry, provided that strict transparency and reporting standards are met.

Looking ahead, the full platform aims to provide the granularity of data necessary to design lower-carbon, higher-quality care pathways, identify and address emissions hotspots in medical devices and processes, and strengthen health systems' ability to track progress toward decarbonisation. The platform also seeks to encourage the generation of healthcare Product Category Rules (PCRs), such as the *British Standards Institution PAS 2090 Product Category Rules for Pharmaceuticals*,[3] and invites industry partners to come forward with life cycle inventory data and Environmental Product Declarations (EPDs) to support robust, comparable analysis.

How you can help

A project of this scale and ambition succeeds only by drawing on the best expertise from around the world and across disciplines. The Lancet MedZero is looking for support in gathering high-quality data, refining methodologies for calculating carbon footprints, and ensuring that the platform's analytics are both rigorous and clinically relevant.

The collaboration is committed to continuously improving the quality and accuracy of the carbon analytics. Please contact the team if you would like to contribute primary, product-specific data on materials and manufacturing processes, if you have suggestions for methodological improvements or alternate data sources, or have suggestions of new functionalities to suggest and request that may be helpful for users.

Methodological approach and data sources

Key points

- A variety of methodological approaches are used to derive product-specific material and manufacturing data.
- These include process-based approaches drawing upon commissioned audits of prioritised products and inventory data from available literature, parametric models, alongside MRIO approaches.
- Other life cycle stages (transport, use phase and waste disposal) are common to many products, and draw upon consistent parametric models.
- To scale reliably, the Lancet MedZero is building a standards-based provenance and evidence-tiering framework that embeds traceability, integrates multiple modelling approaches with uncertainty, governs AI-derived data quality, and prioritises data improvement using value-of-information methods to ensure carbon estimates are decision-appropriate.

Overview

The carbon analytics reported in the Lancet MedZero takes a full life cycle approach, accounting for emissions from 'cradle to grave', including raw material extraction through to final waste disposal (Table 1).

Table 1: Life cycle stages

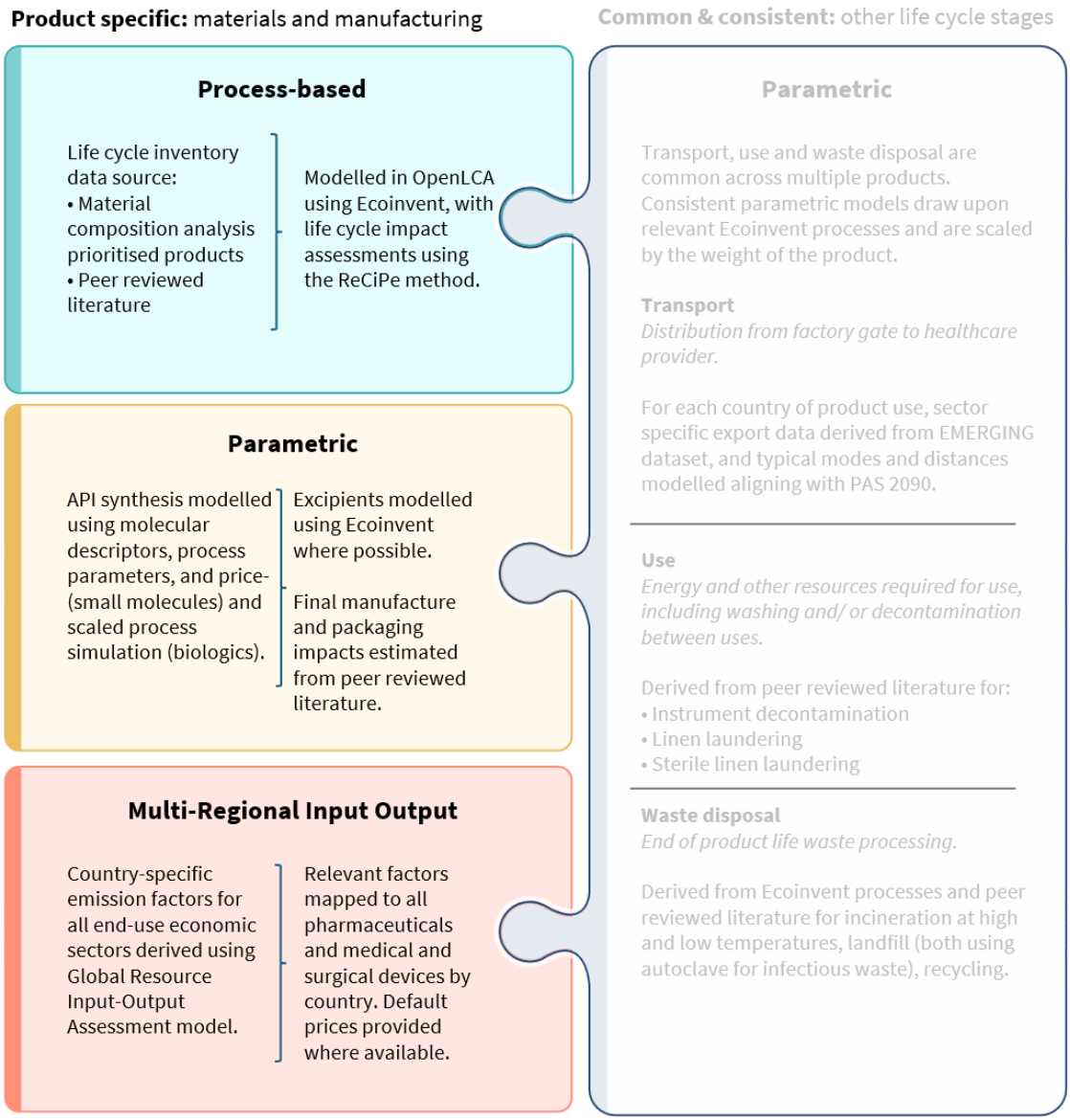
	Life cycle stage	System boundary
Product specific	Material and manufacturing	Processes involved in raw material extraction, processing, and product manufacture up to the factory gate. This includes upstream supply chain transport. At this stage, packaging is not included due to variable inclusion from differing data sources, to enable consistency across products in the platform.
Core common processes	Transport	Distribution of products from the factory gate to the point of use at a healthcare provider, including freight transport, while excluding upstream supply chain transport (which is included within the material and manufacturing stage).
	Use	Energy and resources required during product use, including direct energy consumption for powered products and medical imaging, as well as any washing or decontamination required between uses where applicable.
	Waste disposal	End-of-life treatment processes such as recycling, incineration, and landfill.

Product specific: materials and manufacturing

The type and quantity of material and energy flows associated with the manufacture of products are specific to individual products. A range of methodological approaches are used to derive product-specific material and manufacturing data (Figure 2), including process-based methods informed by commissioned audits of prioritised products and literature-derived inventory data where possible, followed by parametric modelling, and in turn, multi-regional input–output (MRIO) approaches. Where verified supplier-specific inventory data on material and manufacturing processes becomes available this will also be prioritised as the highest-quality source and will take precedence over other data sources. This aligns with the Greenhouse Gas Protocol hierarchy.[6]

Process-based approaches to carbon footprinting track emissions step by step across a product or service's lifecycle, using detailed data on materials, energy use, and emissions at each stage. This life cycle inventory data is then converted to greenhouse gas emissions using established life cycle impact assessment approaches. This approach offers high accuracy, transparency, and clear identification of emission hotspots, and within the Greenhouse Gas Protocol these sit at the highest-quality end of a hierarchy of calculation methods.

Figure 2: Product specific, materials and manufacturing



The Lancet MedZero derives life cycle inventory data on materials and manufacturing of products through commissioned audits of prioritised medical and surgical devices, alongside extracting cradle to factory gate inventory data from high-quality peer reviewed literature. For each product in the Lancet MedZero, the source of material and manufacturing life cycle inventory data is categorised as per Table 2.

Table 2: Material and manufacturing processes data source categories

Material and manufacturing life cycle inventory data type	Details
Product specific, verified primary data from manufacturer	The underlying data and analysis for this product used verified, product-specific material and manufacturing data, including upstream suppliers.
Primary data (direct composition analysis)	The underlying data and analysis for this product used direct measurement to determine product material composition.
Primary data (information from manufacturer)	The underlying data and analysis for this product was based on information from the manufacturer, either through direct correspondence or derived from product information sheets.
Primary data (distributor or hospital)	The underlying data and analysis for this product used information provided by the product distributor or healthcare provider on product material composition.
Mixed primary and secondary data	The underlying data and analysis for this product used a mixture of primary and secondary sources to determine the product material composition.
Secondary data	The underlying data and analysis for this product used secondary sources to determine the product material composition.
Expert judgement	The underlying data and analysis for this product used expert judgement to estimate the product material composition.
Peer reviewed source with unclear provenance	The underlying data and analysis for this product drew upon data from a peer reviewed publication where the underlying material and manufacturing sources could not be fully verified.

All process-based modelling is undertaken in openLCA, using Ecoinvent version 3.11.[1] Carbon impacts were characterised using the climate change midpoint impact category of the ReCiPe 2016 (Hierarchist) method.[2] This category in based on the IPCC Fifth Assessment Report (AR5) 100-year global warming potentials greenhouse gas impacts. Whilst alternate impact assessment methods could have been used, ReCiPe was selected to provide flexibility to enable additional midpoint or endpoint impact categories to be included in future, and alternate impact assessment approaches will be considered in future.

The material and manufacturing life cycle stage includes raw material extraction alongside the manufacturing process itself. To ensure consistency, where manufacturing processes are not already embedded in Ecoinvent materials, these were modelled using industry average Ecoinvent manufacturing processes such as market values for aluminium/ steel product manufacturing, blow moulding, film extrusion, polymer foaming, extrusion, plastic pipes, and weaving of synthetic fibres.

Energy is a key driver of country-specific differences in the carbon footprint of manufacturing a given product. The country of manufacture is therefore important given different grid carbon intensities based on the relative percentages of renewables and fossil fuels. To enable the manufacturing country context to be amended by users, the energy component of all Ecoinvent[1] final-form manufacturing processes is extracted and modelled live according to the selected country's grid intensity.

Direct material composition analysis: prioritised medical and surgical devices

The Lancet MedZero has undertaken a series of commissioned audits, targeting high-volume products within the clinical setting, to determine the material composition of prioritised medical and surgical devices. Products are disassembled into their component parts either through being pulling apart or through cutting products into their component parts (e.g. a syringe into packaging, barrel, plunger and seal). The total weight of packaged products, and of their component parts is determined using electronic scales accurate to 0.01g (UW2200H Electronic Balance, Shimadzu, Kyoto, Japan).

For plastics, glass, textiles, and some metal coatings, the material composition of a sample of each component is determined for every product, using Fourier-Transform Infrared - Attenuated Total Reflectance (FTIR-ATR) via a Lumos FT-IR with A220 Macro-ATR sampling module (Bruker Optics). To improve accuracy of spectrogram results, a baseline signal is measured to enable inherent signal noise to be removed, repeated sampling in different orientations is used, and the top layer of the sample (containing residues and surface contaminants) is removed where necessary.

Two reference libraries are used to ascertain the material composition; the Bruker ATR-Polymer Library (Bruker Optics GmbH & Co. KG, Ettlingen) containing 177 reference compounds; and the KIMW-FTIR-Polymer reference library containing over 1,000 compounds frequently used in the plastics industry. To evaluate how closely the measured spectrum for a given sample matched that of the reference libraries, a Hit Quality score is determined (0-1,000). For materials with a low match (Hit Quality <500), if the weight of the component part is small (<5g) the composition is assumed to be the closest peak of the spectrum, under the assumption that due to its low mass any uncertainty will not produce any a significant difference in the final carbon footprint. For larger components (>5g) with low match, the closest potential peaks are identified, and a sensitivity analysis undertaken. The carbon footprint of potential materials are then modelled using the Ecoinvent database[1] and ReCiPe 2016 (Hierarchist) method,[2] and the material with highest carbon footprint is assigned.

FTIR-ATR is not suitable for solid metal material identification due to high reflectivity and conduction, resulting in weak or ambiguous infrared absorption. Such metals are characterised based on published manufacturers data, and where unavailable, metals are analysed using X-ray Fluorescence (XRF). XRF irradiates a sample with high-energy X-rays, causing the material to emit characteristic secondary X-rays at element-specific energies, enabling quantitative elemental identification. Where materials exist as co-polymers, the ratio of constituent polymers is

interpreted through quantitative infrared spectroscopic analysis based on established calibration curves, peak area ratios, or Beer-Lambert law applications set within the KIMW-FTIR-Polymer reference library. Where the ratio could not be determined through these approaches, an equal split between polymers is assumed.

Peer reviewed literature

Life cycle inventory data focusing on materials and manufacturing processes is extracted from extant life cycle assessments on healthcare products in peer reviewed literature, provided sufficient and replicable detail was provided, with potential literature sources identified through HealthcareLCA.[7] Data extracted from peer reviewed literature included; the bill of materials of products and packaging (weights and materials, including of component parts); manufacturing processes where available; the country of manufacture where specified; the approach taken to identify the materials; and manufacturing processes (see Quality indicators). Data extracted for reusable products included the number of uses across the product lifetime and the approach for preparing the product for reuse (including the sterile barrier system type and size) categorised to one of the Lancet MedZero models for reprocessing (see Use). Where reusable instruments are modelled as part of sets with multiple instruments, the proportional weight of a given instrument relative to all instruments in the set is determined (e.g. a 100 g instrument in a 2 kg set is assumed to be 5%).

The carbon footprint generated through the Lancet MedZero will differ from the original source publication due to the application of a consistent approach for other life cycle stages across the Lancet MedZero; the inclusion of final form manufacturing (variably included in source data); the exclusion of packaging; and because the life cycle impact assessment method originally applied to inventory data may differ or be outdated.

Parametric approaches

Process-based approaches have the advantage of reflecting measurable physical flows and process steps but can become impractical when products become extremely complex or when process information is protected or unavailable, as in the case of some classes of healthcare products and devices, especially pharmaceuticals. MRIO approaches can also be difficult to use in these circumstances as these product categories can contain large price heterogeneities, leading to inaccuracies when applying average sectoral emissions intensities.

Parametric approaches are streamlined versions of process-based or hybrid LCA methods that allow for rapid generation of life cycle inventory data and assessment results based on a small number of product or process attributes, rather than complete modelling of all physical flows. Parametric approaches are particularly useful when products have common manufacturing processes that scale along a common physical basis (such as product sterilization by product

volume), or when many versions of a product exist with different formulations, sizes, colours, etc. but that share primary feedstocks or conversion steps.

In this initial version of the Lancet MedZero, parametric modelling is applied specifically to the pharmaceuticals sector to generate carbon footprint estimates for the WHO Essential Medicines List,[8] encompassing 1578 formulations for 736 unique medicines, covering the majority of the pharmaceutical market in dose number terms. Those pharmaceuticals that have already been studied using process-based approaches will have those detailed results from remodelling (described in the preceding section), while all other medicines will use MRIO modelling for the pharmaceutical sector in the country of use. Future versions of Lancet MedZero will iterate and expand the parametric modelling approach to all pharmaceuticals without published LCA studies.

Modelling Methodology

Parametric modelling of pharmaceutical for the Lancet MedZero is aligned with the guidelines set out in the British Standards Institute *PAS 2090: Product Category Rules for Life Cycle Assessments* in terms of scope and the use of default factors.[3] Separate modelling steps are developed for API synthesis and purification, excipients, fill and finish operations, and packaging, with small molecules and biologics treated under distinct sub-models reflecting their different production architectures.

For small-molecule APIs, parametric estimation draws on a combination of chemical-structural attributes of the compound, characteristics of its synthesis pathway, and economic descriptors. Candidate model specifications are trained and validated against a curated dataset of published process-based estimates remodelled in openLCA for consistency with Ecoinvent version 3.11 background processes, as well as an expansive dataset of over 200 chemical engineering process step calculations for medicine. For biologics, API modelling is derived from a previously published single process simulation, with adjustments based on batch size.[9]

For excipients, where exact compounds and concentrations are known, these are matched to appropriate Ecoinvent entries or modelled following standard process-based approaches. Where excipient data is unavailable, average values are applied based on published industry methods.[10] For final manufacturing and fill and finish operations, energy requirements for mixing, compression, coating, sterilising, and filling are derived from literature values and parameterised per unit dose, differentiated by dose form. For packaging, average material types and quantities are applied for blister packs following published industry methods, while values for bulk bottles, glass vials, and pre-filled syringes are derived from literature sources per dose or per unit volume as appropriate.

MRIO approaches

Comprehensive carbon accounting across health system supply chains requires a scalable methodology capable of covering the full breadth of pharmaceuticals and medical products in use today. Process-based life cycle assessment provides the highest resolution emission estimates, but its application to date covers a fraction of the millions of individual drugs, devices, and consumables used globally. Parametric approaches offer a path to rapid expansion in data coverage in the coming years, but complete footprint attribution across the full procurement portfolio of a health system will always require a complementary MRIO approach.

MRIO modelling is an established tool for a variety of carbon footprinting applications, including in hybrid-LCA studies.[11] By linking monetary spend on products to emissions intensities based on global economic modelling, this approach enables a footprint estimate to be derived for any product for which a purchase value and product classification exist. This completeness comes at the cost of granularity: MRIO factors reflect average sector-level intensities rather than product-specific production processes.

This approach is therefore best characterised as a starting point for any given product, to be progressively replaced by higher-resolution estimates as data from process-based and parametric approaches expand over time.

Selection of MRIO model

The Global Resource Input–Output Assessment (GLORIA) MRIO version 60 model[12,13] is used as the basis for deriving spend-based GHG emission factors.

Selection is guided by four criteria: (i) global coverage and symmetry: GLORIA spans 164 countries and regions in consistent sectors, providing a broader basis for calculations than many MRIO models; (ii) data recency and continuity: the model is actively maintained with regular updates to tables covering multiple years; (iii) sectoral resolution: the 120 economic sectors in the model include explicit segmentation of the pharmaceutical sector most directly relevant to healthcare supply chains; and (iv) openness and reproducibility: GLORIA is produced under creative commons licence for non-commercial use, with underlying data and code readily available, enabling independent verification of results.

The following sections set out the method used to calculate the upstream GHG emissions embodied in producing one monetary unit of health-related goods and services consumed by a given health system.

Definition of country-specific emission factors

The GLORIA tables are transformed into input–output format. The emission multiplier vector $\boldsymbol{m}$ is the matrix multiplication of the direct emission intensity vector $\boldsymbol{q}$ and the Leontief inverse $\boldsymbol{L}$:

$$q_{i,r} = \frac{Q_{i,r}}{X_{i,r}}$$

$$\boldsymbol{m} = \boldsymbol{qL} \text{ where } \boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{A})^{-1}$$

where for every sector of production i in country or region r, $Q_{i,r}$ is the direct GHG emissions attributed to production and $X_{i,r}$ is the gross output of that sector. $\boldsymbol{A}$ is the technical coefficients matrix, and $\boldsymbol{I}$ is the identity matrix. The emission multiplier $\boldsymbol{m}$ represents the total cradle-to-gate emissions per unit of economic output (kgCO_2e / USD) from every sector and country across the global supply chain.

Country-specific emission multipliers (or spend-based emission factors) for any given sector f_i^c are derived from the weighted average of sector-level emission multipliers $m_{i,r}$ with weights given by final demand in consuming country c across all producing countries r:

$$f_i^c = \frac{\sum_r m_{i,r} Y_{i,r}^c}{\sum_r Y_{i,r}^c}$$

where $Y_{i,r}^C$ represents final demand in consuming country c for goods or services from sector i produced in country r. This is applied to every consuming country in the GLORIA database. The resulting $\boldsymbol{f}$ vector reflects the import-weighted intensity of consumption of goods and services, representing the average sourcing pattern in each country.

Treatment of outliers

Sector-level emission factors vary considerably across purchasing countries, reflecting genuine differences in the balance and source of imports and domestic production, the energy mix and production technologies used across upstream supply chains, economic structure, purchasing power, and data quality. The distribution of these multipliers across countries for a given sector is broadly log-normal with a moderate positive skew.

Lower-middle income countries (LMICs) tend to exhibit higher GHG/USD multipliers even after import weighting. This pattern likely reflects several overlapping factors: a higher prevalence of low-cost products (and therefore greater emissions per dollar spent) relative to high-income settings where more expensive drugs and devices are included in the product mix; higher carbon intensity of domestic production, lower energy efficiency, and lower labour costs per unit output; and input–output balancing artefacts that can have an outsized effect on smaller economies, where the total demand for sector i in country c is very small compared to aggregate global demand.

A replacement procedure guards against implausible or erroneous values distorting spend-based estimates. For each set of country factors in sector i, the interquartile range (IQR) is computed across all country-level factors.

A factor for country c in sector i is flagged as an outlier if it falls outside Tukey's fences,[14] defined as 1.5 times the interquartile range (IQR) below the first quartile or above the third quartile:

$$f_i^c \notin [\, Q_1 - 1.5 \times \mathrm{IQR}\,, Q_3 + 1.5 \times \mathrm{IQR}\,]$$

The upper fence captures implausibly high intensities that would overstate emissions; the lower fence is less restrictive given the right-skewed distribution and is retained without adjustment. Where a factor is flagged as an outlier, an appropriate average from the relevant region is used, drawing on all non-outlier country factors within that region.

Margins, currency and inflation

The platform uses GLORIA basic price sheets: the amount receivable by the producer, excluding taxes and duties on products, wholesale and retail margins, and last-mile transport margins. Basic prices reflect the production cost structure facing the supplier rather than the full market price paid by the purchaser, and are the appropriate valuation for input–output analysis as they ensure consistency with the GLORIA supply-and-use tables from which emission factors are derived.

The price applied to these factors should therefore be entered as close to basic prices as possible (i.e. excluding taxes like value-added tax or tariffs, and excluding delivery fees). Analysis of the carbon intensities of those margins suggests that transport and wholesale/retail margins carry broadly similar emission intensities to the healthcare sectors being modelled; prices that include some degree of these margins therefore remain appropriate for spend-based estimation and are unlikely to introduce bias larger than the inherent uncertainty of expenditure-based methods.

Product price data are typically available in local currencies and across multiple reporting years. Two adjustments are applied to convert these values to USD in the default GLORIA base year of 2026. First, spend in local currency is converted to nominal USD using International Monetary Fund's (IMF) International Financial Statistics database exchange rates for the year of analysis.[15] The resulting USD values are deflated to the GLORIA base year using the US GDP deflator index to account for inflationary impacts. Historical deflator values are sourced from the Federal Reserve;[16] forward values for years beyond this series are drawn from IMF World Economic Outlook forecasts.[17]

Applying emission factors to products

GLORIA emission factors are defined at the level of 120 economic sectors. UNSPSC[4] commodities and additional product entries from sources used for default assumptions (see Derivation of default assumptions for products) were mapped to GLORIA economic sectors based on the most appropriate alignment in terms of either economic function or material composition. In cases where a clear economic-sector match was not sufficient or appropriate, commodities were instead assigned according to their predominant material characteristics. Where products could plausibly correspond to multiple material categories, entries were duplicated to reflect each relevant classification. For example, a patient urinal may be represented as both a pulp-based product and a plastic product, with separate database entries created for each material pathway.

Each relevant UNSPSC code was then assigned using a structured concordance approach to the relevant MRIO sector using sector descriptions, concordance tables, and, where ambiguous, the underlying supply-and-use table structure. In total, the model links UNSPSC codes to ten sectors from GLORIA, namely. These ten sectors represent first-order sectors of demand; those sectors themselves purchase from tens of thousands of country-sector pairs across the global economy.

The corresponding emission factor f_i^c of the purchasing country and MRIO sector can then be applied directly to product-level expenditure to yield a footprint estimate in kg CO_2e.

Derivation of default assumptions for products

To provide a "default" carbon estimate for products in the database, a benchmark basic price (excluding value-added taxes and delivery costs) was established using primary data provided by a number of hospitals and national health systems. Each line item in the relevant dataset was assigned to a UNSPSC Code, which allowed a mapping to the relevant MRIO sector, i, as above.

For every product p in the database, a default emission estimate E_p^A was generated using the following equation:

$$E_p = f_i^A \, P_p^A$$

where P_p^A is the basic unit price from country A adjusted into USD as described above, and f_i^A is the emission factor for country A and sector i matched to the product classification.

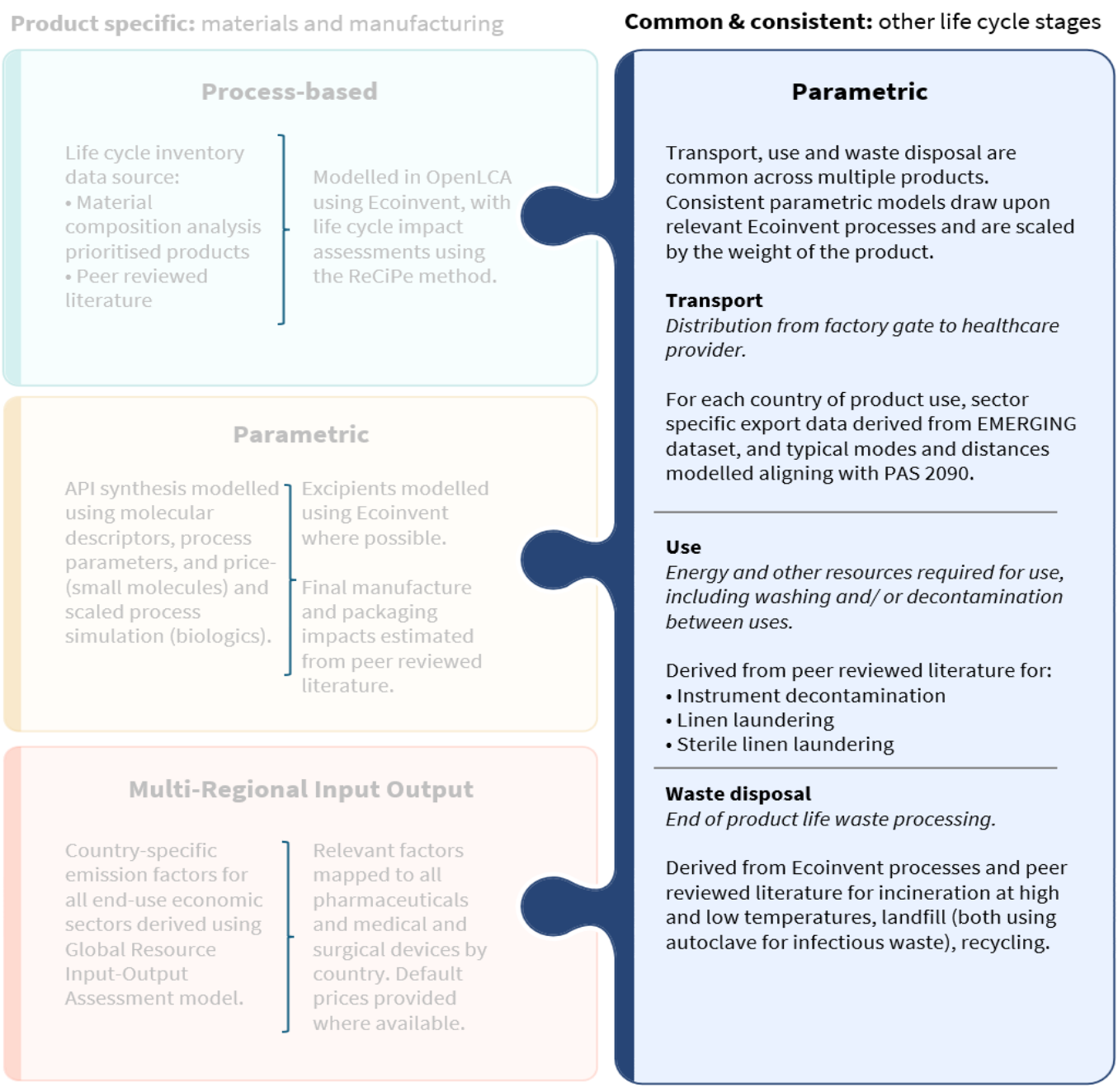
To determine default price estimates in local currencies and enable adjustments, these footprint estimates were used to back-calculate into the equivalent local currency price in 2026, P_p^C that would result in the same product footprint if the weighted-average emission factor specific to that country f_i^c were used to derive the footprint:

$$P_p^C = \frac{E_p}{f_i^c}$$

Common, consistent: other life cycle stages

Aside from product specific material and manufacturing processes, other life cycle stages (transport, use and waste disposal) are common across multiple products, and so a consistent parametric model is developed based on shared physical processes, drawing upon relevant Ecoinvent processes, and scaled by the weight of the product (Figure 3).[1] Although peer-reviewed publications focusing on a small number of products in specific settings may have more accurate product specific models for these life cycle stages, this pragmatic approach enables the Lancet MedZero to feature products at scale and to allow users to choose from a range of configuration combinations. These models will be continually refined, with a range of improvements already in development.

Figure 3: Common, consistent life cycle stages



Where default unit prices were included in the Lancet MedZero for MRIO approaches, the weight of the product was additionally estimated using pragmatic approaches to achieve coverage at scale across tens of thousands of products, and emissions associated with transport and waste to be estimated using parametric approaches. For pharmaceuticals, where the weight or volume of liquid was directly reported in the name this was extracted (uniformly assuming 1g/ml). The median average weight of tablets was applied for each form. For medical and surgical devices, these weights were estimated using publicly available databases.

These approaches combined enable estimated default values to be provided for the price and weight of tens of thousands of healthcare products. The Lancet MedZero approach allows the default to be presented in a locally meaningful unit without requiring reliable local price data, which is frequently unavailable or inconsistent across markets. Users can override the default price with their actual price in local currency, updating the footprint estimate by applying the country-specific factor to a new spend value, ensuring the footprint reflects local market prices where available. Further, the weight may be amended where the user has such information for their specific product.

Transport

The 'transport' life cycle stage refers to the distribution of the product from the factory gate to the healthcare provider. This excludes upstream transport involved in second and third tier supply chains, which is already included within the material and manufacturing stage and assumes global average supply of a given product, weighted by market share.

For each country of use (i.e. country of import), the typical transport distance is determined by first identifying the countries exporting to a given import country for each economic sector, and weighting their contribution, using the Multi-regional Input-output Table for the Global Emerging Economies (EMERGING v2.5).[18] The transport between each country pair (exporting country and importing country) is then classified as local, intracontinental, or intercontinental, and each import country assigned as small, medium, or large, using guidelines from British Standards Institution PAS 2090 product category rules for pharmaceuticals (referred to herein as PAS 2090).[3]

Default assumed freight distances and modes of transport for each category are taken from PAS 2090.[3] The weighted, country specific typical distance and modal split, combined with the product weight, are then used to estimate transport emissions using relevant Ecoinvent processes.[1] Any missing countries use continental averages, and global defaults assume an average across all countries. Users may choose to manually override these default assumptions by changing the primary mode of transportation and transport distance, selecting from air, sea, rail or lorry.

Use

The “use” phase refers to the energy and resources required during product use, including direct energy consumption for powered products and medical imaging, as well as any washing or decontamination required between uses where applicable.

Bespoke parametric models have been built for processes commonly used for preparing reusable products for reuse. This includes steam sterilisation of reusable surgical instruments, laundering of linens, and both steam sterilisation and laundering for sterile linens. All use processes are assumed to require 150 km (round trip) via lorry to an offsite facility, accounting for transport of both the product and associated sterile barrier system. [19,20] Further customisation will be enabled soon.

All use phase models are developed using openLCA, using Ecoinvent version 3.11[1] and selecting market values. Although developed using process-based modelling, the approach is parametric because key input (such as tray size, product weight, and loading) are defined as adjustable parameters, allowing the models to be scaled and adapted to different use scenarios. Further, the processes are amended based upon the user’s location, to account for country-specific grid carbon intensities.

Instrument decontamination

A parametric model for washing and steam sterilisation of reusable instruments has been developed, assuming typical loading of machines, drawing on published inventory data.[19] This is derived for a standard-sized tray (medium set, equivalent to one ‘DIN’), enabling this to be scaled to small sets (half a DIN), and large sets (two DINs), and individually wrapped instruments (drawing upon audit of typical loading).[19] Parametric models are also derived for sterile barrier systems, classified as reusable rigid containers and single-use tray wrap, and individually wrapped instruments.[19]

Emissions are allocated by the product weight relative to the whole set as reported in the source peer reviewed publication. Where an instrument is assumed to be part of a set but the weight of the instruments within the full set is not provided, this is assumed to be 1.5 kg for small sets, 2.25 kg for medium sets, and 3 kg for large sets.[11] For instruments undergoing alternative modes of decontamination, the life cycle inventory is extracted and modelled for these products as per the peer reviewed literature source.

Laundering

Finally, a third bespoke parametric model of laundering healthcare linens (such as scrubs and bedsheets) has been developed drawing upon published inventory data.[20] For sterile linens (such as surgical gowns and drapes) these are assumed to have an additional steam sterilisation step, modelled using published inventory data.[21] Both processes are modelled for one kg of linen, enabling this to be scaled by the weight of the linen product.

Powered products

Powered products such as medical imaging and electrosurgical equipment are modelled on a per-scan/use basis, using the duration of use and load factor as reported in the peer reviewed literature from which the inventory data was derived. Energy consumptions reflects active operation only, with standby consumption excluded.

Waste Disposal

'Waste disposal' refers to end-of-life treatment processes such as recycling, incineration, and landfill, with all waste assumed to be treated and disposed in the country of use. Again, parametric models have been developed for waste disposal for the Lancet MedZero platform, enabling associated emissions to be scaled by the weight of the product. Waste models draw upon Ecoinvent processes for high temperature incineration, low temperature incineration, and sanitary landfill, incorporating treatment of waste emissions (i.e., emissions arising from the treatment of the waste itself), process-specific emissions (i.e., direct emissions and resource use from the treatment equipment, independent of the waste being treated), and facility emissions (i.e., emissions associated with construction of the waste facility), where these are not already combined.[1] Further, transportation from the healthcare provider to the waste facility transportation is also modelled aligning with the Ecoinvent processes[1] for recycling which assumes an average distance to the waste facility and accounts for empty return trips and average vehicle loading. For infectious waste requiring autoclave prior to incineration or landfill, this is modelled using published inventory data.[22]

The recycled content approach is used for recycled products and modelled using Ecoinvent processes[1], which assigns the burdens of the recycling processes to the final product, whilst emissions associated with collection and transport prior to the material entering the recycling process is assigned to the original product.[23]

The Lancet MedZero draws upon country specific Ecoinvent waste processes,[1] and where unavailable, regional average processes are assumed. The default waste disposal route used across the Lancet MedZero is high temperature incineration as this is commonly used within healthcare facilities. However, where users wish to amend the mode of disposal they may refer to to Table 3 help determine the likely mode of disposal based on the name of the relevant healthcare waste stream.

Table 3:Typical names of healthcare waste streams and associated modes of waste disposal

Mode of waste disposal	Names of healthcare waste streams commonly utilising mode of wase disposal
High temperature incineration	Anatomical waste/ human and blood products; biohazardous waste; biological waste; chemical waste; clinical waste; cytotoxic waste; cytostatic waste; hazardous waste; infectious waste; isolation waste; medically contaminated sharps waste; medicinal/ pharmaceutical waste; microbiological waste; pathological waste; regulated medical waste
Low temperature incineration	General waste; hygiene waste; municipal waste; domestic waste; non-hazardous medical waste; non-infectious offensive waste; non-medical waste
Sanitary landfill	General waste; hygiene waste; municipal waste; domestic waste; non-hazardous medical waste; non-infectious offensive waste; non-medical waste
Autoclave and low temperature incineration	Infectious waste
Autoclave and sanitary landfill	Infectious waste
Recycling	Recycling

Artificial intelligence and evidence quality governance

Scaling the platform to tens of thousands of products exposes a problem that better data alone will have difficulty solving. Each estimate in the Lancet MedZero rests on a chain of sources, assumptions and modelling choices. At the current scale, a careful analyst can trace that chain. At the scale the platform aims for, traceability must be built into the infrastructure itself.

The Lancet MedZero are in the process of developing a provenance framework for this purpose, drawing on the W3C PROV family of standards.[24] Every carbon estimate will carry structured, machine-readable metadata recording what sources were consulted, what transformations were applied, and what calibration the result has undergone. As currently designed, the provenance layer will feed an evidence-tiering system that determines what each carbon footprint estimate is actually suited for: whether it can support exploratory benchmarking and hotspot analysis, inform a procurement comparison, or underpin a policy decision with high-accountability.

Additionally, more advanced approaches are under development to address the challenge of how to address situations where different approaches produce different carbon estimates for the same product. The platform currently handles this through a hierarchy as described above. The collaboration is developing a fusion layer that preserves this information, producing a single estimate with an evidence-based uncertainty envelope rather than simply picking one method over another. The approaches range from hierarchical Bayesian pooling (where borrowing strength across similar products is defensible), to robust methods that widen uncertainty bounds when the models themselves are mis-specified. The most robust approach will likely vary by product class.

Natural language processing (NLP) will be used in future to accelerate evidence extraction from published peer reviewed literature, manufacturer documentation and procurement records. The important constraint is that AI-derived evidence enters the same provenance and tiering framework as everything else, and is replicable and deterministic. Automated extraction is faster than manual curation, but faster is not the same as better. It can be tempting to treat NLP outputs as equivalent to expert-curated data, however safeguards are needed in the platform such that users aren't required to individually judge the quality of NLP generated carbon estimates. In practice, this means that any information extracted by AI that has not been validated against expert review will not reach higher evidence tiers, regardless of how confident the model appears.

A less obvious but potentially more consequential use of computational methods is in deciding where to invest effort next. The Lancet MedZero currently grows by a combination new data submissions, commissioned audits, the development of new models, and added functionality. That process is valuable but not systematic. Value-of-information methods, borrowed from health decision science, offer a way to estimate which additional audit or modelling effort would most reduce uncertainty for the decisions that actually matter. A product class where better data would change a procurement ranking is more urgent than one where even large improvements in accuracy would leave the ranking unchanged. Connecting this logic to the provenance layer creates a feedback loop: when a user requests evidence that falls short of what their decision requires, the system can identify the specific data gap and the most efficient route to closing it.

Quality assurance, interpretation and use cases

Key points

- Each product is assigned a quality indicator reflecting the method used for materials and manufacturing (process-based, parametric, or MRIO), while a parametric approach is applied consistently for transport, use, and disposal.
- The Lancet MedZero is developed collaboratively across international institutions
- All data undergo rigorous review, including cross-checks by at least two technical experts, comparison against original sources, and spot checks for selected products; discrepancies are investigated and resolved.
- The Lancet MedZero is designed for stakeholders across healthcare and sustainability, including clinicians, health systems leaders, policymakers, researchers, procurement teams, industry, and funders, to support lower-carbon decision-making and system change.

Quality rating

The Lancet MedZero assigns one of three quality indicators for each product, reflective of the method used to evaluate emissions associated with underlying the materials and manufacturing (Table 4), with green assigned to process-based approaches, amber for parametric, and red for MRIO derived estimates. This hierarchy aligns with the Greenhouse Gas Protocol approach prioritisation.[6] Designed for simplicity, the quality rating is immediately visible when searching for products, helping guide users towards higher quality estimates, with further details available on the modelling approach in the more information tab.

Table 4: Traffic light quality rating

Quality rating	Materials and manufacturing modelling approach	Transport, use and disposal approach
	Process-based	Parametric
	Parametric	
	MRIO	

Lancet MedZero review process

Lancet MedZero exists as a collaboration between *The Lancet*, the Health Intervention and Technology Assessment Program Foundation of Thailand, the National Institute for Environmental Studies of Japan, Northeastern University, USA, the National University of Singapore, the University of Birmingham, and The University of Melbourne, Australia. All academic partner institutions are involved in data verification.

All life cycle inventory data derived from peer reviewed literature are checked by at least two technical experts from the Lancet MedZero's academic partners. Further, detailed spot checks are performed on 5% of products, including the extraction of inventory data. For life cycle inventory derived using direct composition analysis through bespoke audits (with no other reference point), such data was modelled twice by two partner organisations and any discrepancies ratified.

While *The Lancet* plays a critical role in convening and supporting the collaboration, individual data entries within the Lancet MedZero have not undergone to formal peer review by *The Lancet*. As the collaboration develops, there are plans to introduce ongoing review and synthesis through regular academic publications, further strengthening the scientific foundation and oversight of the platform over time.

Interpretation and use cases

The Lancet MedZero is designed to support a wide range of users working at the intersection of sustainability and healthcare. This includes clinicians seeking to incorporate lower-carbon decision-making into care pathway redesign and quality improvement, with a cross-cutting role in education and building carbon literacy across the health sector. Going further, the platform can be used to support health system leaders and policymakers in system-wide carbon baselining, target setting, and strategic planning, alongside integration of sustainability into national health policies and regulation. Beyond the delivery of care, the Lancet MedZero may be deployed by researchers seeking to include carbon data into studies that previously focused primarily on clinical outcomes, health economic evaluations, and broader health system and policy research. Funders and journals may also draw on the Lancet MedZero to strengthen requirements for carbon reporting within studies and clinical trials, alongside integration of sustainability into research evaluation and research prioritisation.

The platform is underpinned by a structured approach to data quality and interpretation, recognising that not all carbon estimates are equally robust or suitable for the same decisions. High-quality, product-specific data on material and manufacturing inputs informing process based approaches may support direct product comparisons and procurement decisions in future. In contrast, estimates derived from less granular primary data, mixed sources, or secondary datasets are better suited to identifying broad trends, estimating emissions across groups of products or care pathways, and prioritising areas for further analysis. Across all use cases, caution is required to ensure that outputs are applied appropriately to their level of certainty, with higher-stakes decisions relying on more robust, validated data and lower-tier estimates used to guide exploration, prioritisation, and continuous improvement.

In the future, procurement teams may be able to use the Lancet MedZero to support more sustainable purchasing decisions by exploring relative carbon footprints, engaging suppliers, and informing early-stage specification and tender design. Over time, the collaboration will actively work to support the development of healthcare-specific PCRs and the wider provision of primary life cycle inventory data and EPDs. In turn, these higher-quality datasets can be used by industry partners to guide product redesign and benchmark environmental performance across portfolios.

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Annex 1 – The global collaboration

The Lancet MedZero is a global collaboration of academic institutions from the Asia Pacific, Europe, and North America, convened by *The Lancet*. All academic partner institutions carry equal scientific responsibility for the platform and have contributed to its strategic direction, development, methods, governance, and quality assurance processes.

The platform's work is organised across seven interdependent domains, each with a defined scope of work. Outputs are reviewed collectively across the collaboration before integration into the platform.

Domain	Name	Institution
Process-Based Modelling	Professor Forbes McGain (Lead, Domain 1), Dr Scott McAlister, Catherine O'Shea	University of Melbourne
	Assistant Professor Jonathan T.E. Lee, Lydia Tang, Sage Mosgrove	National University of Singapore
Parametric Modelling	Professor Matthew Eckelman (Lead, Domain 2)	Northeastern University
	Dr Agnes Henson (Product Lead, the Lancet MedZero)	National University of Singapore
Input-Output Modelling	Professor Keisuke Nansai (Lead, Domain 3), Dr Jacob Fry	National Institute of Environmental Studies
	Thomas Andrew, Lydia Loh, Reni Chng Cai Lok, Aruzhan Shalabayeva	National University of Singapore
Clinicians and Policymakers	Sarin KC (Lead, Domain 4), Yin May Tun	Health Intervention and Technology Assessment Program
Novel Methods and Artificial Intelligence	Professor Slava Jankin (Lead, Domain 5)	University of Birmingham

Domain	Name	Institution
Coordination and Research Translation	Professor Nick Watts (Executive Director, the Lancet MedZero), Associate Professor Chantelle Rizan (Technical Director, the Lancet MedZero), Jit Sohal (Impact Lead, the Lancet MedZero), E-Sean Lum, Mita Huq	National University of Singapore
	Dr Jessamy Bagenal	The Lancet

The coordination and governance of the initiative is overseen by the leads of each of the work streams above. No partner receives industry funding in connection with this platform, and the collaboration's scientific outputs are produced and reviewed independently of commercial interests, consistent with the commitment to providing evidence that clinicians and health policymakers can trust.