Clinical Trials: Carbon footprint assessment guidance

Guidance Document

Sustainable Healthcare Coalition

Final version
March 2024

ERM

SIGNATURE PAGE

Clinical Trials Carbon Footprinting

Guidance Document (Final)

Carolyn Thomas

Partner

ERM UK Ltd
2nd Floor
Exchequer Court
33 St Mary Axe
London EC3A 8AA

CONTENTS

List of Figures

List of Tables

Acronyms and Abbreviations

Name	Description
AZ	AstraZeneca
CO_2 eq	Carbon dioxide equivalent
ERM	Environmental Resources Management
GWP	Global warming potential
ICR	Institute of Cancer Research
iLCCT	Industry Low Carbon Clinical Trials group
IMP	Investigational Medicinal Product
ISO	International Standards Organization
J&J	Johnson & Johnson
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
SHC	Sustainable Healthcare Coalition
SMI	Sustainable Markets Initiative

1. ACKNOWLEDGEMENTS

This Guidance Document has been developed by Environmental Resources Management Limited (ERM) on behalf of the Sustainable Healthcare Coalition (SHC), as a part of the program of the Industry Low-Carbon Clinical Trials (iLCCT) group. This project was funded by AstraZeneca, Merck and Novartis as part of their collaboration with members of the iLCCT group. The Guidance Document follows the earlier publication of a Method Document for clinical trial footprinting, which was funded by Novo Nordisk A/S.

The iLCCT group is comprised of the following organizations.

List of iLCCT members:

- AstraZeneca (AZ);
- the Institute of Cancer Research (ICR);
- Johnson & Johnson (J&J);
- Merck;
- Novartis;
- Novo Nordisk A/S;
- the Pistoia Alliance;
- Roche;
- Sanofi;
- the Sustainable Healthcare Coalition (SHC); and
- the University of Liverpool.

Convening body and technical authors:

- Convening body – the Sustainable Healthcare Coalition (SHC)
- Technical authors – Environmental Resources Management Limited (ERM)

2. INTRODUCTION

This Guidance Document is intended to support users in estimating the carbon footprint of a clinical trial in conformance with the iLCCT – Clinical Trial Environmental Footprinting Method, Version 1.0, 13th July 2023, herein referred to as the Method document, developed on behalf of the SHC.

The Guidance outlines the specific steps involved in assessing the carbon footprint of a clinical trial at any stage: whether it is in the design and planning stage, is ongoing; or has been completed.

The Guidance Document is structured according to the following sections.

- Section **1: Acknowledgements**.
- Section **2: Introduction** – Introduction to the document and explanation of its scope.
- Section **3: Overview of clinical trial footprinting** – Introduction as to how to perform a clinical trial footprint study.
- Section **4: Data Collection and Calculation** – Detailed explanation as to how to collect and to process data for undertaking a clinical trial footprint study, according to clinical trial (sub) stages, with proxy data provided for those users who would benefit from secondary data with which to supplement their own information.
- Section **5: Interpretation and Reporting** – Description of reporting and interpretation of a clinical trial footprint.
- Section **6: Generic Emission Factors** – Compilation of the proxy data provided to be used in the absence of better and more specific information.

The following terminology is adopted in the Guidance Document:

- The term “shall” is used to indicate what is obligatory;
- The term “should” is used to indicate a recommendation, rather than a requirement;
- The terms “may” or “can” are used to indicate an option that is permissible;
- The term “trial” is used to refer to a clinical trial;
- The term “study” is used to refer to an estimation of the carbon footprint of a clinical trial; and
- The term “study commissioner” is used to refer to the party(ies) who require and have initiated the estimation of the carbon footprint of a clinical trial.
- The term “primary data” is used to describe data from specific activity/processes in the studied clinical trial;
- The term “secondary data” is used to describe process data that are not from the specific activity/processes in the studied clinical trial; and
- The term "proxy data” is used to describe data from a similar activity that are used as a substitute for the given trial activity. Proxy data can be extrapolated, scaled up, or customized better to represent the required trial activity.

The normative references for, and sources of definitions of terms used in, this document, are:

- ISO 14040:2006, Environmental management – Life cycle assessment – Principles and framework[1] (hereafter referred to as *ISO 14040*);

[1] ISO 14040: Environmental management – Life cycle assessment – Principles and framework. Geneva : International Organisation for Standardisation., 2006a.

- ISO 14044:2006, Environmental management – Life cycle assessment – Requirements and guidelines[2] (hereafter referred to as *ISO 14044*);
- Greenhouse Gas Protocol, Product Life Cycle Accounting and Reporting Standard[3] (hereafter referred to as *GHG Product Standard*); and
- Sustainable Healthcare Coalition, Care Pathways: Guidance on Appraising Sustainability, Main Document[4] (hereafter referred to as *SHC CP Guidance*).

These references allow for a wider scope of clinical trial carbon footprints, according to the defined intended study application and requirements of the study commissioner – such as an expanded choice of environmental impacts to be appraised and reported – whilst maintaining overall compliance and alignment with the Method Document.

This Guidance Document is not intended to be prescriptive and therefore does not preclude the choice of compliance with alternative methods (e.g. the European Commission's Product Environmental Footprint approach[5]), if this is stated in the defined goal and scope of the study.

Users of this guidance document should be aware that the emission factors provided below to support the calculation of the carbon footprint of clinical trials are accurate, in terms of time relevance, at the date of publication. Users should be mindful that some of the emission factors will become subject to error as time progresses from this date. For example, transportation or electricity emissions factors may vary as transport fuel types and national grid mixes change..

2.1. THE DEVELOPMENT OF THE GUIDANCE

This Guidance Document has been developed as part of a program undertaken by the industry Low Carbon Clinical Trials (iLCCT) group, in collaboration with academic organizations and the Pistoia Alliance. The iLCCT group was convened by the SHC in response to the Sustainable Markets Initiative (SMI) Heath Systems Task Force – a group with the objective of taking joint, scalable action to accelerate the delivery of net zero healthcare[6] – and comprises several organizations committed to developing tools and guidelines to facilitate the decarbonization of clinical trials conducted by industry and academia. The technical authors of this guidance document are Environmental Resources Management Limited (ERM).

The key milestones and associated timelines of the method development are detailed below:

- Guidance initiation: 17th April, 2023;
- Guidance drafted: 13th November, 2023;
- Consultation workshop: 27th November, 2023;
- Guidance consultation closed: 12th January 2024;
- Guidance finalized: 5th March 2024; and
- Launch and release of guidance: TBD.

2.2. RATIONALE FOR THE DEVELOPMENT OF THIS GUIDANCE

As outlined in the SMI Health Systems Task Force white paper[7], the global healthcare industry contributes an estimated 4-5% of total global greenhouse gas emissions, of which clinical trials are expected to contribute an important component – up to 100 million tonnes of carbon dioxide equivalent (CO_2 eq) per year[7].

[2] ISO 14044: Environmental management – Life cycle assessment – Requirements and guidelines. Geneva : International Organization for Standardization, 2006b.
[3] GHG protocol Product Standard | Greenhouse Gas Protocol. sl : ghgprotocol.org.
[4] SHC. Sustainable Care Pathways Guidance. sl : Sustainable Healthcare Coalition (shcoalition.org).
[5] EU. European Platform on LCA | EPLCA (europa.eu).
[6] SMI. Health Systems taskforce. sl : Sustainable Markets Initiative (sustainable-markets.org).
[7] SMI. Health Systems taskforce. sl : Sustainable Markets Initiative (sustainable-markets.org).

In addition, Adshead et al[8] estimated a total carbon footprint of 27.5 million tonnes CO_2 eq from 350,000 registered clinical trials, further highlighting the pressing requirement to decarbonize. Adshead et al also proposed a strategy for achieving this decarbonization – to be addressed as a priority, the development of methods and calculation tools which will enable reliable estimations of the total environmental impacts of clinical trials and the ability to identify particular areas of activity with a high impact-intensity (or 'hotspots').

This Guidance Document addresses the second stage of this strategy, and is a foundation for the development of calculation tools for estimating the footprint of clinical trials. It follows the development of a separate Method Document that sets out the methodological background concerned with how an environmental footprint study of a trial should be performed. The Method Document sets out a common reference standard for parties to use whilst footprinting a clinical trial(s) under their ownership or control, or a trial(s) in which they are partaking or in which they have an interest.

The Guidance Document is intended for use by those with limited experience of undertaking life cycle assessment (LCA), although prior familiarity with LCA concepts and methods will be of assistance. It is intended to be a stand-alone document, and there should be no need for the user to refer to the Method Document in conducting a study unless they wish to familiarize themselves with the methodological background.

The principal aim of the Guidance is to provide more specific support to users in the form of the steps that should be undertaken in a footprint study of a trial, thus facilitating quantification of the carbon footprint across all types of clinical trials undertaken globally. The Guidance also provides secondary or proxy data for clinical trial footprinting studies that can be used in the absence of more specific and higher quality information.

The Method and the Guidance Document together constitute the first and second stages of a broader program, which subsequently is intended to incorporate development of an on-line calculation tool further to operationalize consistent clinical trial footprinting and reporting.

[8] Adshead, Fiona, et al. A strategy to reduce the carbon footprint of clinical trials. 2021. pp. 281-282.

3. OVERVIEW OF CLINICAL TRIAL FOOTPRINTING

In order to calculate the carbon footprint of any product, process or service, a holistic approach is required that demands the whole trial system to be understood and established, from the extraction of raw materials, through use(s) to management at end of life. Without a holistic view, an important contribution to the footprint might be overlooked and conclusions drawn, and recommendations made, concerning hotspots and potential reduction initiatives might be incorrect. This is true also for the assessment of clinical trials – to evaluate accurately and reliably the footprint of a clinical trial, all the materials and activities constituting the trial must be considered, other than those that are *de minimis*.

Clinical trials are, by nature, complex and dynamic activities. To help ascertain the impacts of the inflows and outflows that will contribute to the trial footprint, an essential first step of a clinical trial footprinting study is to map all the activities that will take place during the trial, from its design and inception all the way to its close out. This will include, for example, producing and dispensing an investigational medicinal product (IMP) or other intervention to participants, staff commuting, participants travelling to the clinical trial site for a procedure and storage/disposal of samples taken from participants.

Once all of the activities of which the trial is comprised have been mapped out, the next step is then to determine the impact or carbon footprint of each of these, based on the emissions that arise from the production/use of the materials, services, energy used and the management of wastes generated to fulfil the purpose of the specified activity. Typically, this will be an iterative exercise, with an initial high-level study used to determine materiality, i.e. identify those activities which are likely to make the most significant contributions to the footprint of the trial. Such a materiality assessment helps to focus data collection and calculations on these parts of the trial, rather than those which make only negligible contributions to the footprint, but for which data collection would consume time and resources.

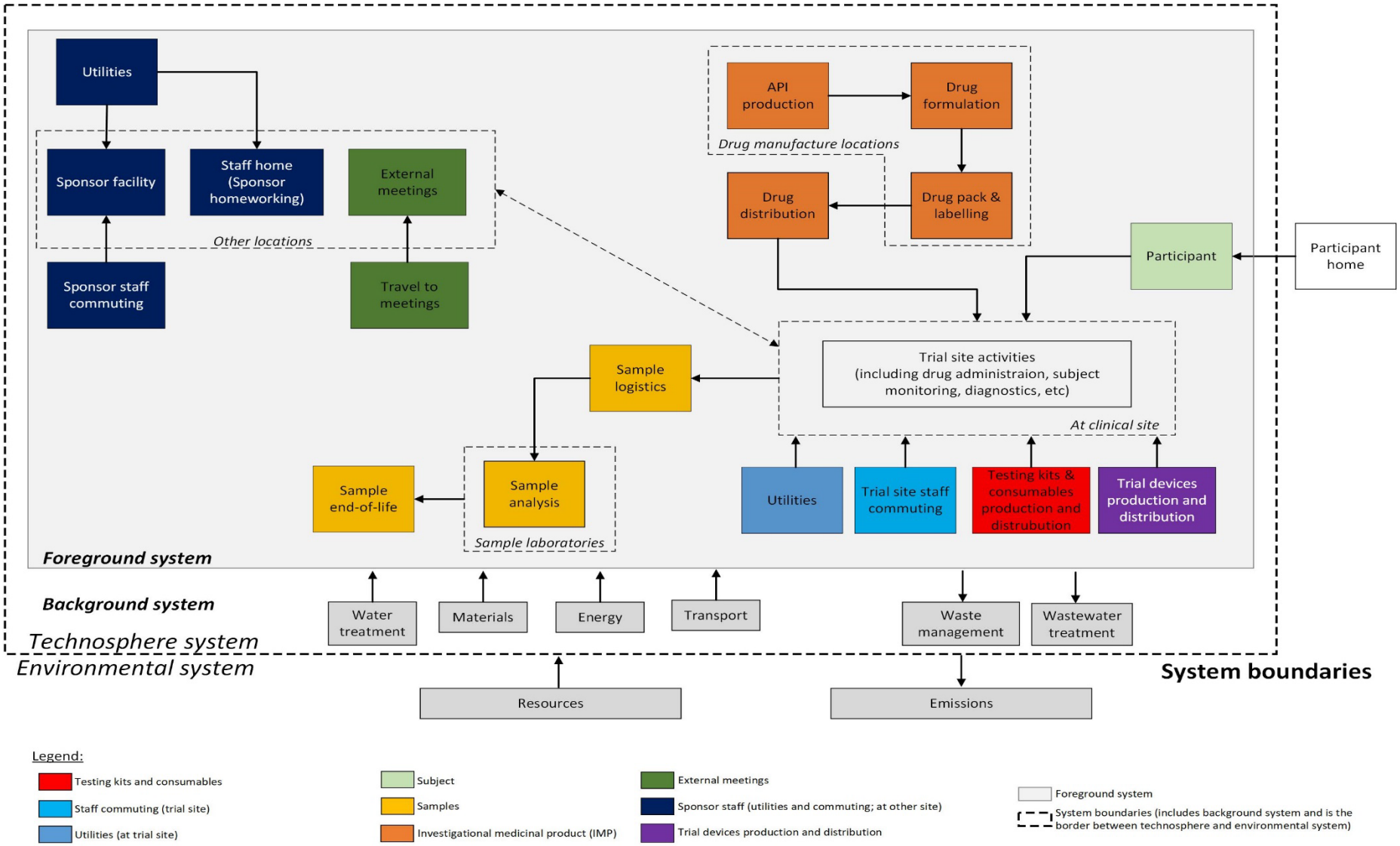
Ultimately, the granularity with which the footprint is estimated, and the degree of iteration, will depend on the information available for the trial and the objectives and resources of the study. In some cases, the desired accuracy of the study will be higher, and in others legitimately lower. Where the objective is a high degree of accuracy, it will be important that the materiality principle is used to identify those activities where effort on data collection will need to be placed in order to meet the study goal.

Finally, once all activities have been appraised, the overall trial footprint can be evaluated through aggregation, and key hotspots then identified. This step might be conducted either at the activity level (e.g. trial management, trial sites), or at the individual material/service level (fuel consumption for sample shipping), should this be allowed by the granularity of the data employed.

A helpful way to identify the input and output flows that will be associated with a clinical trial is to develop a process flow diagram or map. This is a visual representation of the clinical trial and a list of activities considered to be core clinical trial activities, an example of which is shown in Figure 1 below. Other examples can be found in the literature, including Griffiths et al[9].

[9] Jessica, Griffiths, et al. Quantifying the carbon footprint of clinical trials: guidance development and pilot study. sl : PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs, 2023.

Figure 1 - Example of a generic clinical trial process map



The typical steps taken in calculating the footprint of a clinical trial can be summarized as:

I. Define and map the trial;

II. Estimate the scale/quantity of each activity in the trial;

III. Obtain emission factors;

IV. Calculate trial impact;

V. Refine map and data through targeted data collection, and/or developing, specific emission factors; and

VI. Sensitivity analysis, interpretation and reporting.

Steps I-V are illustrated in the following diagrams (Figure 2 to Figure 6). Sensitivity analysis, interpretation and reporting, i.e. Step VI, is addressed in Section 5.

Figure 2 - Steps to calculate the footprint of a clinical trial - step I: Map trial activities

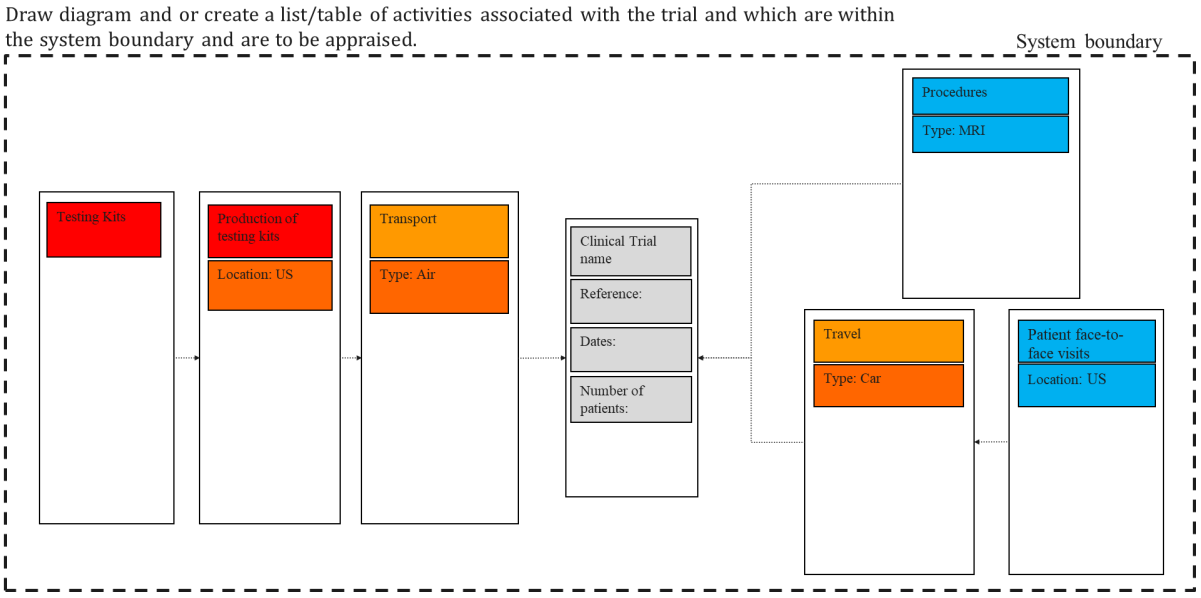


Figure 3 - Steps to calculate the footprint of a clinical trial - Step II: Estimate quantity of each activity

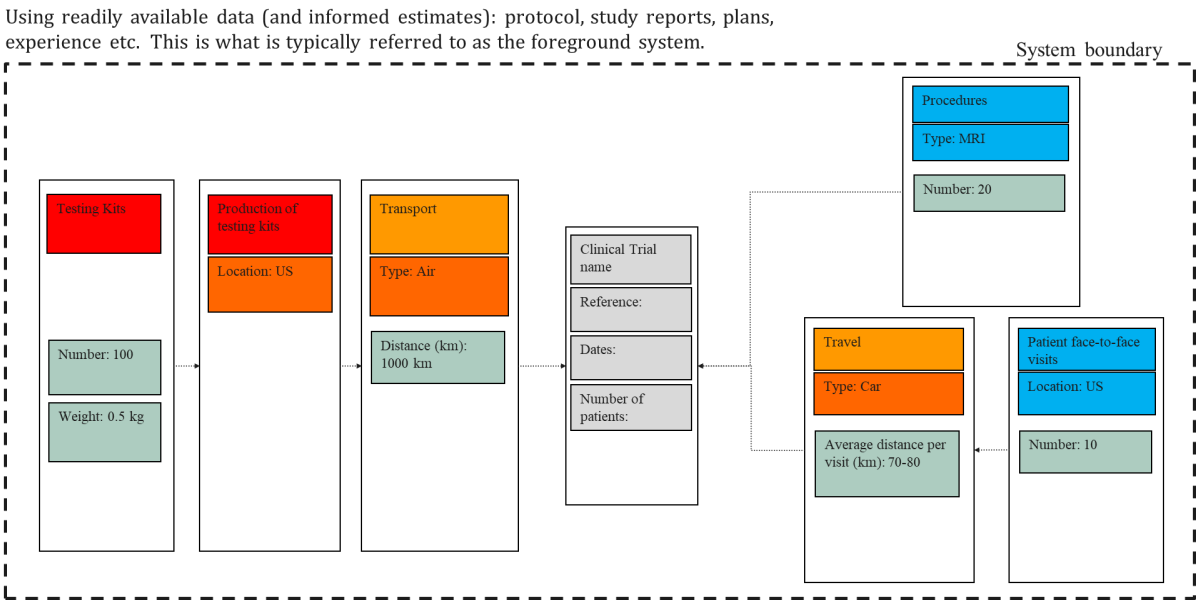


Figure 4 - Steps to calculate the footprint of a clinical trial – Step III: Source emission factors

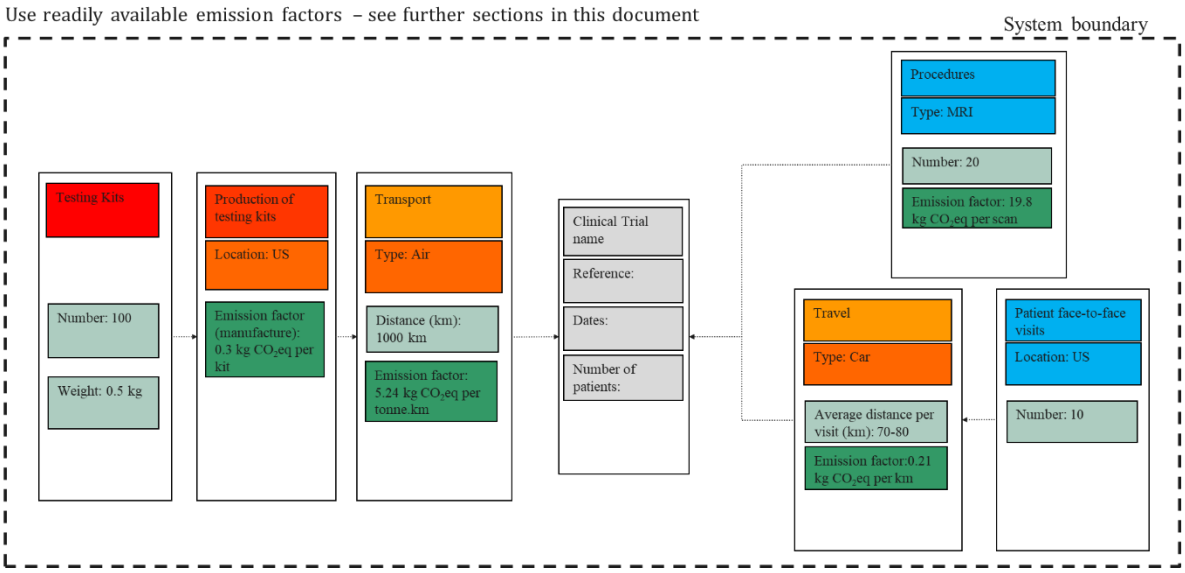


Figure 5 - Steps to calculate the footprint of a clinical trial – Step IV: Estimate impacts

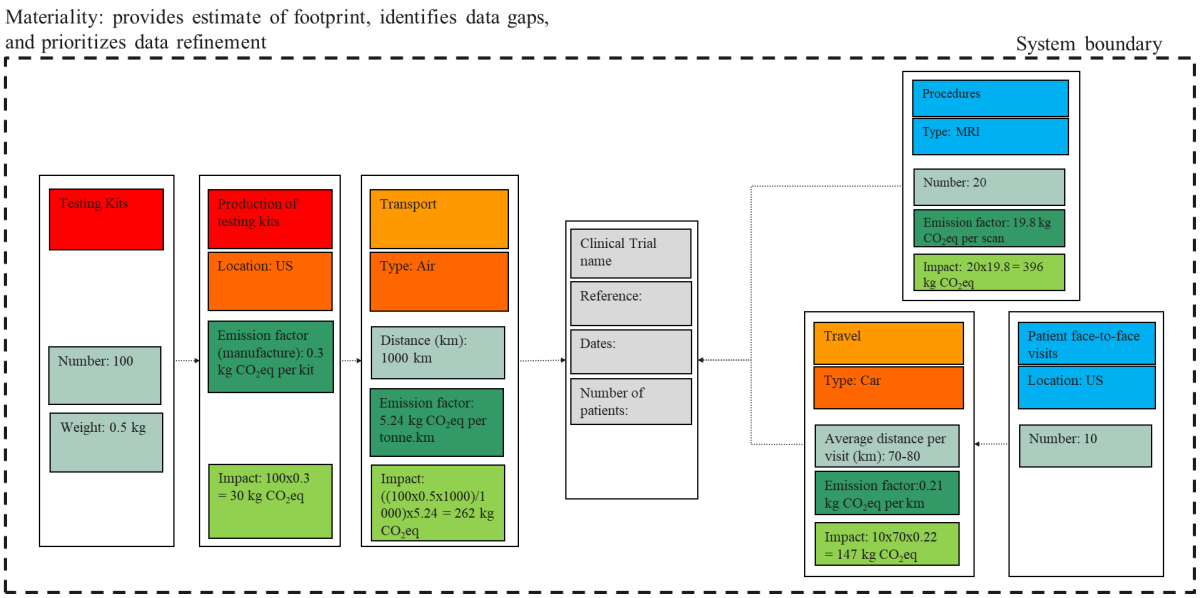
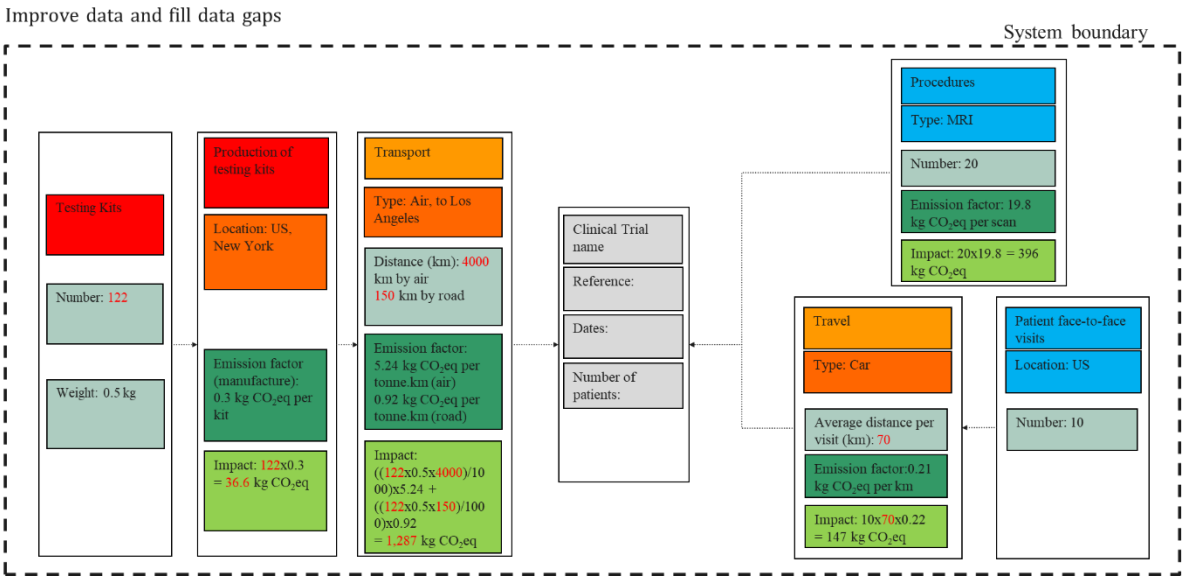


Figure 6 - Steps to calculate the footprint of a clinical trial – Step V: Refine assessment



Steps I-IV (Figure 2 to Figure 5) are the steps for determining materiality and those steps associated with defining the goal and scope of a detailed assessment. In this Guidance Document these steps are sometimes referred to as a 'first iteration' of the footprint study. In the form of a materiality assessment, Steps I-IV in themselves will provide valuable insight into the footprint of trials and the process of footprinting. Steps V (Figure 6) and VI (sensitivity analysis, interpretation, reporting, see Section 5) are associated with completing a more detailed assessment.

Defining the goal and scope will include specifying the purpose of the study and how that goal will be met through consideration of key issues such as:

- System boundaries;

- Functional unit;
- Allocation choices;
- Data requirements; and
- Data quality requirements.

The system boundary specifies what is to be appraised and accounted for in the assessment in order to meet the stated goal of the study. Consideration will need to be given to attributing activities correctly to a trial and to determining which activities associated with a trial are standard of care and which are caused by conducting the trial.

A materiality assessment (Step I-IV) can help to identify the most important data points in the study so that these can be prioritized, for example by collecting primary rather than secondary data. This would involve an initial crude estimation of the footprint using a mix of secondary data and assumptions, along with indicative or readily-available data that describe the clinical trial (e.g. the number of participants, number of samples, etc). Resources can then be directed at those data points that are likely to be significant, rather than expended on those that will contribute only to a very limited extent to the footprint (i.e. are not material).

Once study goal and scope definition matters are agreed, and the draft activity map created, it may be appropriate to group specific processes/activities (as shown in a process flow diagram) into distinct modules, as this can simplify data collection (i.e. grouping according to data owner) and footprint calculations, as well as results interpretation and reporting. For example, IMP production, IMP packaging and IMP distribution could all be grouped into a single IMP module (as shown in Figure 1).

Data collection should focus mainly on primary data, at least for the foreground system[10], although there may be instances where secondary data will be sufficient to meet the objectives of the study, and some secondary data may be particularly relevant or of high quality. Once data collection is complete, the data should be processed and modelled using a life cycle inventory database, or another source of emission factors, in order to generate carbon footprint results. Where primary data are not available within the constraints of the study, assumptions and additional secondary data are needed to close data gaps.

Study impact results will be interpreted to indicate the overall footprint of the trial, to highlight hotspots and, through sensitivity analysis, to identify the effect of key sources of uncertainty in the study data. The study may be an iterative process, with a first pass of the study (i.e. a materiality assessment) used to indicate parameters where the collection of further data will provide additional clarity and certainty and subsequent updates where more granular empirical data are used to revise the study

Generally, the study should be reported sufficiently thoroughly that it can be shown to meet its stated goal, that it conforms to the Method Document and can be replicated to support further studies, benchmarking and meta-analysis.

This Guidance Document is formulated to support users in footprinting clinical trials, with a focus on the data collection and calculation steps for each activity to be included in a study.

[10] The foreground system consists of the specific trial activities/processes which may be directly or indirectly under the control of the study commissioner

4. DATA COLLECTION AND CALCULATION

This chapter provides specific guidance on how to appraise any and all activities that may be associated with a clinical trial, either through detailed appraisal or through the use of default and proxy values. Default and proxy values are provided to support materiality assessments and for expediency purposes to allow assessments to be completed in the absence of trial-specific data. Where the user chooses to apply these data, they are reminded that they may not characterize closely the specific activities of the trial being footprinted and this potential error should be recognized, ideally addressed through sensitivity analysis and stated in any report produced.

This chapter is structured so as to reflect an intuitive understanding of the activities of which a trial is comprised. As a result, there is a degree of repetition associated with guidance on estimating the footprint of certain contributions common across activities, e.g. travel, utilities consumption etc. The repetition has been retained in order to assist users who refer only to a limited number of chapter sections, and who might otherwise overlook an aggregated section on one or more of these contributions.

4.1. CLINICAL SUPPLY

4.1.1. Investigational medicinal product (IMP)

To appraise the impact contribution made by the investigational medicinal product (IMP) or other intervention[11] to the footprint of a clinical trial, one needs to know the quantity of the IMP that is sourced and used. It is also necessary to account for the carbon footprint of those life cycle stages upstream of the clinical trial itself that are associated with provision of the IMP, i.e. manufacture, packaging, and distribution. The contribution to the trial carbon footprint made by use and disposal at end of life should also be taken into account.

Carbon footprint of the manufacturing and packaging stages of an IMP

Ideally, specific cradle-to-gate life cycle impact data would be available for the IMP using a recognized life cycle method[12]. In some cases, an LCA study reporting these data might have been completed for the IMP or an analogue. In their absence, the user has a number of choices, which include the following:

- Contact the manufacturer for life cycle data or emission factors for the specific product.
- Search for suitable data via a literature review and in life cycle inventory databases.
- If the product is a small molecule blister pack, then its GHG emissions can be estimated using the ABPI tool (https://www.abpi.org.uk/r-d-manufacturing/abpi-blister-pack-carbon-footprint-tool/).
- Develop a streamlined in-house approach to estimating the IMP manufacturing footprint, consistent with the goal of the studies conducted and the accuracy required of the results.
- Undertake a full product assessment[13]

Data requirements
• Total quantity manufactured/ procured • Emission factor for manufacture, i.e. cradle to gate

Undertaking a specific product assessment is recommended only where IMP has been identified as a hotspot through a first iteration of the study and/or the effort entailed is warranted by the intended use of the results of the study.

[11] This current version of the Guidance Document focuses on trials of pharmaceutical products. However, trials of the effect of any intervention on health-related biomedical and behavioural outcomes can be footprinted using the same approach and logic. Mapping out the activities and consumptions associated with any such trial beyond those addressed in the Guidance will be an essential stage in a reliable estimation of its footprint.

[12] ISO14040; ISO14044; and GHG Protocol Product Standard Guidance for Pharmaceuticals and Medical Devices

[13] ISO14040; ISO14044; and GHG Protocol Product Life Cycle Accounting and Reporting Standard

Alternatively, and if applicable, one may use the default values presented below, which have been taken from previous clinical trial assessments and the literature:

- Vial, packed (2mL vial, with 10% pure substance): 5.00 kg CO_2 eq per vial;
- Tablet, packed in blister (150 mg): 0.20 kg CO_2 eq per tablet; and
- Tablet, packed in bottle (150 mg): 0.20 kg CO_2 eq per tablet.

Unused IMP shall be also considered, i.e. account made of the total quantity of IMP produced, which will comprise IMP administered to participants together with overage/unused IMP. Therefore, if there is a minimum batch size for manufacture, and none of the overage has an alternative use, then the impacts of the whole batch should be allocated to the trial studied. In some cases, overage/unused IMP has been shown to make a significant contribution to the footprint of the trial.

Carbon footprint for the distribution of IMP

Ideally, specific data would be available for the distribution of IMP relating the transport of the IMP to trial sites or to the participant's home and the energy consumed in its storage, the manufacture of packaging, devices, shipping containers and associated gel packs for cooling, as well as temperature monitoring equipment (e.g. data loggers). In practice, these data may not be available and distances, transport mode and average loading of the product using secondary data sources will be required to estimate the impact, together with proxy data for associated equipment.

There are many emission factors for different transportation modes available that are applicable in estimating distribution impacts. Consideration should be given to the mode of transport and its utilization (i.e. how effectively it is used), with adjustments made where possible to make these factors relevant to the product studied. Where chilled transportation is used to deliver a product, this should be taken into consideration.

Emission factors for transport impacts are commonly provided in the unit of tonne-kilometres (tkm). A simple calculation is therefore required to estimate the impact of transport (as represented in the box).

Transport footprint modelling		
Distance travelled (km)	x	Gross mass (including transit packaging) (tonnes)

This can then be multiplied by the mode of transport emission factor provided to calculate the impact of transport.

A limitation of published emission factors is that they have an in-built utilization or loading efficiency.

Data requirements
• Quantity shipped • Distances by transport mode • Emission factors for transport mode

The data required to calculate IMP distribution is therefore the gross weight shipped and the distance travelled by each mode of transport employed, together with emission factors for each mode of transport.

In the absence of more accurate data, one may use the following emission factors for transport:

- Dry ice (manufacture + ultimate evaporation): 3.7 kg CO_2 eq/kg dry ice.
- Frozen shipper, 12 L (7.2 kg net wight): 26.5 kg CO_2 eq/unit.
- Ambient shipper, 5.7 L (0.2 kg net weight): 0.345 kg CO_2 eq/unit.
- Transport road (ambient)[14]: 0.12 kg CO_2 eq/tkm
- Transport road (chilled)[14]: 0.14 kg CO_2 eq/tkm
- Transport air[14]: 1.23 kg CO_2 eq/tkm

Notes: ambient road transport is assumed to be all HGV (diesel) with an average laden load. The emission factor includes Well to Tank (WTT) emissions. Chilled road transport is assumed to be all refrigerated HGV with

[14] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

an average laden load, including WTT. Air transport is assumed to be an international flight, the emission factor includes a WTT factor and indirect Radiative Forcing (RF) values associated with water vapour and contrails. All are based on UK Government 2023 GHG conversion factors[14].

Carbon footprint of the disposal stage of an IMP

Account may be made of the environmental burdens of used IMP drug after excretion and unused drug if it is disposed to the wastewater system. However, these contributions to the trial footprint are often excluded from the study system boundaries due to a lack of environmental fate and environmental characterization factors. Nonetheless, the environmental impacts of the mass of unused IMP and packaging managed at end of life shall be accounted for, considering the expected disposition of waste management routes, e.g. the incineration of hazardous clinical waste, and their composition, e.g. cardboard, plastics etc.

The following are emission factors for disposal. These can be multiplied by the mass of IMP and IMP packaging to estimate impact the disposal in the absence of specific data.

Alternatively, users may apply the default values presented below, which have been taken from previous clinical trial assessments.

- Vial (2 mL vial; empty), to hazardous waste incineration: 0.04 kg CO_2 eq.
- Tablet blister packaging (per tablet), to hazardous waste incineration: 0.01 kg CO_2 eq.
- Tablet bottle packaging (per tablet), to hazardous waste incineration: 0.01 kg CO_2 eq.
- IMP kit[15] (packaging), to hazardous waste incineration: 0.20 – 1.50 kg CO_2 eq.
- Mixed[16] waste to incineration: 1.57 kg CO_2 eq/kg.
- Mixed[17] waste to landfill: 0.355 kg CO_2 eq/kg

Note: these emission factors include transport to disposal.

In cases where packaging is recycled or reused, only the transport to the recycler/refurbisher is accounted for (which aligns with the recycled content method in carbon footprinting guidance). Following this method, the impact of the recycling/refurbishment processes and subsequent distribution is not attributed to the study trial, it is attributed to the subsequent user.

4.1.2. Testing / diagnostics kits

Data requirements
• Total quantity manufactured / procured • Emission factor for manufacture

To appraise the contribution of testing or diagnostics kits to the footprint of a clinical trial, one needs to know the number consumed, as well as to account for the carbon footprint of the life cycle stages upstream of the clinical trial itself that are involved in their provision, i.e. the manufacture, packaging and distribution of the testing / diagnostics kits. The contribution to the trial carbon footprint made by use and disposal at end of life should also be taken into account.

Carbon footprint of the manufacture of testing / diagnostics kits

Trial kits and their material composition and mass may vary considerably between trials. Ideally, specific cradle-to-gate life cycle impact data compiled using a recognized life cycle method would be available for the testing and diagnostics kits. In their absence, the user has the choice of employing literature data for each component product and the kit packaging (or similar), or potentially undertaking a bespoke assessment where appropriate. The latter is recommended only where the testing/diagnostics kit has been identified as a

[15] IMP kit primary and secondary packaging (weight range from 0.1 to 0.6 kg)

[16] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.

[17] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away.

hotspot through a first iteration of the study and/or the effort entailed is warranted by the intended use of the study results.

Where the components of a kit, including its packaging, are known, the impact can be estimated using secondary life cycle data and emission factors for the materials and processing/conversion into final product.

Alternatively, as an initial estimate of the footprint of the trial kit, one may use the default values presented in Table 1 on a component basis, which have been taken from a previous clinical trial assessment[18]. The carbon impact of each component may be scaled where its mass is known or can be measured.

Table 1 - Composition, mass and carbon footprint (cradle-to-gate) of testing kit Components

Component	**Mass (kg)**	**Carbon impact (kg CO_2eq) per component**
Cardboard box	0.078	0.084
Paper (labels and instructions)	0.004-0.015	0.0046-0.038
Gel pack	0.009-0.018	0.015-0.03
Pipette (PE)	0.001	0.004
Vacutainer holder (PP)	0.002	0.007
Needle (steel)	0.001	0.005
Specimen bag (PE)	0.006-0.014	0.018-0.041
Tubes (PP)	0.004-0.031	0.014-0.096
Vials (PP)	0.02-0.035	0.068-0.12
PAXgene tube (PET)	0.027	0.11
CTAD tubes (glass)	0.016	0.022
CPT tubes (glass)	0.014	0.020
Collection/safety kit (average plastic)	0.014	0.044
Sea airbags (PET)	0.006	0.024
Jiffy bags (paper)	0.0027	0.0024

Carbon footprint of distributing testing / diagnostics kits

Ideally, specific data would be available for testing/diagnostic kit distribution that relate to their packaging and transportation of the testing/diagnostic kit to trial sites.

In practice, these data may not be available and secondary data sources for distances, transport mode and average loading of the product will be required to estimate the impact.

There are many emission factors for different transportation modes which can be applied in estimating distribution impacts. Consideration should be given to the mode of transport and its utilization, and adjustments made where possible to make these factors relevant to the product studied. Where chilled transportation is used to deliver a product, this should be taken into consideration.

Emission factors for transport impacts are commonly provided in the unit of tonne-kilometres (tkm). A simple calculation is therefore required to estimate the impact of transport. This can then be multiplied by the emission factor to calculate the impact of transport.

Transport footprint modelling		
Distance travelled (km)	x	Gross mass (including transit packaging) (tonnes)

[18] Jessica, Griffiths, et al. Quantifying the carbon footprint of clinical trials: guidance development and pilot study. sl : PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs, 2023.

Data requirements
• Quantity shipped • Distances by transport mode • Emission factors for transport mode

A limitation of published emission factors is that they have an in-built loading efficiency.

The data required to calculate distribution is therefore the weight shipped and the distance travelled by each mode of transport employed, together with emission factors for each mode of transport.

In the absence of more accurate data, one may use the following emission factors for transport:

- Dry ice (manufacture + ultimate evaporation): 3.7 kg CO_2 eq/kg dry ice.
- Frozen shipper, 12 L (7.2 kg net wight): 26.5 kg CO_2 eq/unit.
- Ambient shipper, 5.7 L (0.2 kg net weight): 0.345 kg CO_2 eq/unit.
- Transport road (ambient)[19]: 0.12 kg CO_2 eq/tkm
- Transport road (chilled)[19]: 0.14 kg CO_2 eq/tkm
- Transport air[19]: 1.23 kg CO_2 eq/tkm

Notes: ambient road transport is assumed to be all HGV (diesel) with an average laden load. The emission factor includes Well to Tank (WTT) emissions. Chilled road transport is assumed to be all refrigerated HGV with an average laden load, including WTT. Air transport is assumed to be an international flight, the emission factor includes a WTT factor and indirect Radiative Forcing (RF) values associated with water vapour and contrails. All are based on UK Government 2023 GHG conversion factors[19].

Carbon footprint of disposing testing / diagnostics kits

The environmental impacts of the mass of unused and used testing/diagnostic kit components managed at end of life shall be accounted for, considering the disposition of waste management routes, e.g. the incineration of hazardous clinical waste, and their composition e.g. cardboard, plastics etc.

The quantity of each waste material by waste management route can be multiplied by emission factors to estimate the impact of disposal.

Alternatively, users may use the default value presented below, which has been taken from a previous clinical trial assessment.

Data requirements
• Quantity disposed by disposal route • Emission factors for disposal route

- Mixed[20] waste to incineration: 1.57 kg CO_2 eq/kg
- Mixed[21] waste to landfill: 0.355 kg CO_2 eq/kg

In cases where kits and/or packaging are recycled or reused, only the transport to the recycler/refurbisher is accounted for (i.e. using the recycled content method). The impact of the recycling/refurbishment processes and subsequent distribution is not attributed to the study trial, but it is attributed to the subsequent user.

4.1.3. Investigational medicinal technology / devices

To appraise the contribution of medicinal technology or devices used during a clinical trial to its impact, one needs to know the number consumed, as well as to account for the carbon footprint of the life cycle stages upstream of the clinical trial itself that are involved in their provision, i.e. manufacture, packaging and distribution of the devices. The contribution to the trial carbon footprint made by use and disposal at end of life should also be taken into account.

[19] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

[20] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.

[21] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away.

Carbon footprint of the manufacturing of medicinal technology / device

Ideally, specific cradle-to-gate life cycle impact data would be available from the manufacturer for the medicinal technology or device, using a recognized life cycle method. In their absence, the user has the choice of using literature data for a similar product, or potentially undertaking a bespoke assessment where appropriate. The latter is recommended only where the medicinal technology/device has been identified as a hotspot in an earlier iteration of the study and/or the effort entailed is warranted by the intended use of the study results of the.

A potential source of data and emission factors for medicinal technology/devices is HealthcareLCA, a database of environmental assessments within healthcare (https://healthcarelca.com).

Carbon footprint of distributing medicinal technology / device

Ideally, specific data would be available for the medicinal technology/device distribution that relate to its packaging, transport of the medicinal technology/device to trial sites and energy consumed in its storage.

In practice, these data may not be available and secondary data sources regarding manufacturing impact, transport distances, transport mode and average loading of the product will be required to estimate the impact.

There are many emission factors for different transportation modes that are applicable in estimating distribution impacts. Consideration should be given to the mode of transport and its utilization, and adjustments made where possible to make these factors relevant to the product studied. Where chilled transportation is used to deliver a product, this should be taken into consideration.

Emission factors for transport impacts are commonly provided in the unit of tonne-kilometres (tkm). A simple calculation is therefore required to estimate the impact of transport (as represented in the box). This can then be multiplied by the emission factor to calculate the impact of transport.

Transport footprint modelling		
Distance travelled (km)	x	Gross mass (including transit packaging) (tonnes)

Data requirements
• Quantity shipped • Distances by transport mode • Emission factors for transport mode

A limitation of published emission factors is that they have in-built loading efficiency.

The data required to calculate distribution is therefore the weight shipped and the distance travelled by each mode of transport employed, together with emission factors for each mode of transport.

In the absence of more accurate data, one may use the following emission factors for transport.

- Dry ice (manufacture + ultimate evaporation): 3.7 kg CO_2 eq/kg dry ice.
- Frozen shipper, 12 L (7.2 kg net wight): 26.5 kg CO_2 eq/unit.
- Ambient shipper, 5.7 L (0.2 kg net weight): 0.345 kg CO_2 eq/unit.
- Transport road (ambient)[22]: 0.12 kg CO_2 eq/tkm.
- Transport road (chilled)[22]: 0.14 kg CO_2 eq/tkm.
- Transport air[22]: 1.23 kg CO_2 eq/tkm.

Notes: ambient road transport is assumed to be all HGV (diesel) with an average laden load, including WTT. Chilled road transport is assumed to be all refrigerated HGV with an average laden load, including WTT. Air transport is assumed to be international flight, including a WTT factor and with RF values. All are based on UK Government GHG conversion factors 2023 factors.

[22] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

Carbon footprint of use of medicinal technology / device

The use stage of the trial may be accounted for in another module, e.g. surgical implant procedures (see Section 4.3.5) or the trial site impact (see Section 4.4.1). The user shall make sure that this contribution is addressed and is not double counted.

Specific life cycle impact data for product use may be available from the manufacturer for the medicinal technology or device, using a recognized life cycle method.

Alternatively, where use of the product involves energy consumption, requires consumables, generates wastes or results in direct emissions (e.g. propellant emissions), these can be quantified on a per use basis and multiplied by appropriate emission factors.

Data requirements
• Use phase energy consumption / consumables consumption / waste generation / direct emissions • Emission factors

Carbon footprint of disposal stage for medicinal technology / device

Where materials are disposed of after use, the impact of disposal should be accounted for, considering the disposition across waste management routes, e.g. the incineration of hazardous clinical waste, and their composition, e.g. stainless steel, plastics etc.

The quantity of each waste material by waste management route can be multiplied by emission factors in order to estimate the impact of disposal.

Data requirements
• Quantity disposed by disposal route • Emission factors for disposal route

Alternatively, users may apply the default value presented below, which has been taken from previous clinical trial assessments.

- Mixed waste incineration[23]: 1.57 eq/kg.
- Mixed waste landfill[24]: 0.355 kg CO_2 eq/kg

In cases where medicinal technology/device and packaging are recycled or reused, only the transport to the recycler/refurbisher is accounted for (i.e. the recycled content method). The impact of the recycling/refurbishment processes and subsequent distribution is not attributed to the study trial, but it is attributed to the subsequent user.

4.1.4. Participant (or trial site) electronic devices

To appraise the contribution of electronic devices used during a clinical trial to its impact, one needs to know the number used, as well as to account for the carbon footprint of the life cycle stages upstream of the clinical trial itself that are involved in their provision, e.g. manufacture, packaging and distribution of the devices, together with the contribution of the use and end of life stages.

Carbon footprint of manufacturing a participant electronic device

Ideally, specific cradle-to-gate life cycle impact data would be available from the manufacturer for the electronic/diagnostic devices (e.g. a blood pressure monitor) using a recognized life cycle method. In their absence, the user has the choice of using literature data for a similar product, or potentially undertaking a bespoke assessment where appropriate. The latter is recommended only where the device has been identified as a hotspot in an earlier iteration of the study and/or the effort entailed is warranted by the intended use of the study results.

Alternatively, one may use the default value presented below.

[23] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.

[24] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away

- Device (smartphone (0.187[25] kg)[26]), cradle-to-gate manufacture: 54.78 kg CO_2 eq.
- Device (tablet (0.461[27] kg)[28]), cradle-to-gate manufacture: 63.2 kg CO_2 eq.

Notes: smartphone assumed to be iPhone 15 pro (128GB). Tablet assumed to be a fifth generation iPad air (64GB).

Where a device is leased, a proportion of the manufacturing impact should be allocated to the trial when the proportion of the device' lifetime (i.e. number of uses) accounted for by the specific trial studied is known.

Carbon footprint of distributing electronic device

Ideally, specific data would be available for the device distribution and any reverse logistics required, relating to its packaging, transportation of the device to and from trial sites and participants and any energy consumed in storage.

In practice, these data may not be available and secondary data sources regarding distances, transport mode and average loading of the product will be required to estimate the impact.

There are many emission factors for different transportation modes that are applicable in estimating distribution impacts. Consideration should be given to the mode of transport and utilization, and adjustments made where possible to make these factors relevant to the product studied.

Emission factors for transport impacts are commonly in the unit of tonne-kilometres (tkm). A simple calculation is therefore required to estimate the impact of transport (as represented in the box).

This can then be multiplied by the emission factor to calculate the impact of transport.

Transport footprint modelling		
Distance travelled (km)	x	Gross mass (including transit packaging) (tonnes)

Data requirements
• Quantity shipped • Distances by transport mode • Emission factors for transport mode

A limitation of published emission factors is that they have in-built loading efficiency.

The data required to calculate the distribution impact is therefore the weight shipped and the distance travelled by each mode of transport and emission factors for each mode of transport.

In the absence of more accurate data, one may use the following emission factors for transport:

- Ambient shipper, 5.7 L (0.2 kg net weight): 0.345 kg CO_2 eq/unit.
- Transport road (ambient)[29]: 0.12 kg CO_2 eq/tkm.
- Transport air[29]: 1.23 kg CO_2 eq/tkm.

Notes: ambient road transport is assumed to be all HGV (diesel) with an average laden load, including WTT. Chilled road transport is assumed to be all refrigerated HGV with an average laden load, including WTT. Air transport is assumed to be an international flight, including a WTT factor and with RF values. All are based on UK Government GHG conversion factors 2023 factors.

Carbon footprint of use for participant electronic device

The use stage may be accounted for in another module, for example trial site impact (see Section 4.4.1) if used at trial site. The user should assure themselves that this contribution is addressed and is not double counted.

[25] Weight excludes packaging

[26] Apple. Product Environmental Report: iPhone 15 Pro and iPhone 15 Pro Max. sl : Available at

[27] Weight excludes packaging

[28] Product Environmental Report, iPad Air (5th generation). sl : https://www.apple.com/environment/pdf/products/ipad/iPad_Air_PER_March2022.pdf, 2022.

[29] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

Specific life cycle impact data for product use may be available from the manufacturer for the device, using a recognized life cycle method.

Where devices may consume energy, require consumables, generate waste or result in direct emissions (e.g. propellant emissions), these can be quantified on a per use basis and multiplied by appropriate emission factors. See Section 6.

Data requirements
• Use phase energy consumption / consumables consumption / waste generation / direct emissions • Emission factors

Alternatively, one may use the emissions factors below.

- Tablet use: 0.033 kg CO_2 eq/day UK
- Tablet use: 0.0548 kg CO_2 eq/day US
- Table use: 0.0876 kg CO_2 eq/day Australia
- Smartphone use: 0.058 kg CO_2 eq/day UK
- Smartphone use: 0.096 kgCO_2 eq/day US
- Smartphone use: 0.153 kgCO_2 eq/day Australia

Notes: for a tablet, 0.015 kWh is needed to charge for an 8h period (i.e. 0.12 kWh/day) and an electricity emission factor of 0.275 kg CO_2 eq/kWh is used (based on the UK Government GHG conversion factors 2023 values for UK, including a factor for transmission and distribution losses). For a smartphone, 0.052 kWh is needed to charge for a 4h period (i.e. 0.21 kWh/day) and an electricity emission factor of 0.275 kg CO_2 eq/kWh used (based on the UK Government GHG conversion factors 2023 values for UK, including a factor for transmission and distribution losses). For the US, an emission factor has been sourced from the EPA[30] including transmission and distribution losses. As the EPA does not report WTT factors, the UK government GHG conversion factors 2023 has been used as a proxy for this contribution. For Australia, the electricity grid impact has been sourced from the Australian government[31].

Carbon footprint of disposal stage for participant electronic device

Where the device is disposed locally after use, the impact of disposal should be accounted for, considering the disposition by waste management route, e.g. landfill of WEEE.

In cases where electronic devices and packaging are recycled or reused, only the transport to the recycler/refurbisher is accounted for (i.e. in alignment with the recycled content method). The impact of the recycling/refurbishment processes and subsequent distribution is not attributed to the study trial, but it is attributed to the subsequent user.

Data requirements
• Quantity disposed by disposal route • Emission factors for disposal route

Where a device is leased, a proportion of the manufacturing impact should be allocated to the trial when the proportion of the device' lifetime (i.e. number of uses) accounted for by the specific trial studied is known.

The quantity of electronic material by waste management route can be multiplied by emission factors to estimate the impact of disposal.

Alternatively, users may apply the default values presented below.

- Electrical waste (WEEE) to landfill[32]: 0.00888 kg CO_2 eq/kg.
- Electrical waste (WEEE) transport to recycling[32]: 0.0213 kg CO_2 eq/kg.

[30] https://www.epa.gov/egrid/summary-data (0.457 kg CO_2 eq/kWh)

[31] https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-account-factors-2023.pdf (0.73 kg CO_2 eq/kWh)

[32] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

4.2. PARTICIPANT VISITS AND ACCOMMODATION

4.2.1. Participant visits to trial sites

To appraise the contribution of participants' visits to trial sites to the impact of the trial, one needs to know the total number of visits made, which can be broken down into the number of visits per participant and the number of participants, together with the average distances over which participants need to travel, the average mode of transportation used by the participants and any accommodation provided.

The total number of visits to trial sites can be obtained from clinical trial records and will be specific to each individual trial. An illustrative example would be 1,000 participants, each of which would need to travel 10 times to the trial site. As a result, the total number of visits across the trial as a whole would be 10,000. The number of visits made by participants who were unsuccessful at the screening stage should also be included in the appraisal.

Travel by participants will vary across trials, geographies and participant populations, as reflected in the limited literature on this topic.

- Participants were understood to travel on average 67 miles (i.e. a 216 km round trip) to attend clinical trials in one paper[33]. In the case of trials concerned with rare diseases, participants may travel up to 135 miles to the trial site (i.e. a 434 km round trip).
- The median one-way distance participants travelled for an oncology trial in Ireland was 41.4 km (i.e. an 82.8 km round trip)[34].
- The median distance participants travelled for an oncology trial in the US was 20 miles (i.e. a 64 km round trip)[35].

Emissions associated with participant travel have been shown in some cases to make a significant contribution to the overall footprint of a clinical trial. Consequently, it will be desirable to collect primary data on travel for the participants in a trial, or a sample of them, which may be achieved through provision of a questionnaire. In the absence of primary data, or where the effort required to obtain primary data is not justified by the materiality assessment, secondary sources may be used instead, and these should be tested in sensitivity analysis. For example, in a base case one may consider that a participant's visit to the trial site would be associated with a round-trip distance of approximately 60-80 km[36,37]. The values found in the literature reported above may be used in sensitivity analysis, or where there is good reason to believe these are more representative of travel in the trial studied.

Data regarding mode of transportation may also be obtained through primary data collection and the use of a questionnaire at the trial sites. Where it is not possible or justifiable to collect such data, the alternative approaches are: (i) to use local/country travel survey data by purpose (such as commuting, shopping, visits to healthcare facilities etc) which are sometimes available in country statistics; or (ii) to assume travel by car. The latter approach is likely to be a conservative one, although in some cases the trial may involve participants who require travel by air (for example in the case of rare diseases, mentioned above) or other modes of transport such as ambulance. Where country-specific data are not available, Table 2 presents a summary of reasonable assumptions to use in a first iteration of footprinting a trial.

[33] https://www.outsourcing-pharma.com/Article/2022/11/09/clinical-trial-participants-travel-67-miles-to-study-sites-on-average-analysis-finds

[34] https://link.springer.com/article/10.1007/s11845-021-02915-6

[35] https://academic.oup.com/jnci/article/95/18/1370/2520444

[36] Lim, J, et al. Impact of travel distance on outcomes for clinical trial patients: the Kinghorn Cancer Centre experience. sl : Intern Med J. 2023 Feb;53(2):242-249. doi: 10.1111/imj.15561. Epub 2022 Aug 3. PMID: 34613656, 2023.

[37] Borno, HT, et al. At What Cost to Clinical Trial Enrollment? A Retrospective Study of Patient Travel Burden in Cancer Clinical Trials. sl : Oncologist. 2018 Oct;23(10):1242-1249. doi: 10.1634/theoncologist.2017-0628. Epub 2018 Apr, 2018.

Table 2 - Relevant parameters for calculating the footprint of participant visits to trials

Parameter	Proxy proposed
Total number of visits	*To be defined* (trial-specific)
Distance travelled by participant	Between 60 and 80 km[38,39]
Mode of transport	100% car

The carbon footprint of travel over the estimated distances can be calculated using the values presented above, along with an emission factor for mode of transport. For example, considering 100% travel by car, a 70 km round trip and an emission factor of 0.21 kg CO_2 eq/km[40]; the impact of a single visit by a participant to a trial site would be 14.0 kg CO_2 eq/participant visit.

The values below relate to travel by a selection of different travel modes:

Passenger car, petrol[41]: 0.21 kg CO_2 eq/km

Aeroplane travel (long haul)[41]: 0.29 kg CO_2 eq/passenger.km

Aeroplane travel (domestic)[41]: 0.31 kg CO_2 eq/passenger.km

Bus travel (average local bus)[41]: 0.13 kg CO_2 eq/passenger.km

Coach travel[41]: 0.03 kg CO_2 eq/passenger.km

Light rail/tram travel[41]: 0.04 kg CO_2 eq/passenger.km

National rail travel[41]: 0.04 kg CO_2 eq/passenger.km

Taxi travel[41]: 0.26 kg CO_2 eq/km

Carbon footprint of participant accommodation

Ideally, and if data regarding participant accommodation (e.g. hotel, stay in hospital etc) have been provided an assessment of the impact of energy use, food & drink, waste and consumables would be included in the study. In their absence, the user has the choice of employing literature data for a similar activity, or potentially undertaking a bespoke assessment where appropriate. The latter is recommended only where the participant accommodation has been identified as a hotspot in an earlier iteration of the study and/or the effort entailed is warranted by the intended use of the study results.

Alternatively, one may use the default values presented below, which are taken from secondary sources.

- Hotel stay (UK)[42]: 10.4 kg CO_2 eq/room per night.
- Hotel stay (US)[42]: 16.1 kg CO_2 eq/room per night.
- Hotel stay (Japan)[42]: 39.0 kg CO_2 eq/room per night.
- Hotel stay (UAE)[42]: 63.8 kg CO_2 eq/room per night.
- Low-intensity inpatient[43]: 37.9 kg CO_2 eq/bed day.
- High-intensity inpatient[43]: 89.5 kg CO_2 eq/bed day.

[38] Lim, J, et al. Impact of travel distance on outcomes for clinical trial patients: the Kinghorn Cancer Centre experience. sl : Intern Med J. 2023 Feb;53(2):242-249. doi: 10.1111/imj.15561. Epub 2022 Aug 3. PMID: 34613656, 2023.

[39] Borno, HT, et al. At What Cost to Clinical Trial Enrollment? A Retrospective Study of Patient Travel Burden in Cancer Clinical Trials. sl : Oncologist. 2018 Oct;23(10):1242-1249. doi: 10.1634/theoncologist.2017-0628. Epub 2018 Apr, 2018.

[40] Based on the carbon footprint of average petrol car included in emission factors published by UK Government 2023: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023

[41] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

[42] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

[43] SHC. Sustainable Care Pathways Guidance. sl : Sustainable Healthcare Coalition (shcoalition.org).

4.2.2. Participant remote visits

To appraise the contribution of participants' remote (e.g. virtual monitoring) visits to the trial footprint, one needs to know the total number of remote visits, which can be broken down into the number of visits per participant and the number of participants in the trial, together with the length of time for which each remote visit lasts.

Based on the length of time of each remote visit or time spent by the participant using monitoring equipment, one may calculate the electricity consumed, e.g. by a laptop, smart phone or tablet, to conduct the remote visit. Additional utilities, such as lighting and or heating, may be excluded from the assessment, on the basis that the participant would be at home and these utilities consumed regardless of the remote visit, or that the additional energy use would be negligible.

In the absence of specific data, one may use the values below.

- Remote visit time (assumption): 60 minutes/visit.
- Laptop electricity use (estimated): 0.050 kW.
- Laptop use (estimated)[44]: 0.014 kg CO_2 eq/hour

The contribution of the remote visit made by the trial staff to the impact of the trial may also be included, if this has not been accounted for as part of the trial site impacts (see Section 4.4.3), or if trial staff are working from home. A reasonable approximation would be to use the same parameters and values, i.e. the carbon footprint contribution made by the participant and the staff taking part in a remote visit would be the same. Care should be taken to ensure that the staff contribution is not double counted.

4.2.3. Home visits

To appraise the contribution of trial staff visits at the participants' homes, for activities such as monitoring, IMP administration and sample taking, to the footprint of the trial , one needs to know and account for the total number of home visits (which can be broken down to number of visits per participant and the number of participants), the number of staff attending, how far they travel and by what transport mode, the consumables used (e.g. PPE), equipment used and waste generated.

Any other differences between a site visit (by the participant) and a home visit (by the staff to the participants' homes) need to be included, e.g. additional storage and transport for samples, or additional use of devices at participants' homes.

In the absence of better data and assessment of each of the above, one may use the values below in the first instance.

- Road travel (car)[45]: 0.21 kg CO_2 eq per km.
- Sample courier (by motorbike)[45]: 0.14 kg CO_2 eq per km.
- Gloves, sterile pair (total weight with packaging 39.2 g) (cradle-to-gate manufacture)[46]: 102 g CO_2 eq/unit.
- Face mask (weight 4.36 g), (cradle-to-gate manufacture)[46]: 15 g CO_2 eq/unit.

Notes: road travel by car is assumed to be an average petrol car, including WTT. By courier, it is assumed to be an average motorbike, including WTT. All are sourced from UK Government GHG conversion factors 2023.

The end-of-life management of consumables should be taken into account. One may use the default values presented below in combination with the weights above, based on secondary sources.

[44] Considering 0.275 kg CO_2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)

[45] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

[46] Rizan, C, et al. The carbon footprint of products used in five common surgical operations: identifying contributing products and processes. sl : Journal of the Royal Society of Medicine. 2023;116(6):199-213. doi:10.1177/014107682311661, 2023.

- Mixed waste incineration[47]: 1.57 kg CO_2 eq/kg.
- Mixed waste landfill[48]: 0.355 kg CO_2 eq/kg

Example calculation
Assuming a 50 km round trip by car, two sample collections by courier (100 km total) and two sets of gloves and face masks =
50x0.21 + 100x0.14 + (2x102 + 2x15 + ((2x39.2 + 2x4.36) x1.57))/1000 = 24.5 + 0.371
= 24.87 kg CO_2 eq

4.3. TRIAL PROCEDURES (ON-SITE AND REMOTE)

4.3.1. IMP administration

To appraise the contribution of IMP administration to the impact of clinical trials, one needs to know if any materials (i.e. locally sourced consumables) are used in addition to testing and IMP kits, together with the quantities consumed. The latter can be based on average quantities consumed per participant, with these values multiplied by the number of participants in the trial. Examples of such administration consumables would be syringes and needles, in the case of a vaccine administration; and gloves and face masks.

Ideally, specific cradle-to-gate life cycle impact data would be available for such consumables, using a recognized life cycle method. In their absence, the user has the choice of employing literature data for similar products or potentially undertaking a bespoke assessment(s) where appropriate. The latter is recommended only where administration has been identified as a hotspot in an earlier iteration of the study and/or the effort entailed is warranted by the intended use of the study results. Alternatively, one may use the default values presented below, which are taken from secondary sources and other clinical trial studies.

- Syringe, 20 mL (total weight with packaging 16.6 g) (cradle-to-gate manufacture)[49]: 82 g CO_2 eq/unit.
- Needle, green (total weight with packaging 1 g), stainless steel (cradle-to-gate manufacture)[49]: 3.0 g CO_2 eq/unit.
- Gloves, sterile pair (total weight with packaging 39.2 g) (cradle-to-gate manufacture)[49]: 102 g CO_2 eq/unit.
- Face mask (weight 4.36 g), (cradle-to-gate manufacture)[49]: 15 g CO_2 eq/unit.

It is expected that utilities associated with the test intervention/administration process will have been included in general utilities for the test site. However, if this is not the case, they should be accounted for separately.

The end-of-life management of administration consumables should be taken into account. One may use the default values presented below in combination with the weights above, based on secondary sources.

- Mixed waste incineration[50]: 1.57 kg CO_2 eq/kg.
- Mixed waste landfill[51]: 0.355 kg CO_2 eq/kg

[47] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.
[48] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away.
[49] Rizan, C, et al. The carbon footprint of products used in five common surgical operations: identifying contributing products and processes. sl : Journal of the Royal Society of Medicine. 2023;116(6):199-213. doi:10.1177/014107682311661, 2023.
[50] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.
[51] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away.

4.3.2. Sample collection & processing

To appraise the contribution of sample collection and processing to the impact of clinical trials, one needs to understand the total number of samples taken in the trial, the type of sample (e.g. blood, urine, etc) and the number of shipments for analysis, together with whether the shipment is made under ambient or cooled/frozen conditions and the mode(s) of transport used in shipping to external laboratories over a specified distance. Consumables associated with sample collection that are in addition to test kits, such as syringes and PPE, should also be quantified.

Typical data requirements
• Quantity shipped ambient or frozen • No. of samples per ambient shipment • No. of samples per frozen shipment • Weight of ambient shipment • Weight of frozen shipment • Type and quantity of cooling agent • Distance by transport mode • Emission factors for transport mode, packaging manufacture, cooling agent, e.g. dry ice

Ideally, specific cradle-to-gate life cycle impact data would be available for such collection and processing of samples, using a recognized life cycle method. In their absence, the user has the choice of employing literature data for similar products or potentially undertaking a bespoke assessment(s) where appropriate. The latter is not advised unless sample collection and processing is identified as a hotspot in an earlier iteration of the study and/or the effort entailed is warranted by the intended use of the study results. Alternatively, one may use the default values presented below, which are taken from secondary sources and other clinical trial studies.

- Syringe, 20 mL (total weight with packaging 16.6 g) (cradle-to-gate manufacture)[52]: 82 g CO_2 eq/unit.
- Needle, green (total weight with packaging 1 g), stainless steel (cradle-to-gate manufacture)[52]: 3.0 g CO_2 eq/unit.
- Gloves, sterile pair (total weight with packaging 39.2 g) (cradle-to-gate manufacture)[52]: 102 g CO_2 eq/unit.
- Face mask (weight 4.36 g), (cradle-to-gate manufacture)[52]: 15 g CO_2 eq/unit.

The end-of-life management of consumables should be taken into account. One may use the default values presented below in combination with the weights above, based on secondary sources:

- Mixed waste incineration[53]: 1.57 kg CO_2 eq/kg.

Mixed waste landfill[54]: 0.355 kg CO_2 eq/kg.

Carbon footprint of distributing samples

Ideally, specific data would be available for the efficiency and method of distribution of samples and any reverse logistics relating to packaging, energy associated with storage and transportation of the samples from trial sites and participants. The number of samples per shipment, the gross weight of a shipment and the total number of shipments are likely to be drivers of impact.

In practice, these data may not be available and distances, transport mode and average weights and will be required to estimate the impact.

There are many emission factors for different transportation modes available that are applicable in estimating distribution impacts. Consideration should be given to the mode of transport and utilization, and adjustments made where possible to make these factors relevant to the product studied.

[52] Rizan, C, et al. The carbon footprint of products used in five common surgical operations: identifying contributing products and processes. sl : Journal of the Royal Society of Medicine. 2023;116(6):199-213. doi:10.1177/014107682311661, 2023.

[53] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.

[54] Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away.

Emission factors for transport impacts are commonly in the unit tonne-kilometres (tkm). A simple calculation is therefore required to estimate the impact of transport (as represented in the box).

This can then be multiplied by the emission factor to calculate the impact of transport.

A limitation of published emission factors is that they have an in-built loading efficiency.

Transport footprint modelling		
Distance travelled (km)	x	Gross mass (including transit packaging) (tonnes)
=		
Transport data (tkm)		

The data required to calculate the distribution impact is therefore the weight shipped and the distance travelled by each mode of transport and emission factors for each mode of transport and the packaging materials.

In the absence of more accurate data, one may use the following emission factors for transport.

- Dry ice (manufacture + ultimate evaporation): 3.7 kg CO_2 eq/kg dry ice.
- Frozen sample shipper, 12 L (7.2 kg net wight): 26.5 kg CO_2 eq/unit.
- Ambient sample shipper, 5.7 L (0.2 kg net weight): 0.345 kg CO_2 eq/unit.
- Transport road (ambient)[55]: 0.12 kg CO_2 eq/tkm.
- Transport road (chilled)[55]: 0.14 kg CO_2 eq/tkm.
- Transport air[55]: 1.23 kg CO_2 eq/tkm.

Notes: ambient road transport is assumed to be all HGV (diesel) with an average laden load, including WTT. Chilled road transport is assumed to be all refrigerated HGV with an average laden load, including WTT. Air transport is assumed to be an international flight, including a WTT factor and with RF values. All are based on UK Government GHG conversion factors 2023.

4.3.3. Laboratory samples analysis and storage

To appraise the contribution of laboratory samples analysis and storage to the impact of clinical trials, one needs to understand the total number of samples analysed, the consumables, energy used and the waste generated during analysis, plus the duration of storage and any associated energy consumptions, and the impact of each. See above for transport between laboratories and storage facilities. The waste management route for the sample at end of life should also be known.

Ideally, specific cradle-to-gate life cycle impact data would be available for such laboratory samples analysis, storage and disposal, using a recognized life cycle method. In their absence, the user has a choice of using literature data for a similar process(es) or potentially undertaking a bespoke assessment where appropriate. The latter is recommended only where laboratory samples analysis and handling has been identified as a hotspot in an earlier iteration of the study and/or the effort entailed is warranted by the intended use of the results of the study. Alternatively, one may use the default values presented below, which are taken from secondary sources and other clinical trial studies.

- Sample storage[56]: 0.00162 kWh/sample/day.
- Sample storage[57]: 0.446 g CO_2 eq /sample/day
- Full blood examination: 0.0459 kg CO_2 eq/test.
- Coagulation profile: 0.00256 kg CO_2 eq/test.
- Urea and electrolytes: 0.0153 kg CO_2 eq/test.

[55] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

[56] https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/ulf_freezer_user_guide.pdf

[57] Considering 0.275 kg CO_2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)

- C-reactive protein: 0.00997 kg CO_2 eq/test.
- Arterial blood gases: 0.0111 kg CO_2 eq/test.
- Sample disposal: 0.025 kg CO_2 eq/10mL sample.

Notes: sample storage power consumption is for a 17.3 cubic foot ULT fridge set to -80°C assumed to be 5 years old, samples being stored are assumed to be 0.01 L volume. The sample analysis emission factors were estimated from the literature[58] by excluding sample taking and applying US electricity factors.

4.3.4. Imaging (MRI, CT, X-rays etc)

To appraise the contribution of imaging to the impact of clinical trials, one needs to understand the total number of imaging procedures, such as the number of MRIs, CT scans etc. Values for either the average number per participant or the total number for the trial can be used.

Ideally, specific cradle-to-gate life cycle impact data would be available for such imaging procedures, using a recognized life cycle method. In their absence, the user has a choice of employing literature data for a similar process or potentially undertaking a bespoke assessment where appropriate. The latter is recommended only where imaging procedures have been identified as a hotspot in an earlier iteration of the study and/or the effort entailed is warranted by the intended use of the study results.

In the absence of higher quality data, one may use the default values presented below, which are based on secondary sources and other clinical trial studies.

- MRI scan[59]: 17.5 kg CO_2 eq/MRI.
- CT scan[59]: 9.2 kg CO_2 eq/CT scan.
- X-ray[59]: 0.90 kg CO_2 eq/X-ray.
- Ultrasound[59]: 0.5 kg CO_2 eq/ultrasound.

Notes: Imaging impacts included scanner electricity use and all consumables and associated waste, including bedding, imaging contrast, and gloves.

4.3.5. Surgical procedure(s)

To appraise the contribution of surgical procedure(s) to the impact of clinical trials, one needs to understand the total number of procedures undertaken, using either an average number per participant or the total number of undertaken for the trial as a whole, together with the type of surgical procedure(s) involved.

Ideally, specific cradle-to-gate life cycle impact data would be available for such a procedure(s), using a recognized life cycle method. In their absence, the user has a choice of employing literature data for a similar procedure or potentially undertaking a bespoke assessment if appropriate. The latter is not recommended unless surgical procedures are identified as a hotspot in an earlier iteration of the study and/or the effort entailed is warranted by the intended use of the study results.

A potential source of data and emission factors for surgical procedures is HealthcareLCA, a database of environmental assessments within healthcare (https://healthcarelca.com).

In the absence of better quality data, one may use the default value presented below, where procedure duration is known, which is based on secondary sources.

- Surgical procedure[60]: 54.4 kg CO_2 eq/hour.

[58] McAlister, S, et al. The carbon footprint of pathology testing. sl : Med J Aust 2020; 212 (8): 377-382. || doi: 10.5694/mja2.50583, 2020.

[59] McAlister, S, et al. The carbon footprint of hospital diagnostic imaging in Australia. sl : Lancet Reg Health West Pac. 2022 May 3;24:100459. doi: 10.1016/j.lanwpc.2022.100459. PMID: 35538935; PMCI, 2022.

[60] SHC. Sustainable Care Pathways Guidance. sl : Sustainable Healthcare Coalition (shcoalition.org).

Notes: surgical procedure impact includes consumables, equipment, medical gases, staff travel, energy, water, and waste.

4.3.6. Therapeutic procedure(s)

To appraise the contribution of therapeutic procedure(s) to the impacts of clinical trials, one needs to understand the total number of procedures undertaken, using either the average number of procedures per participant or the total number of procedures undertaken for the trial as a whole, as well as the type of therapeutic procedure(s) involved.

Ideally, specific cradle-to-gate life cycle impact data would be available for such a procedure(s), using a recognized life cycle method. In their absence, the user has a choice of employing literature data for a similar process or potentially undertaking a bespoke assessment if appropriate. The latter is not recommended unless therapeutic procedure(s) is identified as a hotspot in an earlier iteration of the study and/or the effort entailed is warranted by the intended use of the study results.

A potential source of data and emission factors for therapeutic procedures is HealthcareLCA, a database of environmental assessments within healthcare (https://healthcarelca.com).

4.3.7. Data management including storage

To appraise the contribution of all data management demands, including storage, to the impact of clinical trials, one needs to understand the contribution of staff time, total number and size of files created (electronic and physical), using a value either per participant or for the trial as a whole, the number of scans copied to CDs, and any associated distribution and storage of the documentation.

Ideally, specific cradle-to-gate life cycle impact data would be available for data management and its storage and distribution, using a recognized life cycle method. In their absence, the user has a choice of employing literature data for an analogous similar process or potentially undertaking a bespoke assessment if appropriate. The latter is not recommended unless data management and storage is identified as a hotspot in an earlier iteration of the study and/or the effort entailed is warranted by the intended use of the study results. Alternatively, one may use the default values presented below, which are based on secondary sources and other clinical trial studies:

- Hospital files[61]: 0.0057 kg CO_2 eq/page.
- Scans[61]: 0.015 kg CO_2 eq/scan burned to CD.
- CD/DVDs[61]: 0.83 kg CO_2 eq/CD manufactured.
- Data storage, electronic[62]: 0.0046 kWh/GB
- Electronic data transfer[63]: 0.06 kWh/GB
- Electricity[64]: 1,032 kWh per employee per year (FTE).
- Heat[64]: 1,476 kWh per employee per year (FTE).
- Employee commuting: 11 kg CO_2 eq/day.

[61] Jessica, Griffiths, et al. Quantifying the carbon footprint of clinical trials: guidance development and pilot study. sl : PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs, 2023.

[62] Dlzar Al Kez, Aoife M. Foley, David Laverty, Dylan Furszyfer Del Rio, Benjamin Sovacool. Exploring the sustainability challenges facing digitalization and internet data centers. sl : Journal of Cleaner Production, 2022. https://doi.org/10.1016/j.jclepro.2022.133633.

[63] Aslan, J., Mayers, K., Koomey, J.G. and France, C. Electricity Intensity of Internet Data Transmission: Untangling the Estimates. sl : Journal of Industrial Ecology, 22: 785-798., 2018. https://doi.org/10.1111/jiec.12630.

[64] Department of Health, Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare Environment and sustainability Part A: Policy and management. sl : Department of Health, 2015.

Notes: employee commuting is assumed to be a 50 km round trip by car. Utilities data are taken from UK Department for Health (Table 10, page 57)[64]. For a general office, this is 86 kWh/m^2 and 123 kWh/m^2 for electricity and heating respectively. Assuming 12m^2 [65] of floor area per FTE.

4.3.8. Trial documentation

To appraise the contribution of trial documentation to the impact of clinical trials, one needs to understand the total number of documents provided, either per participant or as a total for the trial as a whole, the number of pages of paper per trial document and the means by which documentation is distributed (i.e. in hard copy or electronically).

Ideally, specific cradle-to-gate life cycle impact data would be available for trial documentation and its distribution, using a recognized life cycle method. In their absence, the user has a choice of employing literature data for a similar product/process or potentially of undertaking a bespoke assessment if appropriate. The latter is not recommended unless trial documentation is identified as a hotspot in an earlier iteration of the study and/or the effort entailed is warranted by the intended use of the study results.

Alternatively, one may use the default value presented below, which is based on secondary sources and other clinical trial studies.

- Documentation[66]: 0.0057 kg CO_2 eq/page.

Carbon footprint of distributing trial documentation

Ideally, specific data would be available for trial documentation distribution and any reverse logistics from trial sites and participants.

In practice, these data may not be available and distances, transport mode and average weights and will be required to estimate the impact.

Data requirements
• Weight of documentation shipment
• Transport distance by mode

There are many emission factors for different transportation modes available that are applicable in estimating distribution impacts. Consideration should be given to the mode of transport and utilization, and adjustments made where possible to make these factors relevant to the product studied.

Transport footprint modelling		
Distance travelled (km) x	x	Gross mass (including transit packaging) (tonnes)
=		
Transport data (tkm)		

Emission factors for transport impacts are commonly in the unit tonne-kilometres (tkm). A simple calculation is therefore required to estimate the impact of transport (as represented in the box).

This can then be multiplied by the emission factor to calculate the impact of transport.

A limitation of published emission factors is that they have an in-built loading efficiency.

The data required to calculate the distribution impact is therefore the weight shipped and the distance travelled by each mode of transport, together with emission factors for each mode of transport and the packaging materials employed.

In the absence of more accurate data, one may use the following emission factors for transport.

- Transport road (ambient)[67]: 0.12 kg CO_2 eq/tkm.
- Transport air[67]: 1.23 kg CO_2 eq/tkm.
- Electronic data transfer[68]: 0.06 kWh/GB

[65] UK. UK EMPLOYMENT DENSITY GUIDE, 3rd edition November 2015. 2015.

[66] Jessica, Griffiths, et al. Quantifying the carbon footprint of clinical trials: guidance development and pilot study. sl : PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs, 2023.

[67] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

[68] Aslan, J., Mayers, K., Koomey, J.G. and France, C. Electricity Intensity of Internet Data Transmission: Untangling the Estimates. sl : Journal of Industrial Ecology, 22: 785-798., 2018. https://doi.org/10.1111/jiec.12630.

- Electronic data transfer[69] (UK): 0.0165 kg CO_2 eq/GB
- Electronic data transfer (US): 0.0274 kg CO_2 eq/GB
- Electronic data transfer (Australia): 0.0438 kg CO_2 eq/GB

Notes: ambient road transport is assumed to be all HGV (diesel) with an average laden load, including WTT. Air transport is assumed to be an international flight, including a WTT factor and with RF values. All are based on UK Government GHG conversion factors 2023. For the US, an emission factor has been sourced from the EPA[70] including transmission and distribution losses. As the EPA does not report on WTT factors, the UK government GHG conversion factors 2023 has been used as a proxy for this contribution. For Australia, the electric grid impact has been sourced from the Australian government[71].

4.4. TRIAL SITE(S)

4.4.1. Trial site(s) impact (Utilities)

To appraise the contribution of trial site(s) utilities (overhead) to the impact of trial sites and the trial as a whole, there are a number of possible approaches: site-specific data for energy, waste and water (ideally per FTE); representative site data for energy, waste and water per FTE; or using estimates based on the literature.

If specific site data are unavailable, one needs to understand the number of sites and their location, or at least the country in which the trial is located, number of staff and staff time associated with the trial.

Where site data are available, but not on a per FTE basis, one needs to know the total utilities use of the trial site(s) for the period of the clinical trial (e.g. 3 years) and based on relevant assumptions, one allocates total utilities consumption to the specific clinical trial being studied. Allocation might be based on the number of trials ongoing over that period, i.e. if there were 100 clinical trials ongoing during that period, only 1% of the utilities would be allocated to the clinical trial for which one is calculating a footprint. Other allocation approaches might be more accurate, e.g. using trial site staff timesheets and the proportion of total site effort/FTE spent on the trial of concern to apportion utilities.

When using literature on typical resource use by staff, one needs to know the number of staff working on the trial and the amount of time spent on it in each case. Based on the number of FTEs employed on the trial, one would estimate utilities consumption using secondary data for an analogous site, e.g. a health care centre, using its FTE numbers or the area served as the measure of equivalence.

In the absence of better quality site data, one may use the default values presented below, which are based on secondary sources and other clinical trial studies using a bottom-up approach.

- Electricity[72]: 1,238 kWh per employee per year.
- Electricity[72]: 0.664 kWh per employee per hour.
- Electricity[73] (UK): 340.5 kg CO_2 eq per employee per year.
- Electricity (US): 565.8 kg CO_2 eq per employee per year.
- Electricity (Australia): 903.7 kg CO_2 eq per employee per year.
- Heat[72]: 2,591 kWh per employee per year.
- Heat: 1.390 kWh per employee per hour.

[69] Considering 0.275 kg CO_2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)

[70] https://www.epa.gov/egrid/summary-data (0.457 kg CO_2 eq/kWh)

[71] https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-account-factors-2023.pdf (0.73 kg CO_2 eq/kWh)

[72] Department of Health, Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare Environment and sustainability Part A: Policy and management. sl : Department of Health, 2015.

[73] Considering 0.275 kg CO_2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)

- Heat[74] (UK): 603.7 kg CO_2 eq per employee per year

Notes: data taken from the UK Department for Health (Table 10, page 57)[75]. For a clinic or health centre, this is 75 kWh/m^2 and 157 kWh/m^2 for electricity and heating respectively, with a floor area of 1,317 m^2. Assumed 16.5m^2 [76] of floor area per FTE. An FTE is assumed to work 1864 hours per year, based on an 8 hour working day and 233 working days per year. For the US, an emission factor has been sourced from the EPA[77] including transmission and distribution losses. As the EPA does not report on WTT factors, the UK government GHG conversion factors 2023 has been used as a proxy for this contribution. For Australia, the electric grid impact has been sourced from the Australian government[78].

Example calculation
5 FTEs at a UK trial site
Trial site utilities = ((1,238 x 0.275) + (2,591 x 0.233)) x 5
= 4,721 kg CO_2 eq (based on UK Government GHG conversion factors 2023 values for electricity and heat)

4.4.2. Trial site staff commuting

Ideally, primary data will be available regarding the mode of transport used by staff commuting, together with commuting distances. If these data are not available, and primary data collection is not practicable, one may use country-specific or region-specific statistics on average transport modes, commuting distances and emission factors. Those data can be then linked to the number of staff/FTE working on the trial[79].

The values below relate to travel by a selection of different travel modes:

Passenger car, petrol[80]: 0.21 kg CO_2 eq/km

Aeroplane travel (long haul)[80]: 0.29 kg CO_2 eq/passenger.km

Aeroplane travel (domestic)[80]: 0.31 kg CO_2 eq/passenger.km

Bus travel (average local bus)[80]: 0.13 kg CO_2 eq/passenger.km

Coach travel[80]: 0.03 kg CO_2 eq/passenger.km

Light rail/tram travel[80]: 0.04 kg CO_2 eq/passenger.km

National rail travel[80]: 0.04 kg CO_2 eq/passenger.km

Taxi travel[81]: 0.26 kg CO_2 eq/km

In the absence of better quality data, one may use the default value presented below, which is based on secondary sources and other clinical trial studies.

- Employee commuting: 11 kg CO_2 eq/day.

Notes: employee commuting is assumed to be a 50 km round trip by car.

[74] Considering 0.233 kg CO_2 eq/kWh natural gas (net CV) (based on UK Government GHG conversion factors 2023)

[75] Department of Health, Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare Environment and sustainability Part A: Policy and management. sl : Department of Health, 2015.

[76] NHS. NHS estates, HBN 12 Out-patients department.

[77] https://www.epa.gov/egrid/summary-data (0.457 kg CO_2 eq/kWh)

[78] https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-account-factors-2023.pdf (0.73 kg CO_2 eq/kWh)

[79] For example, if a member of staff spends 10% of their time working on the trial studied, this means that their daily commute should be allocated accordingly.

[80] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

[81] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

4.4.3. Trial site visits and Trial meetings

To appraise the contribution of trial site visits (e.g. monitor visits) and trial meetings one needs to account for impact of attendee travel, meeting venue utilities, consumables use and waste (if not accounted for in trial site and trial management), and accommodation impacts resulting from utilities, waste and consumables.

In practice, such a detailed assessment, or the data to support such an assessment, is unlikely to be available or warranted. The likely approach to be taken is to use primary data or estimates relating to travel distance by mode per attendee, number of hotel nights, location and duration of meetings. This combined with secondary data and emission factors from the literature can be used to estimate the impact of site visits and meetings.

Care should be taken to avoid double-counting, as trial site utilities, trial sponsor staff commuting and facilities would already have been accounted for by the module described in Section 4.5.1.

In the absence of better quality data, one may use the default values presented below, which are based on secondary sources and other clinical trial studies.

- Electricity[82]: 0.143 kWh per attendee hour external meeting.
- Electricity[83] (UK): 0.0393 kg CO_2 eq per attendee hour external meeting.
- Electricity (US): 0.0654 kg CO_2 eq per attendee hour external meeting.
- Electricity (Australia): 0.104 kg CO_2 eq per attendee hour external meeting.
- Heat: 0.204 kWh per attendee hour external meeting.
- Heat[84]: 0.048 kg CO_2 eq per attendee hour external meeting.

- Long haul flight[81]: 0.29 kg CO_2 eq per passenger.km.
- Domestic flight[81]: 0.31 kg CO_2 eq per passenger.km.
- Passenger car[81]: 0.21 kg CO_2 eq per km.
- Taxi (regular)[81]: 0.26 kg CO_2 eq per km.

- Hotel stay (UK)[85]: 10.4 kg CO_2 eq/room per night.
- Hotel stay (US)[85]: 16.1 kgCO_2 eq/room per night.
- Hotel stay (Japan)[85]: 39.0 kgCO_2 eq/room per night.
- Hotel stay (UAE)[85]: 63.8 kgCO_2 eq/room per night.

- Meeting lunches or hotel dinners (vegetarian)[86]: 2.6 kgCO_2 eq per meal per person.
- Meeting lunches or hotel dinners (meat)[86]: 5.92 kgCO_2 eq per meal per person.

Notes: data taken from UK Department for Health, table 10, page 57. For a general office, this is 86 kWh/m^2 and 123 kWh/m^2 for electricity and heating respectively. Assumed 3.1 m^2 of floor area per attendee for a meeting. For long haul flights, an average passenger is assumed, including WTT and RF values. For short haul flights, an average passenger is assumed, including WTT and RF values. For a passenger car, an average petrol

[82] Department of Health, Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare Environment and sustainability Part A: Policy and management. sl : Department of Health, 2015.

[83] Considering 0.275 kg CO_2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)

[84] Considering 0.233 kg CO_2 eq/kWh natural gas (net CV) (based on UK Government GHG conversion factors 2023)

[85] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

[86] WWF. Food in a warming world report. sl : WWF, 2018.

car is assumed, including a WTT factor. Travel and hotel stays are based on UK Government GHG conversion factors 2023.

4.5. SPONSOR TRIAL MANAGEMENT & TRIAL DESIGN

4.5.1. Sponsor trial management utilities

To appraise the contribution of sponsor site(s) utilities (i.e. overhead) to the impact of the trial as a whole, where this is separate from the trial site's contribution, there are a number of possible approaches: sponsor site-specific data for energy, waste and water (ideally per FTE); representative site data for energy, waste and water per FTE; or using estimates based on the literature. In the case of public sector trials, the sponsor role and activities may often be undertaken by the Clinical Trials Unit concerned.

If site-specific data are unavailable, one needs to understand the number of sponsor sites associated with the trial and their location, or at least the country in which the sponsor site is located, number of staff and staff time associated with the trial.

Where sponsor site data are available, but not on a per FTE basis, one needs to know the total utilities use of the sponsor site(s) for the period of the clinical trial (e.g. 3 years) and based on relevant assumptions to facilitate allocation of total utilities consumption to the specific clinical trial being studied. Allocation might be based on the number of trials ongoing over that period, i.e. if there were 100 clinical trials ongoing during that period, only 1% of the utilities would be allocated to the clinical trial for which one is calculating a footprint. Other allocation approaches might be more accurate, e.g. using sponsor staff timesheets and the proportion of total sponsor site effort/FTE spent on the trial of concern to apportion utilities.

When using literature on typical resource use by staff, one needs to know the number of staff working on the trial and the amount of time spent on it in each case. Based on the number of FTEs employed on the trial, one would estimate utilities consumption using secondary data for an analogous site, e.g. an office, using its FTE numbers or the area served as the measure of equivalence.

These data, combined with emission factors, can be used to estimate the trial site impact for the clinical trial.

In the absence of better quality data, one may use the default values presented below, which are based on secondary sources and other clinical trial studies using a bottom-up approach.

- Electricity[87]: 1,032 kWh per employee per year.
- Electricity[87]: 0.554 kWh per employee per hour.
- Electricity[88] (UK): 283.8 kg CO_2 eq per employee per year.
- Electricity (US): 471.6 kg CO_2 eq per employee per year.
- Electricity (Australia): 753.4 kg CO_2 eq per employee per year.
- Heat[87]: 1,476 kWh per employee per year.
- Heat[89]: 343.9 kg CO_2 eq per employee per year.

Notes: utilities data taken from the UK Department for Health, Table 10, page 57. For a general office, this is 86 kWh/m^2 and 123 kWh/m^2 for electricity and heating respectively. Assumed 12m^2 [90] of floor area per FTE. An FTE is assumed to work 1864 hours per year, based on an 8 hour working day and 233 working days per year. For the US, an emission factor has been sourced from the EPA[91] including transmission and distribution losses. As the EPA does not report on WSTT factors, the UK government GHG conversion factors 2023 has

[87] Department of Health, Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare Environment and sustainability Part A: Policy and management. sl : Department of Health, 2015.

[88] Considering 0.275 kg CO_2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)

[89] Considering 0.233 kg CO_2 eq/kWh natural gas (net CV) (based on UK Government GHG conversion factors 2023)

[90] UK. UK EMPLOYMENT DENSITY GUIDE, 3rd edition November 2015. 2015.

[91] https://www.epa.gov/egrid/summary-data (0.457 kg CO_2 eq/kWh)

been used as a proxy for this contribution. For Australia, the electric grid impact has been sourced from the Australian government[92].

4.5.2. Sponsor staff commuting

To appraise the contribution of sponsor staff commuting to the impact of trial sites and the trial as a whole, one needs to know the number of sponsor management sites and their location, or at least the country in which they are located. It is also important to know the number of staff working on the trial and the proportion of their time that is allocated to the trial.

Ideally, primary data would be available regarding the distance that they commute and the mode of transport used. Where these data are not available and it is not practicable to collect primary data, one may use country-specific or region-specific statistics on average transport modes and commuting distances. Those data can be then linked to the number of staff/FTE working on the trial.

The values below relate to travel by a selection of different travel modes:

Passenger car, petrol[93]: 0.21 kg CO_2 eq/km

Aeroplane travel (long haul)[93]: 0.29 kg CO_2 eq/passenger.km

Aeroplane travel (domestic)[93]: 0.31 kg CO_2 eq/passenger.km

Bus travel (average local bus)[93]: 0.13 kg CO_2 eq/passenger.km

Coach travel[93]: 0.03 kg CO_2 eq/passenger.km

Light rail/tram travel[93]: 0.04 kg CO_2 eq/passenger.km

National rail travel[93]: 0.04 kg CO_2 eq/passenger.km

Taxi travel[93]: 0.26 kg CO_2 eq/km

In the absence of better quality data, one may use the default value presented below, which is based on secondary sources and other clinical trial studies.

- Employee commuting: 11 kg CO_2 eq/day.

Notes: employee commuting is assumed to be a 50 km round trip by car.

4.6. OTHER UNSPECIFIED OR NEW ACTIVITIES

Ideally, specific cradle-to-gate life cycle impact data would be available for the activity associated with a trial using a recognised life cycle method[94]. In some cases, an LCA study reporting these data might have been completed for a similar activity or an analogue not in a trial context. In their absence, the user has a number of choices, listed below in order of preference.

- Contact the activity owner for life cycle data and/or an appropriate emission factor.
- Undertake a bespoke assessment[95].
- Search for suitable activity data (material, energy and waste data per unit of activity) or proxy data via a literature review to allow an estimate to be made.
- As a last resort, use financial cost of the activity combined with an environmentally extended input output (EEIO) analysis emission factor (kg CO_2 eq/unit of currency), such as those provided in the sources in Section 6.

[92] https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-account-factors-2023.pdf (0.73 kg CO_2 eq/kWh)

[93] UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.

[94] ISO14040; ISO14044; and GHG Protocol Product Standard Guidance for Pharmaceuticals and Medical Devices

[95] ISO14040; ISO14044; and GHG Protocol Product Life Cycle Accounting and Reporting Standard

5. INTERPRETATION AND REPORTING

Where appropriate given the stated goal and scope of the study, its results, data, methods, assumptions and limitations shall be compiled into a report, in a transparent manner and with sufficient detail to allow the reader to understand the complexities and limitations (e.g. assumptions, data and emission factor quality) associated with conducting the study and with its results. Ideally, the study should be replicable based upon the report, subject to the availability of sensitive data.

Additionally, reporting should follow the specific requirements set by any carbon footprint (or life cycle assessment) method[96] against which conformance will be claimed. In due course, specific requirements for the reporting of clinical trial footprints for the purposes of benchmarking may emerge, associated with the commitments of the SMI.

Where certain assumptions have a material effect on results, these assumptions should be tested in sensitivity analyses. For instance, considering two extremes (a minimum value and a maximum value), in order to verify the influence of such assumption on the final results. This is often called a sensitivity check[97]. Participant travel is a good example of an activity where this is especially relevant. Examples of empirical data and a default approach are provided for this activity in Section 4.2.1 and Table 2 to aid users without primary data. However, in practice, trial-specific participant travel will inevitably vary from these values, whilst experience suggests that this activity will make a significant contribution to the footprint of the trial where it occurs. Consequently, it is important to understand how this contribution changes with alternative assumptions and if iteration of the study, based on primary data, is needed in order to satisfy the study goals.

Ultimately, the accuracy or 'quality' of the result of a study is dependent on the quality of the data used to calculate it. It is critical to consider the quality of the primary and secondary data used, and to demonstrate that they appropriately characterise the trial assessed. There are many ways in which data quality assessments can be performed, the key principle is that due consideration is given to the quality of the data, and that this is carried out and reported transparently.

The generic structure of a report is suggested below.

- **General information and scope**: including unit of analysis (or functional unit), and clinical trial description.
- **System boundaries**: refer to Section 3.
- **Activity data descriptions**: a defined in the system boundaries, the (aggregated) unit processes or activities should be described. This will allow interpretation of potential data gaps and/or completeness of the study.
- **Inventory**: compilation of the activity data (e.g. number of kits shipped for a specific site) for the same unit of analysis (or functional unit).
- **Results**: compilation of the carbon footprint results, including identification of hotspots.

Interpretation: further interpretation of the results may be included in this section. This ought to include, but is not limited to, the following: (a) sensitivity analyses; (b) recommendations for improvement of future clinical trials (e.g. how to reduce impact of a specific hotspot); (c) recommendations for improvement of future footprint studies (e.g. data requirements); (d) data quality assessment; and (e) compilation of assumptions and limitations of the study.

[96] gg ISO14040; ISO14044; and/or GHG Protocol Product Life Cycle Accounting and Reporting Standard

[97] ISO. ISO 14040: Environmental management – Life cycle assessment – Principles and framework. Geneva : International Organisation for Standardisation., 2006a.

6. GENERIC EMISSION FACTORS

Data sources that may be useful when sourcing or modelling additional emission factors are listed below:

UK Government GHG Conversion Factors	https://www.gov.uk/government/collections/government-conversion-factors-for-company-reportinghttps://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting	Provides a broad range of life cycle emission factors (broken down by scope), including energy, transport (freight and passenger), materials and waste.
UK government EEIO emission factors by SIC code	https://www.gov.uk/government/statistics/uks-carbon-footprint	Provides emission factors per unit of economic activity by each sector of the economy. Useful for all areas where financial data is only available, and a proxy is required.
GHG Protocol Third Party Databases	https://ghgprotocol.org/life-cycle-databases	Provides links to sources of life cycle inventory data and emission factors
Global LCA Data Access Network	https://www.globallcadataaccess.org https://www.globallcadataaccess.org	Provides links to sources of life cycle inventory data
HealthcareLCA a database of environmental assessments within healthcare	https://healthcarelca.com	Source of life cycle data and emission factors for healthcare related activities.
US Life Cycle Inventory Database (US LCI)	http://www.nrel.gov/lci/	US life cycle inventory database for materials, energy, transport, waste management processes
US EPA EEIO Supply Chain Greenhouse Gas Emission Factors for US Industries and Commodities	https://catalog.data.gov/dataset/supply-chain-greenhouse-gas-emission-factors-for-us-industries-and-commodities	Provides emission factors per unit of economic activity by each sector of the economy. Useful for all areas where financial data is only available and a proxy is required.
US EPA GHG Emission Factors Hub	https://www.epa.gov/climateleadership	
ecoinvent	https://ecoinvent.org	Life cycle inventory database (global and regional) for materials, energy, transport, waste management processes
sphera LCA datasets	https://sphera.com/product-sustainability-gabi-data-search/	Life cycle inventory database for materials, energy, transport, waste management processes
AUSLCI	https://www.auslci.com.au/	Australian life cycle inventory database for materials, energy, transport, waste management processes
International energy agency (IEA)	IEA – International Energy AgencyIEA – International Energy Agency	Source of electricity emission factors for each country

Environmental Extended Input Output (EEIO) databases – various (other are available)	http://www.eiolca.net/ http://www.cml.leiden.edu/software/data-e3iot.htmlhttp://www.cml.leiden.edu/software/data-e3iot.html	Provides links to databases that provide emission factors per unit of economic activity by each sector of the economy. Useful for all areas where financial data is only available, and a proxy is required.

Some of these data sources include detailed life cycle inventories (LCIs) describing all of the resources required and emissions and waste generated from an activity. It is possible to use these LCI datasets to calculate emission factors by analysing the LCI datasets using impact assessment methods.

Specialist software is normally required to complete this process (examples include SimaPro, GaBi, OpenLCA and others).

Table 3 summarises the proxy data provided in Section 4 of this document, to facilitate their application by users in the absence of primary data.

Users of this guidance document should be aware that the emission factors provided below to support the calculation of the carbon footprint of clinical trials are accurate, in terms of time relevance, at the date of publication. Users should be mindful that some of the emission factors will become subject to error as time progresses from this date. For example, transportation or electricity emissions factors may vary as transport fuel types and national grid mixes change.

Table 3 - Summary of Emission factors contained in the main body for clinical trial footprinting

Module	Activity	Process / Flow / Material	Value	Unit
Clinical supply	Investigational medicinal product (IMP) or intervention	Vial, packed (2mL vial, with 10% pure substance)	5.00	kg CO_2 eq per vial
		Tablet, packed in blister (150 mg)	0.20	kg CO_2 eq per tablet
		Tablet, packed in bottle (150 mg)	0.20	kg CO_2 eq per tablet
		Dry ice	3.7	kg CO_2 eq/kg dry ice
		Frozen shipper	26.5	kg CO_2 eq/unit.
		Ambient shipper	0.345	kg CO_2 eq/unit.
		Transport road (ambient)	0.12	kg CO_2 eq/tkm
		Transport road (chilled)	0.14	kgCO_2 eq/tkm
		Transport air	1.23	kg CO_2 eq/tkm
		Vial (empty), to hazardous incineration	0.04	kg CO_2 eq per vial
		Tablet blister packaging (per tablet), to hazardous waste incineration	0.01	kg CO_2 eq
		Tablet bottle packaging (per tablet), to hazardous waste incineration	0.01	kg CO_2 eq
		IMP kit (packaging), to hazardous incineration	0.20-1.5	kg CO_2 eq per kit
		Mixed waste to incineration	1.57	kg CO_2 eq/kg
		Mixed waste to landfill	0.355	kg CO_2 eq/kg
	Testing/diagnostics kits	Testing kit A (cradle-to-gate manufacture)	0.34	kg CO_2 eq per kit
		Testing kit B (cradle-to-gate manufacture)	0.29	kg CO_2 eq per kit
		Testing kit C (cradle-to-gate manufacture)	0.29	kg CO_2 eq per kit
		Testing kit D (cradle-to-gate manufacture)	0.31	kg CO_2 eq per kit
		Testing kit E (cradle-to-gate manufacture)	0.44	kg CO_2 eq per kit
		Mixed waste to incineration	1.57	kg CO_2 eq/kg
		Mixed waste to landfill	0.355	kg CO_2 eq/kg
	Distributing medicinal technology/device	Dry ice	3.7	kg CO_2 eq/kg dry ice
		Frozen shipper	26.5	kg CO_2 eq/unit.
		Ambient shipper	0.345	kg CO_2 eq/unit.

Module	Activity	Process / Flow / Material	Value	Unit
		Transport road (ambient)	0.12	kg CO_2 eq/tkm
		Transport road (chilled)	0.14	kg CO_2 eq/tkm
		Transport air	1.23	kg CO_2 eq/tkm
	Disposal of medicinal technology/device	Mixed waste to incineration	1.57	kg CO_2 eq/kg
		Mixed waste to landfill	0.355	kg CO_2 eq/kg
	Participant electronic devices	Device (smartphone), cradle-to-gate manufacture	54.78	kg CO_2 eq per device
		Device (tablet), cradle-to-gate manufacture	63.2	kg CO_2 eq per device
		Device (smartphone), use UK	0.033	kg CO_2 eq per day
		Device (smartphone), use US	0.0548	kg CO_2 eq per day
		Device (smartphone), use Australia	0.0876	kg CO_2 eq per day
		Device (tablet), use UK	0.058	kg CO_2 eq per day
		Device (tablet), use US	0.096	kg CO_2 eq per day
		Device (tablet), use Australia	0.153	kg CO_2 eq per day
	Participant electronic device transport	Transport road (ambient)	0.12	kg CO_2 eq/tkm
		Ambient shipper	0.345	kg CO_2 eq/unit.
		Transport air	1.23	kg CO_2 eq/tkm
	Participant electronic device disposal	Electrical waste (WEEE) to landfill	0.00888	kg CO_2 eq/kg
		Electrical waste (WEEE) to recycling	0.0213	kg CO_2 eq/kg
Participant visits and accommodation	Participant visit to trial sites	Participant visit (assuming 70km by car)	14.0	kg CO_2 eq per visit
		Passenger car	0.21	kg CO_2 eq/km
		Aeroplane (long haul)	0.29	kg CO_2 eq/passenger.km
		Aeroplane (domestic)	0.31	kg CO_2 eq/passenger.km
		Bus (local)	0.13	kg CO_2 eq/passenger.km
		Coach	0.03	kg CO_2 eq/passenger.km
		Light rail/tram	0.04	kg CO_2 eq/passenger.km
		National rail	0.04	kg CO_2 eq/passenger.km
		Taxi	0.26	kg CO_2 eq/km
		Hotel stay (UK)	10.4	kg CO_2 eq/room per night
		Hotel stay (US)	16.1	kg CO_2 eq/room per night
		Hotel stay (Japan)	39.0	kg CO_2 eq/room per night
		Hotel stay (UAE)	63.8	kg CO_2 eq/room per night
		Low intensity inpatient	37.9	kg CO_2 eq/bed day
		High intensity inpatient	89.5	kg CO_2 eq/bed day
	Participant remote visits	Remote visit time	60	minutes

Module	Activity	Process / Flow / Material	Value	Unit
		Laptop electricity	0.050	kW
		Laptop electricity	0.01375	g CO_2 eq / hour
	Home visits	Rod travel (car)	0.21	kg CO_2 eq per km
		Sample courier (motorbike)	0.14	kg CO_2 eq per km
		Gloves, sterile pair	102	g CO_2 eq/unit
		Face mask	15	g CO_2 eq/unit
		Mixed waste incineration	1.57	kg CO_2 eq/kg
		Mixed waste to landfill	0.355	kg CO_2 eq/kg
Trial procedures	IMP administration	Syringe, 20 mL (cradle-to-gate manufacture)	82	g CO_2 eq per unit
		Needle, green (cradle-to-gate manufacture)	3.0	g CO_2 eq per unit
		Gloves, sterile pair (cradle-to-gate manufacture)	102	g CO_2 eq per unit
		Face mask (cradle-to-gate manufacture)	15	g CO_2 eq per unit
		Mixed waste incineration	1.57	kg CO_2 eq/kg
		Mixed waste to landfill	0.355	kg CO_2 eq/kg
	Sample collection and processing	Syringe, 20 mL (cradle-to-gate manufacture)	82	g CO_2 eq per unit
		Needle, green (cradle-to-gate manufacture)	3.0	g CO_2 eq per unit
		Gloves, sterile pair (cradle-to-gate manufacture)	102	g CO_2 eq per unit
		Face mask (cradle-to-gate manufacture)	15	g CO_2 eq per unit
		Mixed waste incineration	1.57	kg CO_2 eq/kg
		Mixed waste to landfill	0.355	kg CO_2 eq/kg
	Sample distribution	Dry ice	3.7	kg CO_2 eq/kg
		Frozen sample shipper	26.5	kg CO_2 eq/unit
		Ambient sample shipper	0.345	kg CO_2 eq/unit
		Transport road (ambient)	0.12	kg CO_2 eq/tkm
		Transport road (chilled)	0.14	kg CO_2 eq/tkm
		Transport air	1.23	kg CO_2 eq/tkm
	Laboratory samples analysis and storage	Sample storage	0.00162	kWh/sample/day
		Sample storage	0.446	g CO_2 eq/sample/day
		Full blood examination	0.0459	kg CO_2 eq/test
		Coagulation profile	0.00256	kg CO_2 eq/test
		Urea and electrolytes	0.0153	kg CO_2 eq/test
		C-reactive protein	0.00997	kg CO_2 eq/test
		Arterial blood gases	0.0111	kg CO_2 eq/test
		Sample disposal	0.025	kg CO_2 eq/10mL sample

Module	Activity	Process / Flow / Material	Value	Unit
	Imaging	MRI scan	17.5	kg CO_2 eq per MRI scan
		CT scan	9.2	kg CO_2 eq per CT scan
		X-ray	0.9	kg CO_2 eq per X-ray
		Ultrasound	0.5	kg CO_2 eq per ultrasound
	Surgical procedures	Surgical procedure	54.4	kg CO_2 eq per hour
	Data management including storage	Hospital files	0.0057	kg CO_2 eq per page
		Scans	0.015	kg CO_2 eq per scan burned to CD
		CDs/DVDs	0.83	kg CO_2 eq per CD manufactured
		Data storage, electronic	0.0046	kWh/GB
		Electronic data transfer	0.06	kWh/GB
		Electricity	1,032	kWh per employee per year
		Heat	1,476	kWh per employee per year
		Employee commute	11	kg CO_2 eq/day
	Trial documentation	Documentation	0.0057	kg CO_2 eq per page
	Trial documentation distribution	Transport road (ambient)	0.12	kg CO_2 eq/tkm
		Transport road (chilled)	0.14	kg CO_2 eq/tkm
		Transport air	1.23	kg CO_2 eq/tkm
		Electronic data transfer	0.06	kWh/GB
		Electronic data transfer UK	0.0165	kg CO_2 eq/GB
		Electronic data transfer US	0.0274	kg CO_2 eq/GB
		Electronic data transfer Australia	0.0438	kg CO_2 eq/GB
Trial sites	Trial site impact (overhead)	Electricity	1,238	kWh per employee per year
		Electricity	0.664	kWh per employee per hour
		Electricity, UK	340.5	kg CO_2 eq / employee per year
		Electricity, US	565.8	kg CO_2 eq / employee per year
		Electricity, Australia	903.7	kg CO_2 eq / employee per year
		Heat	2,591	kWh per employee per year
		Heat	603.7	kg CO_2 eq/ employee per year
	Trial site staff commuting	Passenger car	0.21	kg CO_2 eq/km

Module	Activity	Process / Flow / Material	Value	Unit
		Aeroplane (long haul)	0.29	kg CO_2 eq/passenger.km
		Aeroplane (domestic)	0.31	kg CO_2 eq/passenger.km
		Bus (local)	0.13	kg CO_2 eq/passenger.km
		Coach	0.03	kg CO_2 eq/passenger.km
		Light rail/tram	0.04	kg CO_2 eq/passenger.km
		National rail	0.04	kg CO_2 eq/passenger.km
		Taxi	0.26	kg CO_2 eq/km
		Employee commute	11	kg CO_2 eq/day
	Trial site visits and trial meetings (trial site management)	Electricity	0.143	per attendee hour external meeting
		Electricity, UK	0.0393	kg CO_2 eq/ attendee hour external meeting
		Electricity, US	0.0654	kg CO_2 eq/ attendee hour external meeting
		Electricity, Australia	0.104	kg CO_2 eq/ attendee hour external meeting
		Heat	0.204	per attendee hour external meeting
		Heat	0.048	kg CO_2 eq/ attendee hour external meeting
		Long haul flight	0.29	kg CO_2eq per passenger.km
		Domestic flight	0.31	kg CO_2eq per passenger.km
		Passenger car	0.21	kg CO_2 eq per km
		Taxi	0.26	kg CO_2 eq per km
		Hotel stay (UK)	10.4	kg CO_2 eq/room per night
		Hotel stay (US)	16.1	kg CO_2 eq/room per night
		Hotel stay (Japan)	39.0	kg CO_2 eq/room per night
		Hotel stay (UAE)	63.8	kg CO_2 eq/room per night
		Meeting lunches or hotel dinners (vegetarian)	2.6	kg CO_2 eq per meal per person
		Meeting lunches or hotel dinners (meat)	5.92	kg CO_2 eq per meal per person
Sponsor trial management and trial design	Sponsor trial management utilities	Electricity	1,032	kWh per employee per year
		Electricity	0.664	kWh per employee per hour
		Electricity, UK	283.8	kg CO_2 eq/ employee per year

Module	Activity	Process / Flow / Material	Value	Unit
		Electricity, US	471.6	kg CO_2 eq/ employee per year
		Electricity, Australia	753.4	kg CO_2 eq/ employee per year
		Heat	1,476	kWh per employee per year
		Heat	343.9	kg CO_2 eq/ employee per year
	Sponsor staff commuting	Passenger car	0.21	kg CO_2 eq/km
		Aeroplane (long haul)	0.29	kg CO_2 eq/passenger.km
		Aeroplane (domestic)	0.31	kg CO_2 eq/passenger.km
		Bus (local)	0.13	kg CO_2 eq/passenger.km
		Coach	0.03	kg CO_2 eq/passenger.km
		Light rail/tram	0.04	kg CO_2 eq/passenger.km
		National rail	0.04	kg CO_2 eq/passenger.km
		Taxi	0.26	kg CO_2 eq/km
		Employee commute	11	kg CO_2 eq/day

7. REFERENCES

1. ISO 14040: Environmental management – Life cycle assessment – Principles and framework. Geneva : International Organisation for Standardisation., 2006a.
2. ISO 14044: Environmental management – Life cycle assessment – Requirements and guidelines. Geneva : International Organization for Standardization, 2006b.
3. GHG protocol Product Standard | Greenhouse Gas Protocol. sl : ghgprotocol.org.
4. SHC. Sustainable Care Pathways Guidance. sl : Sustainable Healthcare Coalition (shcoalition.org).
5. EU. European Platform on LCA | EPLCA (europa.eu).
6. SMI. Health Systems taskforce. sl : Sustainable Markets Initiative (sustainable-markets.org).
7. SMI. Health Systems taskforce. sl : Sustainable Markets Initiative (sustainable-markets.org).
8. Adshead, Fiona, et al. A strategy to reduce the carbon footprint of clinical trials. 2021. pp. 281-282.
9. Jessica, Griffiths, et al. Quantifying the carbon footprint of clinical trials: guidance development and pilot study. sl : PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs, 2023.
10. The foreground system consists of the specific trial activities/processes which may be directly or indirectly under the control of the study commissioner
11. This current version of the Guidance Document focuses on trials of pharmaceutical products. However, trials of the effect of any intervention on health-related biomedical and behavioural outcomes can be footprinted using the same approach and logic. Mapping out the activities and consumptions associated with any such trial beyond those addressed in the Guidance will be an essential stage in a reliable estimation of its footprint.
12. ISO14040; ISO14044; and GHG Protocol Product Standard Guidance for Pharmaceuticals and Medical Devices
13. ISO14040; ISO14044; and GHG Protocol Product Life Cycle Accounting and Reporting Standard
14. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
15. IMP kit primary and secondary packaging (weight range from 0.1 to 0.6 kg)
16. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.
17. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away.
18. Jessica, Griffiths, et al. Quantifying the carbon footprint of clinical trials: guidance development and pilot study. sl : PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs, 2023.
19. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
20. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.
21. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away.
22. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
23. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.
24. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away
25. Weight excludes packaging
26. Apple. Product Environmental Report: iPhone 15 Pro and iPhone 15 Pro Max. sl : Available at
27. Weight excludes packaging
28. Product Environmental Report, iPad Air (5th generation). sl : https://www.apple.com/environment/pdf/products/ipad/iPad_Air_PER_March2022.pdf, 2022.
29. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
30. https://www.epa.gov/egrid/summary-data (0.457 kg CO2 eq/kWh)
31. https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-account-factors-2023.pdf (0.73 kg CO2 eq/kWh)

32. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
33. https://www.outsourcing-pharma.com/Article/2022/11/09/clinical-trial-participants-travel-67-miles-to-study-sites-on-average-analysis-finds
34. https://link.springer.com/article/10.1007/s11845-021-02915-6
35. https://academic.oup.com/jnci/article/95/18/1370/2520444
36. Lim, J, et al. Impact of travel distance on outcomes for clinical trial patients: the Kinghorn Cancer Centre experience. sl : Intern Med J. 2023 Feb;53(2):242-249. doi: 10.1111/imj.15561. Epub 2022 Aug 3. PMID: 34613656, 2023.
37. Borno, HT, et al. At What Cost to Clinical Trial Enrollment? A Retrospective Study of Patient Travel Burden in Cancer Clinical Trials. sl : Oncologist. 2018 Oct;23(10):1242-1249. doi: 10.1634/theoncologist.2017-0628. Epub 2018 Apr, 2018.
38. Lim, J, et al. Impact of travel distance on outcomes for clinical trial patients: the Kinghorn Cancer Centre experience. sl : Intern Med J. 2023 Feb;53(2):242-249. doi: 10.1111/imj.15561. Epub 2022 Aug 3. PMID: 34613656, 2023.
39. Borno, HT, et al. At What Cost to Clinical Trial Enrollment? A Retrospective Study of Patient Travel Burden in Cancer Clinical Trials. sl : Oncologist. 2018 Oct;23(10):1242-1249. doi: 10.1634/theoncologist.2017-0628. Epub 2018 Apr, 2018.
40. Based on the carbon footprint of average petrol car included in emission factors published by UK Government 2023: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023
41. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
42. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
43. SHC. Sustainable Care Pathways Guidance. sl : Sustainable Healthcare Coalition (shcoalition.org).
44. Considering 0.275 kg CO2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)
45. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
46. Rizan, C, et al. The carbon footprint of products used in five common surgical operations: identifying contributing products and processes. sl : Journal of the Royal Society of Medicine. 2023;116(6):199-213. doi:10.1177/014107682311661, 2023.
47. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.
48. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away.
49. Rizan, C, et al. The carbon footprint of products used in five common surgical operations: identifying contributing products and processes. sl : Journal of the Royal Society of Medicine. 2023;116(6):199-213. doi:10.1177/014107682311661, 2023.
50. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.
51. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away.
52. Rizan, C, et al. The carbon footprint of products used in five common surgical operations: identifying contributing products and processes. sl : Journal of the Royal Society of Medicine. 2023;116(6):199-213. doi:10.1177/014107682311661, 2023.
53. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to an incineration site 50 km away.
54. Considering a generic mix of 60% plastic, 40% cardboard and aluminium (by mass), and that the waste would need to be transported to a landfill site 50 km away.
55. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
56. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/ulf_freezer_user_guide.pdf
57. Considering 0.275 kg CO2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)

58. McAlister, S, et al. The carbon footprint of pathology testing. sl : Med J Aust 2020; 212 (8): 377-382. || doi: 10.5694/mja2.50583, 2020.
59. McAlister, S, et al. The carbon footprint of hospital diagnostic imaging in Australia. sl : Lancet Reg Health West Pac. 2022 May 3;24:100459. doi: 10.1016/j.lanwpc.2022.100459. PMID: 35538935; PMCI, 2022.
60. SHC. Sustainable Care Pathways Guidance. sl : Sustainable Healthcare Coalition (shcoalition.org).
61. Jessica, Griffiths, et al. Quantifying the carbon footprint of clinical trials: guidance development and pilot study. sl : PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs, 2023.
62. Dlzar Al Kez, Aoife M. Foley, David Laverty, Dylan Furszyfer Del Rio, Benjamin Sovacool. Exploring the sustainability challenges facing digitalization and internet data centers. sl : Journal of Cleaner Production, 2022. https://doi.org/10.1016/j.jclepro.2022.133633.
63. Aslan, J., Mayers, K., Koomey, J.G. and France, C. Electricity Intensity of Internet Data Transmission: Untangling the Estimates. sl : Journal of Industrial Ecology, 22: 785-798., 2018. https://doi.org/10.1111/jiec.12630.
64. Department of Health. Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare Environment and sustainability Part A: Policy and management. sl : Department of Health, 2015.
65. UK. UK EMPLOYMENT DENSITY GUIDE, 3rd edition November 2015. 2015.
66. Jessica, Griffiths, et al. Quantifying the carbon footprint of clinical trials: guidance development and pilot study. sl : PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs, 2023.
67. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
68. Aslan, J., Mayers, K., Koomey, J.G. and France, C. Electricity Intensity of Internet Data Transmission: Untangling the Estimates. sl : Journal of Industrial Ecology, 22: 785-798., 2018. https://doi.org/10.1111/jiec.12630.
69. Considering 0.275 kg CO2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)
70. https://www.epa.gov/egrid/summary-data (0.457 kg CO2 eq/kWh)
71. https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-account-factors-2023.pdf (0.73 kg CO2 eq/kWh)
72. Department of Health, Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare Environment and sustainability Part A: Policy and management. sl : Department of Health, 2015.
73. Considering 0.275 kg CO2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)
74. Considering 0.233 kg CO2 eq/kWh natural gas (net CV) (based on UK Government GHG conversion factors 2023)
75. Department of Health, Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare Environment and sustainability Part A: Policy and management. sl : Department of Health, 2015.
76. NHS. NHS estates, HBN 12 Out-patients department.
77. https://www.epa.gov/egrid/summary-data (0.457 kg CO2 eq/kWh)
78. https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-account-factors-2023.pdf (0.73 kg CO2 eq/kWh)
79. For example, if a member of staff spends 10% of their time working on the trial studied, this means that their daily commute should be allocated accordingly.
80. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
81. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
82. Department of Health, Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare Environment and sustainability Part A: Policy and management. sl : Department of Health, 2015.
83. Considering 0.275 kg CO2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)
84. Considering 0.233 kg CO2 eq/kWh natural gas (net CV) (based on UK Government GHG conversion factors 2023)
85. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
86. WWF. Food in a warming world report. sl : WWF, 2018.
87. Department of Health, Health Technical Memorandum 07-02: EnCO2de 2015 – making energy work in healthcare Environment and sustainability Part A: Policy and management. sl : Department of Health, 2015.
88. Considering 0.275 kg CO2 eq/kWh for UK (based on UK Government GHG conversion factors 2023)

89. Considering 0.233 kg CO2 eq/kWh natural gas (net CV) (based on UK Government GHG conversion factors 2023)
90. UK. UK EMPLOYMENT DENSITY GUIDE, 3rd edition November 2015. 2015.
91. https://www.epa.gov/egrid/summary-data (0.457 kg CO2 eq/kWh)
92. https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-account-factors-2023.pdf (0.73 kg CO2 eq/kWh)
93. UK Government. UK Government GHG conversion factors. sl : UK Government, 2023.
94. ISO14040; ISO14044; and GHG Protocol Product Standard Guidance for Pharmaceuticals and Medical Devices
95. ISO14040; ISO14044; and GHG Protocol Product Life Cycle Accounting and Reporting Standard
96. gg ISO14040; ISO14044; and/or GHG Protocol Product Life Cycle Accounting and Reporting Standard
97. ISO. ISO 14040: Environmental management – Life cycle assessment – Principles and framework. Geneva : International Organisation for Standardisation., 2006a.

APPENDIX A: GLOSSARY OF TERMS

Allocation – partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems.

Attributable processes – refer to any flows (materials, energy, wastes) that are directly connected to the design and delivery of studied clinical trial system.

Characterisation factor – a factor derived from a characterisation model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator (e.g. kg CO_2e / kg of gas).

Clinical trial – a research study in which one or more human participants are *prospectively assigned* to one or more *interventions* (which may include placebo or other control) to evaluate the effects of those interventions on *health-related biomedical or behavioural outcomes*.

Functional unit – quantified performance of a product system for use as a reference unit.

Impact category – class representing environmental issues of concern to which life cycle inventory analysis results may be assigned (e.g. climate change).

Impact category indicator – quantifiable representation of an impact category (e.g. infrared radiative forcing, W / m^2).

Materiality assessment – a first or early iteration of a study (Steps I-IV) conducted in order to identify those activities that are likely to make the most significant contributions to the footprint of the trial and thereby direct resources in data collection and calculation to where they will be most effective in delivering an accurate estimation.

Non-attributable processes – are those that are not directly associated with the clinical trial under study can be excluded. Examples of non—attributable processes include corporate functions such as marketing, or the construction of buildings and infrastructure.

Phase 1 (I) clinical trial – a phase I clinical trial tests the safety, side effects, best dose, and timing of a new treatment. It may also test the best way to give a new treatment (for example, by mouth, infusion into a vein, or injection) and how the treatment affects the body. Phase I clinical trials usually include only a small number of participants who have not been helped by other treatments.

Phase 2 (II) clinical trial – a study that tests whether a new treatment works for a certain type of cancer or other disease (for example, whether it shrinks a tumour or improves blood test results). Phase 2 clinical trials may also provide more information about the safety of the new treatment and how the treatment affects the body.

Phase 3 (III) clinical trial – a study that tests the safety and how well a new treatment works compared with a standard treatment. For example, Phase 3 clinical trials may compare which group of participants has better survival rates or fewer side effects. In most cases, treatments move into Phase 3 clinical trials only after they meet the goals of Phase 1 and Phase 2 clinical trials. Phase 3 clinical trials may include hundreds of people.

Phase 4 (IV) clinical trial – a type of clinical trial that studies the side effects caused over time by a new treatment after it has been approved and is on the market. These trials look for side effects that were not seen in earlier trials and may also study how well a new treatment works over a long period of time. Phase 4 clinical trials may include thousands of people.

Primary data – data from specific activity/processes in the studied clinical trial.

Principle of materiality – ensuring that all activities that have a significant impact on the environmental performance results and that could influence any future decisions are included in the footprint.

Proxy data – data from a similar activity that are used as a stand-in for the given trial activity. Proxy data can be extrapolated, scaled up, or customized to better represent the required trial activity.

Secondary data – process data that are not from the specific activity/processes in the studied clinical trial.