carebone

Estimation tool to measure carbon footprint of a patient pathway ››

Methodological guide

Department of Ecological Transformation and Environmental Health / Directorate of Strategy and Transformation

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CONTEXT AND OBJECTIVES ››

Greenhouse gas emissions from the healthcare sector have been estimated at around 8%[1] of French emissions, amounting to 49 million tons of CO2e per year.

Many healthcare facilities are committing to climate action by conducting their **Carbon Footprint assessments®**, providing a **comprehensive view of their emissions**. AP-HP (Assistance Publique - Hôpitaux de Paris) sought to take this a step further by obtaining a more operational view of its emissions throughout a **patient's pathway.** The methodology outlined in this document encompasses all the formulas, assumptions, and sources used to calculate the carbon footprint of **different components** of a patient pathway: medications, medical devices, and medical procedures.

This work was carried out by Inès de Maisoncelle, Department of Ecological Transformation and Environmental Health, Directorate of Strategy and Transformation, Assistance Publique - Hôpitaux de Paris.

[1] According to the final report "Décarboner la santé pour soigner durablement" from the French think tank The Shift Project – 2023 edition

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TOOL OPERATION ⟩⟩

The tool consists of multiple tabs.:

Yellow tab: "Read me": This tab provides methodological explanations of the tool to guide the user.

4 light blue tabs:

In these tabs, users can fill in white cells, while yellow cells are automated

"Patient pathway": Calculator for estimating the carbon footprint of a patient's pathway.

" Medical Procedures": Calculator for estimating the carbon footprint of a medical procedure (regardless of its nature) and maintaining a database of information for use in the "Patient Pathway" tab. After obtaining a result, the user should copy the last line "Extraction for database" and paste it as a value in the "EF - Procedures" tab.

"Medications": Calculator for estimating the carbon footprint of a medication and maintaining a database of information for use in the "Medical Procedures" and "Patient Pathway" tabs. After obtaining a result, the user should copy the last line "Extraction for database" and paste it as a value in the "FE Medications" tab.

"Medical Devices": Calculator for estimating the carbon footprint of a medical device or consumable and maintaining a database of information for use in the "Medical Procedures" and "Patient Pathway" tabs. After obtaining a result, the user should copy the last line "Extraction for database" and paste it as a value in the "FE - MD" tab.

4 greens tabs - USER ASSISTANCE:

- These tabs help users estimate activity data when it's not available or choose an approximation of emission factors (EF) when the exact EF isn't in the database.
- **HELP – Choice of API EF":** Allows the user to select the most relevant emission factor (EF) by evaluating the active pharmaceutical ingredient (API) based on four criteria: the complexity of the molecule, its origin, specific production conditions, and production volumes. The user assesses these criteria on a scale from 1 (lowest energy consumption and GHG emissions) to 3 (highest energy consumption and GHG emissions). The user is guided by instructions in the tab but also needs to conduct documentary research. The complete methodology is detailed in the section "Emission Factors & Sources > Active Substances > Methodology in case of non-existent EF."
- **"HELP – Estimation of Excipient Qty**": Allows the user to estimate the quantity of excipient in the medication when it is unknown. The complete methodology is detailed in the section " Assessing the carbon footprint of medication > Assumptions & Sources > Excipients."

  "HELP – Choice EF Excipient: Guides the user in selecting the most relevant emission factor for excipients. The complete methodology is detailed in the section "Emission Factors & Sources > Excipients > Methodology in case of non-existent EF."

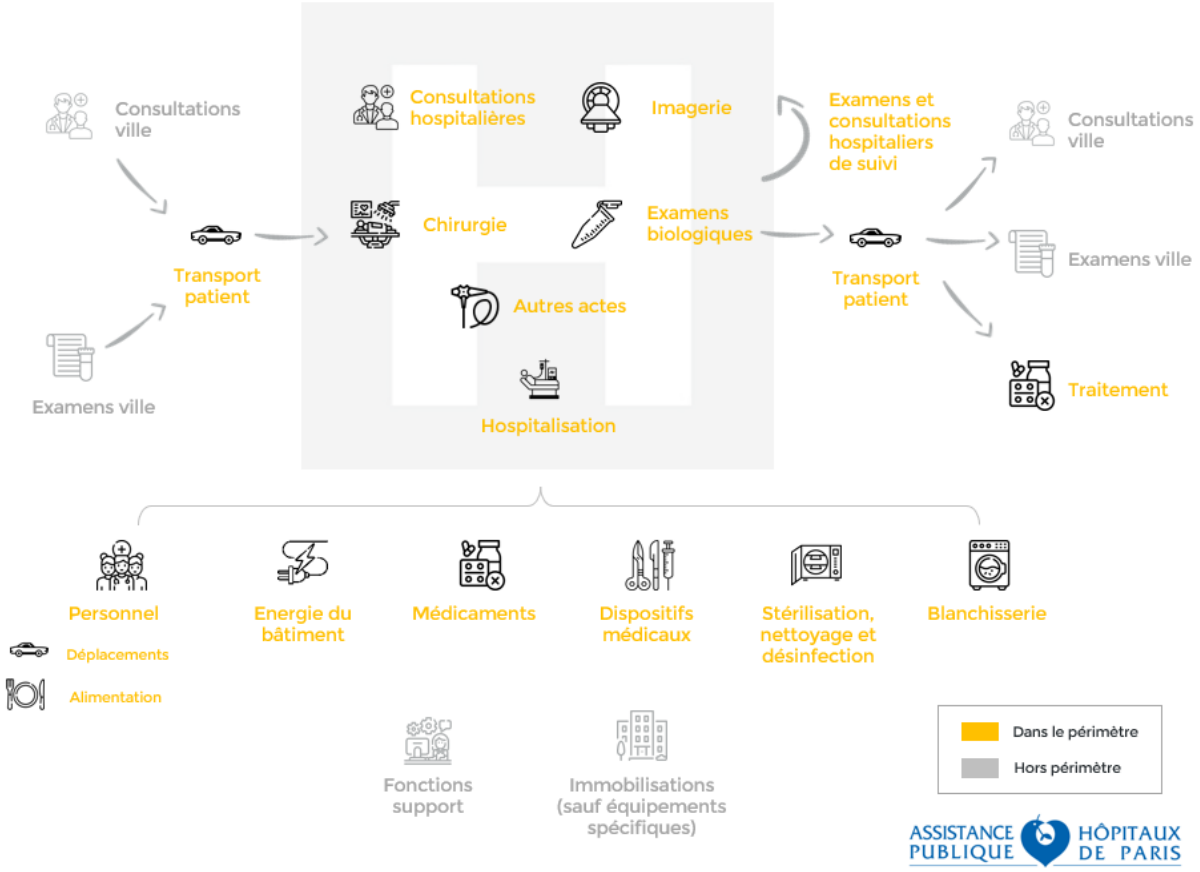
- **HELP - MD Material weigh ":** This tab assists the user in estimating the weight of materials used in medical devices based on their shapes and dimensions. The complete methodology is detailed in the section "Assessing the carbon footprint of Medical Device > Assumptions & Sources > Materials".

28 dark blue tabs:

- 2 tabs for ratios to estimate energy consumption related to the production of medications and medical devices, as well as emissions related to digital data storage;
- 26 tabs corresponding to emission factors.

THE ANALYSIS SCOPE ››

The diagram below illustrates the range of operations covered in the patient pathway.



Scope exclusions

Fixed assets are not included in the scope of this patient pathway carbon footprint calculation tool. Fixed assets typically encompass the environmental impact associated with the production of goods used by the organization, which have a prolonged lifespan and are neither transformed nor sold. These may include equipment, machinery, buildings, facilities, and vehicles. This exclusion was implemented for the following reasons:

A significant portion of AP-HP's fixed assets, such as buildings and facilities, have already undergone depreciation, including the impact of their production.

The energy consumption of buildings and equipment has been adequately addressed in other categories.

Including fixed assets would have added unnecessary complexity to the carbon footprint calculation process, without yielding useful information for decision-making purposes.

An exception has been made for certain medical procedures, such as imaging. Therefore, in the "Medical Procedures" tab, the tool includes a category for "Equipment" because some equipment has a significant impact (MRI, scanner, etc.).

All AP-HP support functions (logistics, human resources, finance, IT, etc.) have not been included in this methodology. As a result, the impact of refrigerant fluids and fugitive emissions is not considered. The only exceptions are staff meals, laundry, cleaning, disinfection, and sterilization, which have been included in the calculation (excluding staff).

Regarding medical devices and medications, the scope is strictly limited to the lifecycle and does not include support functions like research and development, communication, marketing, etc.

Finally, the following categories have been excluded from the tool due to a lack of data or because the methodology was not deemed robust enough. These categories may be integrated into a future version of the tool:

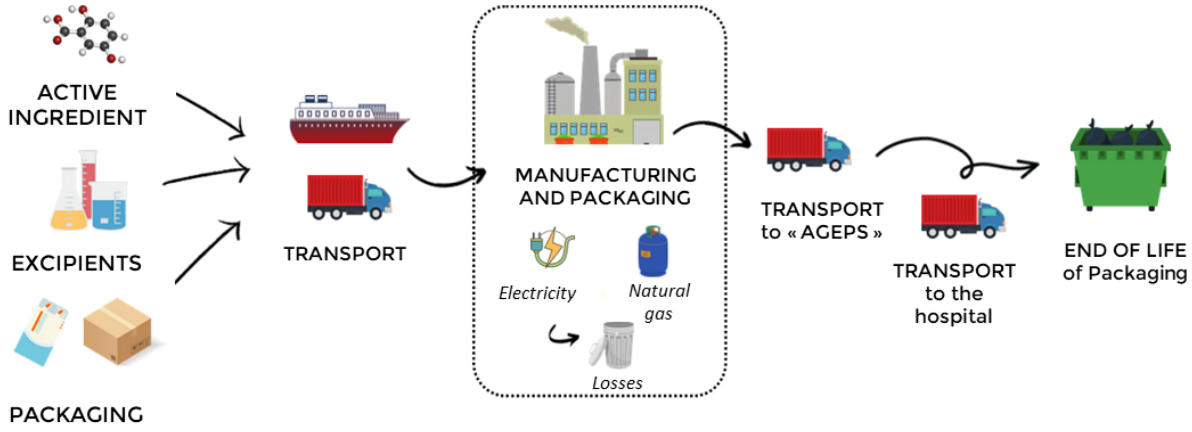
- Equipment maintenance
- Medical fluids (oxygen, medical air, vacuum, etc.)
- Upstream processes related to anesthetic gases (production, distribution, etc.): Various studies consulted have yielded highly variable results on the impact of anesthetic gas production, making the utilization of this data difficult in the tool.
- End-of-life of medications: In a patient pathway, medication is considered consumed.

ASSESSING THE CARBON FOOTPRINT OF MEDICATION ››

1. Overall methodology

Definition: According to the Public Health Code (Article L.5111-1), medication is defined as follows: "*Any substance or combination of substances presented for treating or preventing disease in humans or animals, as well as any substance or composition of substances that can be used in humans or animals or administered to them, for the purpose of establishing a medical diagnosis or restoring, correcting, or modifying their physiological functions by exerting a pharmacological, immunological, or metabolic action*" [1].

The assessing methodology for determining the carbon footprint of a medication is based on the recommendations outlined in the ISO 14040 standard and the ADEME Greenhouse Gas Assessment Method. It is categorized as a "Simplified Life Cycle Assessment (LCA)" and is modeled as depicted in the diagram below. The scope of this simplified LCA encompasses the entire lifecycle of the medication, from production to disposal. Within this model, the user of the tool is required to input specific activity information and data for each stage associated with the medication.



Simplified life cycle of medication production and usage at AP-HP

The LCA methodology necessitates the definition of a Functional Unit before proceeding with calculations. As per the ISO 14044 standard, the Functional Unit is described as the "*Quantified performance of a product system, intended to be used as a reference unit in LCA*." Its role is to establish a benchmark against which activity data will be specified and standardized to ensure the comparability of LCA results on a uniform basis.

In the context of calculating the carbon footprint of medication, the Functional Unit is by default defined as **the smallest unit of medication** (e.g., 1 tablet, 1 capsule, 1 ampoule, 1

bottle, etc.). The methodology accommodates various **dosage forms** (tablet, vial, ampoule, capsule, etc.).

The carbon footprint results are stored in a database of emission factors, which is accessible to all users and applicable to all patient pathways. These results include accompanying uncertainty data, which is also recorded in the database (refer to « Uncertainty »).

2. Equipment and required information

To conduct the carbon footprint assessment of a medication, the following information is necessary:

- The Summary of Product Characteristics (SPC).
- Logistics information regarding the product packaging, such as the number of medications per box, the number of boxes per carton, and the number of cartons per pallet. This data can typically be found on the "AGEPS" website under « Equipment and Health Products Markets » (ap-hop-paris.fr).
- Optionally, a sample of the medication may be required to facilitate weighing.

3. Detailed methodology

The proposed methodology relies on a set of activity data, which can sometimes be challenging to gather. If actual data is available or known, it is recommended to input it into the tool rather than relying on default values.

Otherwise, the tool provides estimations as an initial approach. These estimations are outlined in the "Assumptions & Sources" section, which is based on explicitly stated sources also provided in the same section.

For each item listed below, the user needs to input activity data and select the data collection methodology, specifying how the data was obtained. This allows for the calculation of the uncertainty associated with the estimated carbon footprints (refer to « Uncertainty").

a. General data

This section enables the user to input general medication information required for calculating the carbon footprint:

- Medication name
- Unit format (dosage form: capsule, bag, tablet, ampoule, syringe, pouch, bottle, other format)
- Number of units per box
- Packaging 1: Number of boxes per carton

- Packaging 2: Number of cartons per pallet
- Form: liquid, dry, or solution
- SAP number (internal data for AP-HP)
- CIP 13
- Manufacturer's name
- Calculation manager: First and last name of the individual responsible for calculating this carbon footprint
- Manager's position: Position and organization of the individual responsible for the calculation
- Calculation date

b. *Active pharmaceutical ingredient (s)*

Definition: It refers to the substance present in the medication that gives it its therapeutic or preventive properties. [2]

Emissions related to the manufacturing of the active ingredients of the medication are calculated by recording the quantities mentioned on the SPC. These quantities are entered in grams.

c. *Excipients*

Definition: An excipient is a component of the medication that does not confer its therapeutic or preventive properties but can play a role, notably in absorption (assimilation) and stability, and conditioning its appearance, color, and taste. [3]

Two methodologies can be used for excipients depending on the available information:

If the SPC specifies the quantities of excipients, they can be used in the tool.

Otherwise, the tool proposes a methodology for estimating the quantities of excipients, detailed in the "Assumptions & Sources > Excipients" section.

The quantities of excipients are entered in grams. For liquid forms, the quantity of water for injections purposes (WFI) can be filled in milliliters.

d. *Packaging (Materials and transformation)*

The impact of packaging and instructions manufacturing of the medication is quantified by weighing these elements (in grams) or by using the default methodology described in the "Assumptions & Sources > Packaging" section.

The weight of packaging must be indicated per packaging material (cardboard, paper, aluminum, plastic, etc.). The scope of the packaging includes all levels: from the pallet to the medication box. The user specifies in the tool whether the packaging concerns the pallet, the cardboard, the box, or the unit. The calculation formulas then allow the calculation of emissions related to one unit of medication.

Finally, the user selects the emission factors corresponding to the packaging materials. They also choose, from the following table, the emission factors related to the transformation of these packaging materials. Up to two transformation processes per material can be selected.

e. Upstream transport from the factory

a) Transport of the active substance

This transportation refers to the distance between the active substance production site and the medication production site, expressed in kilometers. The associated greenhouse gas emissions are calculated based on this distance and the weight of materials.

b) Transport of excipients

This transportation refers to the distance between the excipient production site and the medication production site, expressed in kilometers. The associated greenhouse gas emissions are calculated based on this distance and the weight of excipients.

c) Transport of the Packaging

This transport corresponds to:

- On one hand, the journey of packaging materials to the packaging production site;
- On the other hand, the journey of packaging to the medication packaging site.

The distances are expressed in kilometers. The associated greenhouse gas emissions are calculated based on these distances and the weight of packaging materials used.

When this information is not accessible, estimates are provided in the « Assumptions & Sources > Upstream Transport » section.

f. Downstream transport from the factory

The transportation of medication from the factory is divided into three main stages:

- Transport to Packaging Site: This involves moving the medication to the place where it will be packaged. If this site is the same as the factory, then the distance traveled may be zero.

- Transport to Purchasing Center: After packaging, the medication is then moved from the packaging site to the purchasing center, which is often the AGEPS for AP-HP.

- Transport to Hospitals: Finally, the medication is transported from the purchasing center to hospitals where it will be used.

These distances are measured in kilometers. The tool calculates the associated greenhouse gas emissions based on these distances and the total weight of the medication, including active substances, excipients, and packaging materials.

To estimate transportation distances, we recommend using tools such as the Online Freight Shipping & Transit Time Calculator for boat routes and Google Maps for road transportation.

If transportation distance information is unavailable, the tool provides estimates in the "Assumptions & Sources > Downstream Transportation" section.

g. *Formulation and packaging*

This emission category relates to the energy consumption of medication manufacturing and packaging facilities. The data format used in the tool is an energy ratio, expressed in kWh (kWh LHV for natural gas) per kilogram of active substance (API).

If data is unavailable, default values are provided (refer to the "Assumptions & Sources > Formulation and Packaging" section).

h. *Material waste*

a) *Material waste during formulation*

During medication production, a portion of the active substances and excipients may be lost or become waste. A percentage of these losses is automatically calculated based on emissions related to the active substance and excipients and is added to the total emissions.

b) *Packaging material waste*

During the packaging process, a portion of the materials (cardboard, paper, aluminum, plastic, etc.) may be lost or discarded. A percentage of these losses is automatically calculated based on emissions related to packaging and package leaflet and is added to the total emissions.

Assumptions regarding the percentage of losses are available in "Assumptions & Sources > Losses" section.

i. *End-of-life medication*

In this methodology, the medication is considered consumed by the patient. Therefore, this category has been excluded.

j. *End-of-life treatment for packaging and package leaflet*

The impacts associated with the end of life of medication packaging are quantified by selecting the waste treatment method for these materials: recycling, storage, incineration, etc. By default, the emission factor "Packaging - Average End-of-Life" is selected in the absence of additional information.

k. *Total carbon footprint*

The total carbon footprint of the medication corresponds to the sum of greenhouse gas emissions calculated in each of the categories listed above. An "emission factor" is then calculated for this medication in the chosen pharmaceutical form and dosage. It can be saved in the database to be used in calculating the carbon footprint of a medical procedure or patient pathway (refer to "Archiving Protocol").

l. *Avoided emissions due to end-of-life treatment*

Avoided emissions are calculated separately from the carbon footprint and result from the material and energy recovery of waste. They represent greenhouse gas emissions that have been avoided due to the non-production of virgin materials and/or conventional energy. These avoided emissions do not affect the emission factor refer to « Emission Factors & Sources > Active Substances > Methodology in case of non-existent EF » section.

4. Assumptions & Sources

This methodology proposes several assumptions (transport distance, energy consumption ratios, packaging footprint, etc.). It is advisable to adjust these estimates within the tool using real data from the specific case being studied when available.

The assumptions adopted in this methodology and their sources are detailed in the paragraphs below.

a. *General data*

In the absence of real data, the default estimate for the number of cartons per pallet is set at 20.

b. *Active substances*

The quantity of active substance is always available in the Summary of Product Characteristics (SPC) of the medication. However, it's possible that the emission factor

associated with this active substance may not yet exist in the tool's database. In such cases, a methodology has been developed to provide a relevant approximation (refer to "Emission Factors & Sources > Active Substances > Methodology in case of non-existent EF").

c. *Excipients*

When the quantity of excipient is not available, an estimation methodology is provided in the tool (Tab " HELP – Estimation of excipient qty "). It differs for liquid and solid forms:

- Liquid Forms:
    - For each excipient with unknown quantity: the quantity of excipient is estimated at 0.05 g/ml of medication.
    - Except for pH adjusters (e.g., hydrochloric acid, sodium hydroxide): 0.0005 g/ml of medication.

- Dry forms: The total excipient weight is estimated based on the mass of active substances. According to the study by Reker D. 2018 [4], excipients represent 71% of the mass of a tablet. From this total excipient mass, the mass of excipients with known quantities is subtracted.
    - If the result is negative, the quantity of each excipient by default is estimated at 0.5 g.
    - Otherwise, the remaining mass is evenly distributed among the remaining excipients.

⇨ These default values were determined using the following methodology based on currently available data.

The estimation of the excipient quantity was established at 0.05 g/ml for liquid forms and solutions. This value is lower than the threshold doses from the list of excipients with known effects (approximately 0.5 g/ml based on the examples listed below) but still conservative and close to the concentrations of active substance. Indeed, we calculated an average concentration of 0.025 g/ml in active substance based on around thirty liquid medications (see Excel spreadsheet - Appendix 1). Threshold doses provide an order of magnitude for a maximum quantity of excipient. The actual values are likely much lower (hence the choice of a ratio 10 times lower).

An exception was made for pH adjusters at 0.0005 g/ml, considering the quantities of sodium and hydrochloric acid detailed in the SPC of Lipidem (see precise data below).

For dry forms, the estimation of 0.5 g was determined based on threshold doses per intake (e.g., glycerol, PEF, mannitol, etc., based on the examples listed below). This value is used only as a last resort if the estimation methodology based on the quantity of active substance yields an inconsistent result (negative).

Examples of threshold doses from the list of excipients with known effects

- Bronopol: 0.05% in finished product, equivalent to 0.5 g/ml
- Formaldehyde: 0.05% in finished product, equivalent to 0.5 g/ml
- Paraformaldehyde: 0.5% in finished product, equivalent to 5 g/ml
- Ethanol: > 0.05 g/day
- Glycerol: > 1g/dose
- PEG: > 2 g/dose
- Sodium: > 200 mg/day
- Mannitol: > 1g/dose
- Xylitol: > 1 g/dose

2 examples of excipient quantities disclosed in the SPC of Lipidem 200mg/ml, emulsion for infusion.

- NaOH: 2.6 mmol/L, equivalent to 0.000104 g/ml
- HCl: 0.5 mmol/L, equivalent to 0.000085 g/ml

Regarding excipient emission factors, it is possible that the exact EF may not be in the tool's database. In such cases, approximations are provided and explained in the "Emission Factors & Sources > Excipients > Methodology in case of non-existent EF" section.

d. Packaging

An estimation of the carbon footprint of packaging (materials and processing) can be automatically calculated by the tool by selecting the "default" option. This is based on logistical/packaging information, pharmaceutical form, and quantity of medication. Calculations are performed automatically in the "Packaging Estimation" tab. The methodology is presented in Excel spreadsheet Appendix 2.

Annexe 2_Méthodologie_Estir

To estimate greenhouse gas emissions associated with the use of a pallet, it is suggested to use the average weight of a Euro pallet (25 kg), divided by the average number of uses (30 times), resulting in approximately 833 g per use.

Some general methodological clarifications:

- Greenhouse gas emissions related to packaging and quantities of materials (in grams) are normalized per unit based on logistical data (number of medication units per box, carton, pallet).
- Different types of packaging (excluding individual packaging) are always assumed to be cubes by default (for the sake of model simplification). This tends to underestimate the surface area of the packaging. To compensate for this, we assume that packaging fully occupies the space of the upper packaging.
- Default activity data uncertainties are set at 50% (considered as default estimates).

e. *Summary table of default transport assumptions for medications*

The default assumptions used for transportation are presented in the table below. The sources for these assumptions are detailed in the following paragraphs.

Stages	Distances	Transport
Active substances	**200 km** between Zhejiang and Shanghai	Asia truck
	16 000 km between Shanghai and Bâle	Container ship
	40 km of road transport to the factory	European truck
Excipients	**1 000 km** to the factory (for example: between ADM Saint Nolff factory and Basel)	European truck
Packaging	**500 km** from the materials and then the packaging to the packaging site.	European truck
Medication	**250 km** to the packaging site.	European truck
	600 km to the AGEPS.	European truck
	30 km between the AGEPS and the hospital.	European truck

f. Upstream transport from the factory

a) Transport of active substance

When specific information is unavailable, the tool assumes that active substances are manufactured in Asia and transported to Europe via container ship and road transport.

This assumption is based on data indicating that 80% [5] of active pharmaceutical ingredient manufacturers for medicines available in the European Union are situated outside the European Union, primarily in China and India. Notably, studies indicate a slightly higher proportion of European purchases originating from China compared to India. Additionally, the province of Zhejiang in China is identified as a major hub for active ingredient production, hence being selected as the default origin in the tool. [6]

Concerning the destination and formulation of drugs, approximately 40% [5] of finished medicines marketed in the European Union are imported, with the remaining 60% produced within Europe. A significant portion of French medicine imports originates from the European Union, including notable contributions from Germany (11,2%) and Switzerland [7]. Given that Basel hosts the headquarters of major European pharmaceutical companies like Roche and Novartis, it was chosen as the production location in the tool.

- The selected route for transportation spans from Zhejiang to Basel, incorporating:
- 200 km by truck between Zhejiang and Shanghai. (Source: Google maps)
    - ⇨ Selected Emission Factor (FE): Truck transport (including parking, usage, and infrastructure) (100%), RAS - Asia: 0.125 kgCO2e/t.km
- 16 000 km of maritime transport between Shanghai and Basel. (Source: Online Freight Shipping & Transit Time Calculator at Searates.com)
    - ⇨ Selected EF: Container ship - Dry - Asia - Northern Europe: 0.006 kgCO2e/t.km
- 40 km of road transport to the factory.
    - ⇨ Selected EF: Truck transport (including parking, usage, and infrastructure) (100%), RAS - Asia: 0.125 kgCO2e/t.km

b) Transport of excipients

Establishing a typical route for excipients proves challenging due to their diverse roles and origins across various industries such as agri-food and cosmetics [8]. During her thesis research, Camille Primard enumerates several of these industries [9]. To address this, a European location is assumed for excipient production, considering the prevalence of such industries in Europe. For estimating a typical route, the ADM group serves as an example, given its substantial presence in France within its nutrition division, boasting 13 factories out of 33 in Europe [10].

Route type selected: Road transport has been chosen for the route between the ADM factory in Saint Nolff and Basel, covering a distance of approximately 1000 km (source: Google Maps).

- Selected EF: Truck transport (including parking, usage, and infrastructure) (100%) – Europe: 0.09 kgCO2e/t.km

c) *Transport of packaging*

The initial estimates for packaging transport are derived from examples provided in the BEE[2] tool, developed by Citeo for environmental packaging assessments.

- Transport of materials to the packaging production site: 250 km.
- Transport of packaging to the packaging site: 250 km.

  ⇨ Selected EF: Truck transport (including parking, usage, and infrastructure) (100%) - Europe: 0.09 kgCO2e/t.km

g. ***Downstream transport from the factory***

a) *Transport of the drug to the packaging site:*

Initial estimates for this transportation segment are derived from carbon footprint calculations for packaging within the BEE[3] tool, developed by Citeo.

- Transport of the drug to the packaging site: 250 km.
- Selected EF: Truck transport (including parking, usage, and infrastructure) (100%) - Europe: 0.09 kgCO2e/t.km

b) *Transport of the drug between the factory and the AGEPS*

- The selected route involves road transport between Basel and the AGEPS, covering an approximate distance of 600 km (source: Google Maps).
- Selected EF: Truck transport (including parking, usage, and infrastructure) (100%) - Europe: 0.09 kgCO2e/t.km

c) *Transportation of medication between the AGEPS and the hospital*

The Procurement and Distribution Service (SAD) of the General Agency for Health Products (AGEPS) ensures the provision of drugs and specific pharmaceutical health products that have been evaluated and referenced by another department within the Hospital Pharmacy Division of AGEPS, catering to all 37 AP-HP establishments[4]. This Hospital Pharmacy (PUI) maintains stocks of various health products at two separate locations situated on Lavoisier Street in Nanterre. The average distance between the storage facility of AGEPS and the hospitals has been estimated at around 25 km, calculated using the Google Maps tool for

[2] https://bee.citeo.com/

[3] https://bee.citeo.com/

[4] Outside Berck Maritime Hospital, Paul Doumer Hospital, Hendaye Maritime Hospital, San Salvadour Hospital, and Home Hospitalization.

truck routes. To accommodate potential traffic issues and other factors, a conservative estimate of 30 km was adopted.

In our initial approach, we consider drugs to be primarily transported by truck between AGEPS and the hospitals, with a default transport distance of 30 km. While some drugs may not go through AGEPS, we have focused on the predominant scenario.

- Selected Emission Factor (EF): Unspecified Truck Transport in France (comprising fleet, usage, and infrastructure) (50%): 0.270 kgCO2e per tonne-kilometer.

h. *Formulation and packaging*

Energy ratios

When information regarding the formulation and packaging of the medication is unknown, the following assumptions are adopted:

Type	Energy	Ratios
Dry forms	Electricity	- HIGH Assumption: 942 kWh / kg API - MEDIUM Assumption: 659 kWh / kg API - LOW Assumption: 94 kWh / kg API
	Natural Gas	- HIGH Assumption: 1 066 kWh PCI / kg API - Hypothèse MOYENNE : 746 kWh / kg API - LOW Assumption: 107 kWh / kg API
Liquid forms	Electricity	- HIGH Assumption: 627 kWh / kg API - MEDIUM Assumption: 439 kWh / kg API - LOW Assumption: 63 kWh / kg API
	Natural Gas	- HIGH Assumption: 687 kWh PCI / kg API - MEDIUM Assumption: 481 kWh / kg API - LOW Assumption: 67 kWh / kg API
Solutions	Electricity	1,29 kWh / kg solution
	Natural Gas	0,03 kWh / kg solution

These ratios were estimated from the greenhouse gas emissions reports or Corporate Social Responsibility (CSR) reports of certain French pharmaceutical groups such as Delpharm, Sanofi, or Fresenius. Indeed, these companies have disclosed their energy consumption or greenhouse gas emissions[5] to comply with their regulatory obligations. The quantity of drugs produced is also specified in their publications.

Additionally, we calculated the average quantity of active substance per drug based on about sixty medications.

[5] This indirectly allows us to track their energy consumption.

These two sources allowed us to propose average energy ratios based on the quantity of active substance (HIGH assumption).

The HIGH assumption is the default assumption to select. Two other assumptions are proposed to account for differences between types of medications, especially those with large production volumes and often more optimized energy consumption:

- LOW Assumption: recommended for very inexpensive drugs, common drugs, available over-the-counter such as paracetamol, ibuprofen, etc.
- MEDIUM Assumption: recommended for moderately expensive drugs, generics, and some commonly prescribed antibiotics (e.g., amoxicillin, etc.)

These latter two assumptions are the result of comparisons with other scientific publications and life cycle analyses on this type of medication (see Annex 3).

Our estimation ratios relate to the quantities of active substance and not to the overall weight of the drug because the mass of excipients is almost always estimated, and this would further increase uncertainty. For solutions, however, the ratios are calculated relative to the total mass of the solution.

The ratios include both energy consumption related to production and packaging since it is impossible to distinguish between the two with this methodology.

Calculations and sources are detailed in Excel spreadsheets - Annexes 3 and 4.

Production location

As an initial approach, the medication is considered to be manufactured in Base (refer to Assumptions & Sources > Transportation). Therefore, the default emission factors applied are as follows:

- Electricity - OECD Europe: 0.218 kgCO2e/kWh
- Natural Gas - Europe: 0.244 kgCO2e/kWh LHV

i. Material waste during formulation

In the preliminary assessment, a loss rate of 4.5% is considered. This rate is derived from the ABPI Blister Pack Carbon Footprint Tool[6]:

- 2% loss during the formulation process
- 0.5% during packaging
- 2% loss during distribution

[6] https://www.abpi.org.uk/media/1rdb3sno/carbon_blister_pack.xlsm

j. *Packaging material waste*

We consider a 4.5% loss rate for packaging materials in our initial assessment. This rate is derived from the ABPI Blister Pack Carbon Footprint tool:

- 2.5% loss during production
- 2% loss during distribution
-

k. *End-of-life for packaging and package leaflet*

In cases where information is lacking, the default assumptions for applying end-of-life emission factors are as follows:

ASSUMPTIONS	Bottle	Ampoule	Pouch	Tablet	Capsule	Bag	Syringe
Plastic	Packaging - Petro-derived rigid plastic (PP) - Average end-of-life through waste management system		Packaging - Petro-derived flexible plastic PE - Average end-of-life through waste management system	Packaging - Petro-derived rigid plastic (PP) - Average end-of-life through waste management system	Packaging - Petro-derived rigid plastic (PP) - Average end-of-life through waste management system	Packaging - Petro-derived flexible plastic PE - Average end-of-life through waste management system	Packaging - Petro-derived rigid plastic (PP) - Average end-of-life through waste management system
Aluminum/ Steel	Packaging - Aluminum - Average end-of-life through waste management system	Packaging - Aluminum - Average end-of-life through waste management system	Packaging - Aluminum - Average end-of-life through waste management system	Packaging - Aluminum - Average end-of-life through waste management system	Packaging - Aluminum - Average end-of-life through waste management system	Packaging - Aluminum - Average end-of-life through waste management system	Healthcare Waste (HCW) - Incineration
Glass	Household residual waste - Average end-of-life	Healthcare Waste (HCW) - Incineration					Healthcare Waste (HCW) - Incineration
Cardboard	Packaging - Cardboard - Average end-of-life through waste management system	Packaging - Cardboard - Average end-of-life through waste management system	Packaging - Cardboard - Average end-of-life through waste management system	Packaging - Cardboard - Average end-of-life through waste management system	Packaging - Cardboard - Average end-of-life through waste management system		Packaging - Cardboard - Average end-of-life through waste management system
Paper						Packaging - Cardboard - Average end-of-life through waste management system	

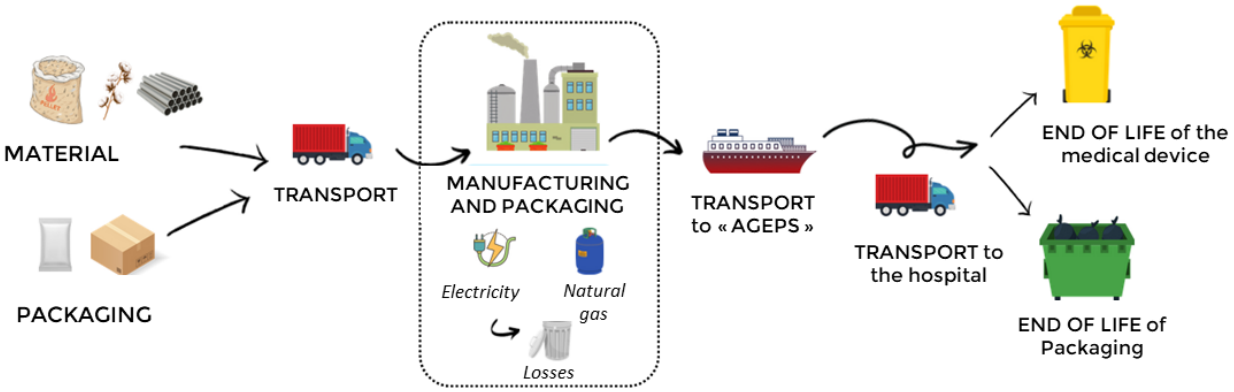
If the user chooses the "default" option to calculate packaging emissions, the emissions linked to the end-of-life of the packaging are also automatically computed.

ASSESSING THE CARBON FOOTPRINT OF A MEDICAL DEVICE ››

1. Global methodology

Definition: A medical device is a health product designed by its manufacturer for use in diagnosing, preventing, controlling, treating, or alleviating a disease or injury. [11]

The methodology for calculating the carbon footprint of a medical device is based on ISO 14040 standard recommendations and ADEME's GHG Assessment Method. It is categorized as a "Simplified LCA approach" because it employs a standardized and simplified life cycle (refer to diagram below). This Simplified LCA covers the entire life cycle from production to disposal. Within this simplified life cycle model, users must input specific activity information and data for each stage to a particular device.



Simplified life cycle of medical device production and usage at AP-HP

The Life Cycle Assessment (LCA) methodology necessitates the definition of the Functional Unit before proceeding with calculations. The ISO 14044 standard defines the Functional Unit as the "*Quantified performance of a product system for use as a reference unit in an LCA.*" The purpose of the Functional Unit is to establish a benchmark against which activity data will be defined and standardized, ensuring comparability of LCA results on a consistent basis.

In the context of calculating the carbon footprint of a medical device using this methodology, the **Functional Unit** defaults to **the smallest possible unit of the device** (e.g., 1 pump needle, 1 syringe 20 ml, 1 hair net, etc.). However, users have the option to provide additional details in the name/title of the calculation, depending on the product's packaging (e.g., 1 pack of 5 sterile compresses, 1 pair of shoe covers, etc.).

The carbon footprint results of medical devices, once calculated, are stored in a database of emission factors. This database is accessible to all users and applicable to all healthcare pathways. Each result includes an associated uncertainty, which is also documented in the database (refer to "Uncertainty").

2. Equipment & required information

To determine the carbon footprint of a medical device, the following information is necessary:

- Technical data sheets of the products, detailing their weights and types of materials used, or at least their dimensions (for further information, refer to estimation methodology "Assumptions & Sources > Materials").
- Logistic information about the product's packaging, including the quantity of medical devices per box, number of boxes per carton, and number of cartons per pallet.
- Within AP-HP, this data can be found on the « PIC Achat » and « AGEPS » websites:
  - ⇨ https://webacha.aphp.fr/accueil
  - ⇨ Marchés Equipements et Produits de santé (ap-hop-paris.fr)
- Optionally, a sample of the medical device is helpful for conducting weighings, especially if technical data sheets are unavailable or incomplete.

3. Detailed methodology

Our methodology is based on a range of activity data, which can sometimes be challenging to gather. When actual data is available or known, it's advisable to input them directly into the tool rather than relying on default values. In cases where actual data is unavailable, the tool provides estimates as an initial approximation. These estimates are outlined in the "Assumptions & Sources" section, with their underlying sources also detailed there.

For each item listed below, users need to input activity data and specify the data collection methodology, i.e., how they acquired this information. This process is crucial for calculating the uncertainty associated with the estimated carbon footprints (refer to "Uncertainty").

a. General data

This section allows users to input general information about the medical device for which they intend to calculate the carbon footprint:

- Device Name: Please refer to "Nomenclature" section
- Sterile: Indicate whether the device is sterile or not.
- Number of Uses: If the device is single-use, please enter "1".
- Quantity per Box: Specify the number of units contained in one box.

- Packaging 1 - Boxes per Carton
- Packaging 2 - Cartons per Pallet
- Supplier Reference
- SAP Number: Internal reference number at AP-HP.
- Manufacturer Name
- Calculation Manager: First and last name of the individual responsible for calculating this carbon footprint.
- Manager's Role: Specify the role and organization of the individual responsible for the calculation.
- Calculation Date: Date when the calculation was performed.

b. *Materials*

The quantities of materials are determined either from technical data sheets or by weighing the device. However, weighing may not always be precise and could introduce bias depending on the characteristics of the scale used. Therefore, an alternative estimation methodology for quantities is also provided in the " **HELP – MD Material weigh** " tab (refer to Assumptions & sources > Materials). Quantities should be categorized by the type of material:

- Plastic
- Metal
- Fiber
- Cardboard & other
- Electronic components
- Chemicals

These quantities are entered in grams, except for electronic components, where the unit must be selected based on the type of component and the emission factor (multiple units are possible: unit, kg, m, or m2).

c. *Packaging (Materials and processing)*

The impacts associated with packaging manufacturing and the device's instructions are assessed by either weighing these components (in grams) or utilizing the default methodology outlined in the "Assumptions & sources > Packaging" section.

The packaging mass should be itemized and recorded according to various material types (such as cardboard, paper, aluminum, plastic, etc.), expressed in grams.

The packaging scope encompasses the entire packaging process: from pallets to medication boxes. Users specify within the tool whether the packaging pertains to pallets, cardboard, boxes, or individual units. The calculation formulas enable the determination of the proportion of emissions associated with a single unit of the medical device.

Finally, users select emission factors corresponding to packaging materials. They also choose, from the subsequent table, the emission factors associated with the processing of these packaging materials, with a maximum of two processing methods per material.

d. *Upstream transport from the factory*

a) *Material transport*

These journeys represent the distances covered by various materials to reach the medical device production facility. They should be provided in kilometers per type of material. The greenhouse gas emissions associated with these transports are calculated in the tool based on the distance traveled and the weight of the materials used.

b) *Packaging transport*

These transports include:

- Firstly, the transportation of packaging materials to the site where the packaging is produced;
- Secondly, the transportation of the packaging to the site where the medical device is packaged.

Distances for these transports are measured in kilometers. The associated greenhouse gas emissions are calculated in the tool based on the distance traveled and the weight of the packaging materials.

In cases where this information is unavailable, estimates are provided in the "Assumptions & sources > Upstream Transport" section.

e. *Downstream transportation from the factory*

The downstream transportation from the factory is segmented into three phases:

- The transport of the medical device to its packaging site. If this site coincides with the production facility, the distance may be 0 km.
- Moving the medical device from the packaging site to the procurement center (the AGEPS for AP-HP) if applicable.
- Conveying the medical device from the procurement center to the hospital.
- If the device doesn't pass through the procurement center, it's necessary to complete only one of the last two lines.

These distances are measured in kilometers. The associated greenhouse gas emissions are calculated based on this distance and the total weight of the device (the sum of the weights of various materials and packaging).

For computing transport distances, we suggest utilizing the following tools:

- For sea journeys: Online Freight Shipping & Transit Time Calculator at Searates.com
- For road transportation: Google Maps

In cases where this information is unavailable, estimations are provided in the "Assumptions & sources > Downstream Transport" section.

f. Manufacturing process

This emission category refers to the energy usage (electricity, gas, etc.) at the medical device manufacturing facility, measured in kWh (PCI kWh for natural gas) per kilogram of materials.

Energy consumption data should be provided for each material type, excluding electronic components and chemicals. It is assumed that the greenhouse gas emissions associated with their production are already accounted for in the emission factors listed in the "Materials" section.

If data is unavailable, default consumption ratios are provided in the "Assumptions & sources > Manufacturing Process" section.

g. Packaging process

This category of emissions refers to the energy consumption (electricity, gas, etc.) at the packaging facility, expressed in kWh (PCI kWh for natural gas) per kilogram of packaging. Default ratios are provided in the "Assumptions & sources > Packaging Process" section.

h. Sterilization

If the medical device is sterile, the following details should be entered in the tool:

- Sterilizer capacity: the number of Euro pallets it can accommodate
- Duration of the sterilization cycle in hours
- Electrical power of the sterilizer in watts
- Average concentration of ethylene oxide over the cycle duration in g/L.

The electricity consumption needed by the sterilizer is estimated based on its power and cycle duration. It is then converted into a functional unit using data related to the sterilizer's

capacity and logistical information (number of devices per box, number of boxes per carton, number of cartons per pallet).

Fugitive emissions of ethylene oxide are estimated based on its concentration and the volume of the sterilizer chamber. The following assumptions are used to calculate the chamber volume:

Number of Euro pallets	Chamber volume (m3)
4	12,7
8	24,8
10	30,6
12	36,9
16	49
24	71,8
32	95

Source: ETO sterilization solutions, RSD [12]

This **method is highly simplified** and imprecise, as it does not consider variable temperature and pressure conditions. It assumes that all ethylene oxide is released into the atmosphere, with no consideration for other mixed gases (carbon dioxide, etc.). Consequently, the default uncertainty is set at 100% (similar to that of "consumption ratios").

It's important to note that the tool's methodology only evaluates the impact of **ethylene oxide sterilization**. Other sterilization methods are not currently supported. Default values can be found in the "Assumptions & Sources > Sterilization" section.

i. Packaging material waste

Throughout the packaging process, some of the materials (such as cardboard, paper, aluminum, plastic, etc.) are inevitably lost or discarded. This loss is measured as a percentage. Assumptions regarding the percentage of material losses can be found in the "Assumptions & sources > Packaging material waste" section.

j. End of life

a) Medical device end of life

The environmental impacts related to the disposal of the medical device at the end of its lifecycle are evaluated by choosing the method of waste management: recycling, storage, incineration, or average end-of-life disposal method for the material.

b) End-of-life treatment for packaging and Instructions

The assessment of the environmental impacts related to the disposal of medical device packaging and instructions involves selecting the waste management method for these materials: recycling, storage, incineration, or average end-of-life disposal method for the material.

k. Total carbon footprint

The total carbon footprint of the medical device comprises the sum of the greenhouse gas emissions calculated for each of the items listed above. An "emission factor" is then derived for this device, which can be stored in the database for use in calculating the carbon footprint of a procedure or patient pathway (see archiving protocol).

l. Avoided emissions due to end-of-life

Avoided emissions are those emissions that are calculated separately from the carbon footprint. They result from the recovery of materials and energy from waste, including both materials and packaging. Essentially, these emissions represent the greenhouse gases that have been prevented from being released into the atmosphere due to the avoidance of producing new materials and/or conventional energy.

These avoided emissions do not affect the emission factor associated with the medical device

4. Assumptions & Sources:

Several assumptions are made in this method, including considerations such as transport distance and energy consumption ratios per kilogram of material or packaging. It's recommended to adjust these estimates within the tool using real data from the specific case study whenever possible.

a. *Materials*

When the exact weight of the different materials used in the medical device are not provided in supplier documentation or technical data sheets, there are a couple of methods to estimate this information.

- Weighing the device using a scale
- Estimating material quantities using the "**HELP - DM Material weigh**" tab.

The estimates provided in the " **HELP - DM Material weigh** " tab are based on a particular methodology:

Each component of the medical device is simplified to basic shapes such as rectangular prisms (solid or hollow), cylinders (solid or hollow), or spheres (solid or hollow).

The volume of each component is then calculated using the appropriate formula for its shape:

For a rectangular prism: Length × Width × Height (where Length is the length, Width is the width, and Height is the height of the rectangular prism)."

- ⇨ Rectangular prism: The volume is calculated using the formula L × l × h (where 'L' represents the length, 'l' stands for the width, and 'h' denotes the height of the rectangular prism)
- ⇨ Cylinder: The volume is calculated using the formula $\pi \times r^2 \times h$ (where 'r' represents the radius and 'h' stands for the height of the cylinder)
- ⇨ Sphere: The volume is calculated using the formula $4/3 \times \pi \times r^3$ (where 'r' represents the radius of the sphere)

When dealing with hollow shapes, we calculate the volume by subtracting the volume of the empty space from that of the solid shape. Detailed information about densities and their sources is provided in the following table:

Materials x	Density (kg/m³)	Source	Link
PEBD	927,5	Eco-profiles of the European Plastics Industry_ PlasticsEurope 2005	http://www.inference.org.uk/sustainable/LCA/elcd/external_docs/ldpe_311147f4-fabd-11da-974d-0800200c9a66.pdf
PEBBD	920		
PEHD	950		
PP	910		
PS	1040	« Matières plastiques - MS.LP - Académie de Dijon »	http://mslp.ac-dijon.fr/IMG/pdf/matieres_plastiques.pdf
PSE	30	« Polystyrène expansé ou PSE_Techniques de l'ingénieur_2008 »	https://www.techniques-ingenieur.fr/base-documentaire/materiaux-th11/matieres-thermoplastiques-monographies-42147210/polystyrene-expanse-ou-pse-am3341/proprietes-du-polystyrene-expanse-am3341niv10004.html
PVC	1380	Wikipédia	https://fr.wikipedia.org/wiki/Polychlorure_de_vinyle
Polyurethane	1100	« Matières plastiques - MS.LP - Académie de Dijon »	http://mslp.ac-dijon.fr/IMG/pdf/matieres_plastiques.pdf
Polycarbonate	1200		
Acier inox	7850	« Propriétés mécaniques des certains matériaux / Daniel GAY, Jacques GAMBELIN, "Dimensionnement des structures",édition Hermès 1999 »	https://www.enib.fr/~mecatro/edm/S4/2021P/propri%C3%A9t%C3%A9s_m%C3%A9caniques_de_certains_mat%C3%A9riaux_1.pdf
Aluminum Alloys	2800		
Cellulose Fibers	1500	« INRS - Fibres de cellulose - Fiche toxicologique n°282 »	file:///C:/Users/4210122/Downloads/FicheTox_282.pdf
Silicone	525	« Moyenne masses volumiques Elastomères de silicone - MEREFSA »	https://www.merefsa.com/fr/produits/elastomere-de-silicone_kgr/
Cotton	448	« DAGRIS - Dictionnaire du coton Densité universelle »	http://hubrural.org/IMG/pdf/dagris_dictionnaire_coton.pdf

b. *Packaging*

The tool can automatically estimate the carbon footprint of packaging (including materials and transformation) by selecting the "default" option. This estimation relies on logistical and packaging details. The calculations are performed automatically in the "Packaging Estimation" tab, and the methodology is explained in Annex 2 of the Excel spreadsheet.

Annexe 2_Méthodologie_Estir

To estimate greenhouse gas emissions linked to pallet usage, it's recommended to divide the average weight of a Euro pallet (25 kg) by the average number of uses (30 times), resulting in approximately 833 grams per use.

Here are some important methodological points:

We convert greenhouse gas emissions related to packaging and material quantities (in grams) to a per-unit basis using logistical data (such as the number of medical devices per box, carton, or pallet).

Different types of packaging (excluding individual packaging) are assumed to be cubic by default, simplifying the model. This tends to underestimate the packaging surface area. To adjust for this, it's assumed that the packaging fully occupies the space of the upper packaging.

By default, uncertainties in activity data are set at 50%, representing default estimates.

c. *Summary table of default transport assumptions for medical devices.*

Steps	Distances	Transport
Materials	**250 km** between the materials manufacturing plant and the factory (plastics, metals, fibers, cardboard, electronic components, chemicals)	Truck transport - Asia
Packaging	**500 km** from the materials source to the packaging facility, then from there to the packaging site	Truck transport - Asia
Medical devices	**250 km** to the packaging site	Truck transport - Asia
	250 km from the factory in China to the port	Truck transport - Asia
	19 000 km between Shanghai and Plailly	Transport by container ship
	45 km to the AGEPS	Truck transport--Europe
	30 km between the AGEPS and the hospital	Truck transport - France

The sources for these assumptions are explained in the following sections.

d. Materials transport from the factory

The default values used for materials transport from the factory are initially based on carbon footprint calculations for packaging found in the BEE[7] tool developed by Citeo to assess the environmental impact of packaging.

a) Materials transport

Initially, materials are assumed to be manufactured approximately 250 km away from the factory and are transported by truck.

- Selected EF: Truck transportation (covering fleet, usage, and infrastructure) (100%), with an emission factor (EF) of 0.125 kgCO2e per tonne per kilometer (Asia).

b) Transport of packaging and instructions

- Transport of materials to the packaging production site: 250 km.
- Transport of packaging to the packaging site: 250 km.
  ⇨ Selected EF: Truck transport (including fleet, usage, and infrastructure) (100%), - Asia: 0.125 kgCO2e/tonne.km

e. Downstream transport from the factory

a) Transport of the medical device between the factory and the packaging site:

The default values used initially are sourced from examples of carbon footprint calculations for packaging in the BEE tool developed by Citeo for assessing the environmental impact of packaging. This distance is estimated at 250 km.

- Selected EF: Truck transportation (covering fleet, usage, and infrastructure) (100%), RAS - Asia: 0.125 kgCO2e per tonne per kilometer

b) Transport of the medical device between the packaging site and the AGEPS:

Initially, the medical device is considered to be manufactured in China, specifically at China Medical City. According to market analysis by BQ+ [13], China Medical City, located in the Jiangsu province, is one of the largest pharmaceutical industrial parks in China in terms of the number of companies, with over 110 medical device manufacturers. Therefore, the selected route is a journey between China Medical City and the AGEPS. The default modes of transport and distances chosen are as follows:

- 250 km by truck between China Medical City and Shanghai (source: Google Maps)

  ⇨ Selected EF: Truck transport (covering fleet, usage, and infrastructure) (100%), - Asia: 0.125 kgCO2e per tonne per kilometer

[7] https://bee.citeo.com/

- 19,000 km of maritime transport between Shanghai and Plailly (source: Online Freight Shipping & Transit Time Calculator at Searates.com).
    - ⇨ Selected EF: Container ship - Dry - Asia - Northern Europe: 0.006 kgCO2e per tonne per kilometer
- 45 km from Plailly to the AGEPS (source: Google Maps)
    - ⇨ Selected EF: Truck transportation (covering fleet, usage, and infrastructure) (100%) - Europe: 0.09 kgCO2e per tonne per kilometer

c) *Transport of the medical device between the AGEPS and the hospital*

Initially, the medical device is considered to be transported by truck (default transport distance: 30 km). The average distance between the AGEPS and hospitals of the AP-HP has been calculated (refer to "Calculating the Carbon Footprint of a Drug > Assumptions and Sources > Downstream Transport" section). Although most medical devices do not pass through the AGEPS, this estimate remains a reasonable approximation, considering the overall emissions calculation.

⇨ Selected EF: Unspecified truck transportation in France (covering fleet, usage, and infrastructure) (50%): 0.270 kgCO2e per tonne per kilometer

f. *Manufacturing process*

When information regarding the production of the medical device is unknown, the following assumptions are adopted:

Energy ratios

Type	Energy	Ratios
Plastic materials	Electricity	4,17 kWh / kg
	Natural gas	2,35 kWh PCI / kg
Cardboard materials	Electricity	2,08 kWh / kg
	Natural gas	1,17 kWh PCI / kg
Fibrous materials	Electricity	- UU: 6,04 kWh / kg - Reusable: 295,84 kWh / kg

	Natural gas	- UU: 3,40 kWh / kg - Reusable: 166,63 kWh / kg
Metallic materials	Electricity	5,73 kWh / kg
	Natural gas	3,22 kWh PCI / kg
Electronic components	Electricity	0 kWh / kg
	Natural gas	0 kWh PCI / kg
Chemical products	Electricity	0 kWh / kg
	Natural gas	0 kWh PCI / kg

These ratios have been estimated based on emission factors from the ADEME's "Forming" database or scientific studies such as Life Cycle Assessment. Calculations and sources are detailed in the Excel spreadsheet - Annex 5:

Annexe 5_Méthodologie_Ratio

Manufacturing location

Initially, we assume that the medical device is manufactured in China, specifically at China Medical City. This location, according to market analysis by BQ+ [12], is one of the largest pharmaceutical industrial parks in China, boasting over 110 medical device manufacturers. Consequently, the default emission factors used are as follows:

- Electricity - China (People's Republic of China): 0.614 kgCO2e per kWh
- Natural gas - Europe: 0.244 kgCO2e per kWh LHV[8]

g. Packaging process

To estimate the energy consumption associated with packaging medical devices, two ratios are used:

- The first ratio, for electricity, is 0.739 kWh per kg of packaging.

[8] We selected the 'Europe' FE option due to the lack of more detailed data

- The second ratio, for natural gas, is 0.416 kWh per kg of packaging.

These ratios have been derived from emission factors collected via the BEE Citeo tool v 3.04. Detailed calculations and sources can be found in the Excel spreadsheet - Annex 6:

Annexe 6_Méthodologie_Ratio

Packaging location

Similar to manufacturing, we assume that the medical device is packaged in China by default. Therefore, the default emission factors used are as follows:

- Electricity - China (People's Republic of China): 0.614 kgCO2e per kWh
- Natural gas - Europe: 0.244 kgCO2e per kWh LHV[9]

h. *Sterilization*

In the absence of actual data, the following assumptions are employed:

- Sterilizer capacity: 16 Euro pallets
- Total sterilization cycle duration: 12 hours
- Sterilizer power: 29,000 Watts
- Ethylene oxide concentration: 1 g/L
- *Source:* Example of a stainless-steel sterilizer (Annex 7)

Annexe 7_ Exemple caractéristiques techn

These data are highly approximate. In particular, the quantity of ethylene oxide depends on temperature and pressure conditions. The uncertainty has been automatically set to 100%.

i. *Packaging material waste*

Initially, a material loss rate of 4.5% is considered at the packaging process level.

[9] We opted for the 'Europe' FE because there weren't more specific data available.

This loss rate comes from the ABPI Blister Pack Carbon Footprint Tool, mentioned in the Methodology - Medicines section

j. End of life

a) End of life for packaging and instructions

In the absence of information, default assumptions to consider for the application of emission factors related to the end of life of packaging are detailed in the following table.

ASSUMPTIONS	**MD with bi-material packaging (paper + flexible plastic)**	**DM with rigid plastic packaging**
Plastic	Packaging - Petro-sourced PE flexible plastic - - Average end-of-life process	Petro-sourced PP rigid plastic, other packaging - Average end-of-life process
Cardboard	Packaging - Cardboard - Average end-of-life process	Packaging - Cardboard - Average end-of-life process
Paper	Packaging - Cardboard - Average end-of-life process	Packaging - Cardboard - Average end-of-life process

ASSESSING THE CARBON FOOTPRINT OF A MEDICAL PROCEDURE ⟩⟩

1. Global methodology

The presented methodology is used to quantify the emissions of a medical procedure (regardless of its nature: surgery, biological tests, imaging, etc.).

2. Equipment and information required

Assessing the carbon footprint of a procedure may require estimating, in advance, the carbon footprint of the various medications and/or medical devices used during that procedure.

3. Detailed methodology

The different steps considered in this method are as follows:

a. General data

In this section user can fill in general information regarding the medical procedure:

- Procedure Name: Refer to "Used Cross-Cutting Protocols / Archiving" section
- CCAM Code (optional)
- Number of staff: the scope includes only healthcare professionals directly involved in the calculated medical procedure, i.e., those with close contact with the patient or the site of the procedure. Personnel such as receptionists, security, cleaning staff, and support functions are excluded from the scope.
- Total duration of the medical procedure: the procedure time is expressed in minutes. It includes all moments of interaction with the patient, as well as preparation and cleaning related to the examination. Preparation times for common areas and staff breaks are excluded from the scope.
- Calculation Manager: the name of the person responsible for calculating the carbon footprint of the procedure
- Date: Date of calculation
- Service and site: The service and site where the medical procedure took place.

b. Staff

The greenhouse gas emissions (GHG) from personnel include emissions related to commuting and staff meals.

- GHG **emissions from commuting** are calculated using the following formula:

$$Commute\ emissions = \frac{Number\ of\ personnel\ \times\ rocedure\ duration\ (min)\ \times Average\ commute\ emissions\ per\ employee)}{Number\ of\ days\ worked\ per\ year\ \times\ Number\ of\ hours\ worked\ per\ day\ \times\ 60}$$

Where:

- Number of days worked per year 226 days[10]
- Number of hours worked per day: 8 hours
- Average annual commute emissions per employee: 901 kgCO2e/year/employee (refer to Emission Factors & Sources > Staff).

- GHG emissions from staff meals are calculated using the following formula:

$$Meal\ emissions = \frac{Number\ of\ personnel\ \times\ Procedure\ duration\ (min)\ \times\ Average\ meal\ emissions\ per\ employee}{Number\ of\ hours\ worked\ per\ day\ \times\ 60}$$

Where:

- Number of hours worked per day: 8 hours
- Average emissions per meal at AP-HP: 2.77 kgCO2e/meal (refer to Emission Factors & Sources > Personnel).
- It is assumed that each staff member consumes one meal per day.
- The average GHG emissions per employee per day are therefore 6.76 kgCO2e.

c. Patient consumables

This category includes all **consumables and personal protective equipment** used or worn by the **patient** during the medical procedure. The user selects the consumable from the dropdown menu.

[10] 365 days in 2022 - 52 Sundays - 52 Saturdays - 10 public holidays (excluding Whit Monday) - 25 paid vacation days.

d. *Medications and anesthesia*

This category encompasses all **medications consumed by the patient** during the medical procedure. The medication is selected by the user from the dropdown menu. The exact title can be quickly found by typing the medication name into the "Search Help" cell. The user must then specify the corresponding **unit and the quantity used** during the medical procedure.

Example: if 2 pouches of 50 ml of paracetamol "Paracetamol Mac 500 mg / 50 ml - injectable solution pouch" are used, the user should enter "ml" in the unit field and "100" in the quantity field.

Anesthetic gases are treated separately. Four halogenated gases are available in the tool: sevoflurane, desflurane, isoflurane, and nitrous oxide. The quantities used should be entered in ml.

e. *Medical devices, consumables, and surgical instruments*

This category includes all **medical devices, consumables, and personal protective equipment used by the personnel** during the medical procedure. **Surgical instruments**, **various autoclavable devices**, and **sterilization containers** are treated separately.

Reusable surgical instruments:

The tool offers two options:

- Small-sized instruments (e.g., anatomical forceps, scissors, scalpels...) – between 20 and 100 grams;
- Medium to large-sized instruments (e.g., needle holders, hemostatic forceps...) – over 100 grams.

The user must specify the **number of instruments used** and the average **number of uses** for these instruments. For reference, emission factors for instruments have been calculated by default for an average of 50 uses. The source of emission factors for surgical instruments is detailed in the section "Emission Factors & Sources > Surgical Instruments".

In a later version of the tool, emission factors may be refined to have more precise categories of instruments. It is also possible to use the "Medical Devices" tab to calculate the carbon footprint of each instrument (refer to the section " Assessing the carbon footprint of a medical device ").

Other Autoclavable Devices

This category includes all reusable devices and equipment that undergo sterilization, other than surgical instruments (e.g., optics, surgical motors, cables, etc.).

It may be necessary to have previously calculated the carbon footprint of these devices using the "Medical Devices" tab or to have researched corresponding Life Cycle Analyses.

The emission factors must then be or copied into the "EF Surg. Instr&MD ste" tab of the tool.

Sterilization containers and baskets

This category includes reusable containers and baskets containing sterilizable instruments and devices. The tool offers a variety of container and basket sizes and shapes in the dropdown menu.

The user must specify the **number of containers/baskets used** and the average **number of uses** for these containers/baskets.

For reference, emission factors for instruments have been calculated by default for an average of 200 uses. The source of emission factors for surgical instruments is detailed in the section "Emission Factors & Sources > Sterilization Containers".

Note: In the model of this version of the tool, the number of baskets and containers used determines the emissions related to the sterilization of reusable instruments and devices (refer to "Detailed Methodology > Cleaning/Disinfection/Sterilization"). It is therefore imperative to accurately fill in this section.

f. Reagents

Diagnostic reagents refer to any chemical or biological substance specially prepared for in vitro use, alone or in combination, in medical biology analyses. Reagents are distinguished from medications by their almost exclusive in vitro use.

The data to be entered into the tool are purchase **volumes per reagent excluding taxes** (in euros) as emission factors are **monetary ratios**.

g. Equipment

Two types of equipment need to be specified:

- Specific Healthcare Equipment;
- Classic Equipment (e.g., screens, computers...)

Specific equipment

The user provides the following information in the tool:

- Equipment name
- Equipment weight in kilograms

- Equipment lifespan in years11 (It is possible to rely on the generally applied accounting depreciation for the targeted equipment)
- Number of procedures per year
- Electrical power of the equipment in watts
- Duration of equipment use during the medical procedure in minutes

The tool automatically calculates the greenhouse gas emissions related to the production of the equipment. The average emission factor "Machinery - manufacturing" is used (refer to "Emission Factors & Sources > Equipment"). This carbon footprint is attributed to the medical procedure by dividing it by the lifespan and the number of procedures per year.

Additionally, the electricity consumption related to the equipment is estimated based on the electrical power and the duration of use using the following formula:

$$Equipment\ electrical\ consumption\ (kWh) = (Power\ (W) \div 1000) \times (Duration\ of\ use\ (min) \div 60)$$

The user must choose the emission factor for the electricity used (France for AP-HP).

Ancillary Classic Equipment

The user selects the emission factor corresponding to the desired equipment and provides the quantity and lifespan.

h. *Cleaning / Disinfection / Sterilization*

In a hospital setting, cleaning and disinfection are essential to ensure safety and quality of care.

Cleaning and disinfection of floors

Regarding the cleaning and disinfection of floors related to the studied medical procedure, the user provides:

- The quantity of detergent and/or disinfectant in milliliters
- Water consumption in liters
- Any consumables or PPE (gloves, masks, etc.) used by staff for cleaning

[11] It is possible to rely on the standard accounting depreciation typically applied to the targeted equipment: 3 years for computer equipment (computers, etc.), 5 to 10 years for office equipment and furniture, and 7 years for imaging equipment.

Cleaning and disinfection of surfaces

Regarding the cleaning and disinfection of surfaces related to the studied medical procedure, the user provides:

- The quantity of detergent and/or disinfectant in milliliters;
- Water consumption in liters;
- Any consumables or PPE (gloves, masks, etc.) used by staff for cleaning.
- Manual pre-disinfection of instruments
-

Manual pre-disinfection of instruments

Regarding the manual pre-disinfection of instruments and sterilizable devices, the user provides:

- The quantity of detergent and/or disinfectant in milliliters
- The consumption in liters
- Any consumables or PPE (gloves, masks, etc.) used by staff for cleaning

Please note, the emission factors for "Hygiene & Cleaning" are not specific to the healthcare sector and have been calculated based on standard products not meeting the hygiene standards of the hospital environment. If there is any doubt about an emission factor, it is recommended to use the most conservative factor, "Disinfectant." The emission factors for "Hygiene & Cleaning" are calculated based on a data in kilograms. A density of 1.178 g/ml has been used in the tool to convert the milliliters provided by the user into kilograms. This information comes from the safety data sheet of the product "Anios Pro DETERGENT DISINFECTANT ACID" from Anios laboratories [14]

Transport to the sterilization unit:

After a medical procedure, the sterilizable instruments and devices are sent to the sterilization department, which can be internalized or outsourced. In case of outsourcing, regular shuttles handle the transport to the central sterilization unit.

The user provides the distance in kilometers between the care unit and the sterilization unit and selects the mode of transportation.

Only **one sterilization method** has been modeled in this initial version of the tool: **hot sterilization by autoclave**. Sterilization typically occurs in two stages:

Automated disinfection (washer-disinfector):

The purpose of washers is to prepare products/devices for sterilization in an autoclave (for example, removal of residues such as blood and proteins on surgical instruments) or for disinfection (semi-sterilization) in preparation for later use.

Information to be provided:

- Washer Capacity in number of standard DIN baskets (cycle of instruments and baskets) and in number of DIN containers (container cycle)
- Average load of the washer in % (this corresponds to the portion actually occupied by instruments or devices in the washer for each washing cycle)
- Electrical power of the washer-disinfector in watts
- Washing cycle duration in minutes
- Consumption of detergent-disinfectant per washing cycle in liters
- Water consumption per washing cycle in liters.

Default assumptions are proposed initially in the "Assumptions & Sources > Cleaning / Disinfection / Sterilization" section.

The user also selects the emission factor for electricity (France for AP-HP).

Automatic calculations:

Proportion of instruments & MD in the total capacity of the washer

The tool automatically calculates the portion of the washer occupied by sterilizable instruments and devices based on the **total number of sterilization baskets**. The tool calculates this total number by summing the DIN basket equivalents of each basket provided by the user (Refer to "Medical devices, consumables, and surgical instruments") with the following automatic assumptions:

Sterilization Basket Reference	DIN Basket Equivalent
Basket 1/1	1
Basket DIN	1
Basket 3/4	3/4
Basket 1/2	1/2

The percentage of devices and instruments is calculated based on the washer's capacity (in number of DIN baskets) and the average load.

Specifically, the tool accounts for all emissions from cycles where the washer's load exceeds the average load. For cycles where the average load is not reached, the tool accounts for the portion related to sterilizable devices and a portion of the unused capacity

of the washer. In these cycles, it is considered that the washer is filled with devices related to the procedure and other devices up to the average load. The unused portion of the washer (1 - Average load) % is accounted for by proportionally distributing it between the devices related to the procedure and the other devices.

The electricity consumption per cycle is estimated based on the power and duration of the cycle:

$$Washer\ electrical\ consumption\ (kWh) = (Power\ (W) \div 1000) \times (Cycle\ duration\ (min) \div 60)$$

The electricity consumption per cycle can be provided by the user (instead of using the power data formula) if this data is known.

Finally, the consumptions of detergent-disinfectant, electricity, and water related to the sterilization of instruments and devices for the procedure are calculated by multiplying the consumption per cycle by the proportion of devices in the total capacity of the equipment.

Sterilization (autoclave):

An autoclave is a device used to sterilize medical or laboratory equipment and kill all microorganisms and spores using high-pressure steam and temperature.

Information to be provided:

- Autoclave capacity in number of standard DIN Bakets.
- Average load of the autoclave in % (this corresponds to the portion actually occupied by instruments or devices in the autoclave for each cycle)
- Electrical power of the autoclave in watts
- Cycle duration in minutes
- Water consumption per cycle in liters

Default assumptions are proposed initially in the "Assumptions & sources > Cleaning / Disinfection / Sterilization" section.

The user also selects the emission factor for electricity (France for AP-HP).

Automatic calculations:

The tool automatically calculates the portion of the autoclave occupied by sterilizable instruments and devices based on the total number of sterilization containers. The tool calculates this total number by summing the DIN baskets equivalents of each container provided by the user (refer to "Medical devices, consumables, and surgical instruments") with the following automatic assumptions:

Sterilization basket reference	DIN basket equivalent
Basket 1/1	1
Basket DIN	1
Basket 3/4	3/4
Basket 1/2	1/2

More specifically, the tool accounts for all emissions from cycles where the autoclave load exceeds the average load. For cycles where the average load is not reached, the tool accounts for the portion related to sterilizable devices and a portion of the unused capacity of the autoclave. In these cycles, it is considered that the autoclave is filled with devices related to the procedure and other unrelated devices up to the average load. The unused portion of the autoclave (1 - Average load) % is accounted for by proportionally distributing it between the devices related to the procedure and the other devices.

The electricity consumption per cycle is estimated based on the power and duration of the cycle:

$$Autoclave\ electrical\ consumption\ \ (kWh) = (Power\ \ (W) \div 1000) \times (Cycle\ duration\ (min) \div 60)$$

This data can be provided by the user instead of using the formula if it is known.

Finally, the electricity and water consumption related to the sterilization of instruments and devices for the procedure are calculated by multiplying the consumption per cycle by the percentage of devices in the total capacity of the equipment.

Packaging

After sterilization, medical instruments and devices are packaged to meet hygiene and compliance requirements. The user provides the weight of plastic or fiber materials and selects the associated emission factors.

i. Laundry

This category corresponds to energy, water, and chemical consumption related to washing hospital textiles: flat linen (sheets, mattress covers, etc.) and staff workwear (gowns, tunics, trousers, etc.)

Flat linen

The user provides the weight in kilograms of flat linen used during the medical procedure. If the exact weight is not known, it can be estimated based on the following indications:

- Sheet: 500 g
- Mattress cover: 350 g

- Fitted sheet: 200 g
- Pillowcase: 160 g

Workwear

The total weight of workwear is automatically calculated in the tool based on the number of staff and the average weight of a work uniform (tunic of 300g + trousers of 500 g + clogs of 200g). This information comes from the references ordered by the central laundry service of the AP-HP (SCB).

The emission factors used for calculating greenhouse gas emissions related to the production of textiles are detailed in "Emission Factors & Sources > Laundry". For staff clothing, greenhouse gas emissions are attributed to the medical procedure based on the duration of the procedure compared to an 8-hour workday.

The user can provide an average duration of textile use, as well as average consumptions of electricity, water, gas, urban heating network, and chemicals per cycle, but data is provided in the "Assumptions & sources > Laundry" section. This data comes from the central laundry service of the AP-HP (SCB).

Finally, the user must provide the round-trip distance in kilometers between the laundry and the care unit.

j. Transport

This category corresponds to the potential transport of goods or items. The user selects the types of transport used and provides the distances traveled in kilometers as well as the weight of the packages in kilograms.

k. Building Energy

This category corresponds to the energy consumption (electricity, gas, etc.) of the building and equipment necessary for the medical procedure. The data to be provided is the number of square meters occupied. It is recommended to only consider the room where the procedure takes place. Other rooms are excluded from the scope (e.g., storage room, pharmacy, sterilization unit, patient waiting area, staff rest room, etc.).

Two types of energy consumption ratios per surface area have been provided based on the activity

- The tertiary sector: Day hospital - Consultation - Examination - Functional rehabilitation - Physiotherapy - Routine analysis laboratory - Conventional hospitalization
- Controlled Environment Zones: Operating theaters - Intensive care units - Cleanrooms (pharmacy, chemotherapy, organ retrieval) - Classified laboratories, etc.

l. Water Consumption

This category corresponds to the water consumption of the building and the equipment required for the medical procedure. Note that water consumption related to disinfection and sterilization should be reported in the dedicated category.

m. Deliverables and Documents

This category corresponds to the informational and awareness materials provided to patients by healthcare professionals, as well as all patient follow-up documents in paper format. The user selects the deliverables and documents used in the context of the procedure from the dropdown menu.

n. Digital Data Storage

This category corresponds to indirect GHG emissions related to the storage of digital data on the Picture Archiving and Communication System - PACS (for imaging procedures only). The user selects the type and quantity of examinations conducted as part of the medical procedure.

The associated emission factors are detailed in "Emission Factors & Sources > Digital Data Storage".

4. Assumptions & Sources

a. Cleaning / Disinfection / Sterilization

By default, the following assumptions are used:

Automated disinfection (washer)

- Washer capacity: 15 DIN baskets and 4 DIN containers
- Average load: 68%
- Detergent: 0.41 liters/cycle (400 ml of Septoclean + 12 ml of Mediklar special)
- Electrical power: approximately 14 kW
- Cycle duration: 60 minutes
- Water: 40 liters/cycle

These data are taken from the technical documentation for the Getinge 88 Turbo washer-disinfector.

Sterilization (autoclave)

- Autoclave capacity: 9 DIN baskets
- Average load: 68%
- Electrical power: 42 kW
- Cycle duration: 75 minutes
- Water: 120 liters/cycle

These data are extracted from the technical documentation for the Getinge HS6613 autoclave.

b. Laundry

The assumptions proposed in the following paragraph come from the central laundry service (SCB) of the AP-HP.

Purchase

As a first approximation, the assumptions for the number of uses are as follows:

- Flat linen (mattress covers, sheets, etc.): 33 times
- Workwear: 59 times.

Washing

By default, the assumptions are as follows:

- Electricity consumption per cycle: 0.36 kWh/kg of laundry
- Natural gas consumption per cycle: 0.15 kWh/kg of laundry
- Steam consumption (from the urban heating network): 1.19 kWh/kg of laundry
- Detergent consumption: 14 g/kg of laundry
- Water consumption: 2.62 L/kg of laundry

Transport

An average distance of 20 km is considered between the AP-HP hospitals and the laundry facility, located at the Pitié-Salpêtrière.

c. Building Energy

By default, the energy consumption assumptions are as follows:

Tertiary sector:

- Electricity: 120 kWh/m2/year
- Heating (natural gas): 152 kWh LHV/m2/year
- Controlled Environment Zones
- Electricity: 518 kWh/m2/year
- Heating (natural gas): 714 kWh LHV/m2/year

These ratios come from data calculated by the CIA Group Energy Performance on February 5, 2021. They correspond to the average values of 7 University Hospital Centers (CHU) for the year 2019. In a future version of the tool, new default assumptions may be proposed to account for the AP-HP's connection to the Parisian Urban Heating Company – CPCU (which emits significantly less greenhouse gases than natural gas) and efforts to reduce energy consumption (purchase of renewable electricity, energy renovation works, etc.).

ASSESSING THE CARBON FOOTPRINT OF A MEDICAL PATIENT PATHWAY

1. Detailed methodology

The methodology presented is used to quantify the emissions of a patient pathway

2. Equipment and information required

Calculating the carbon footprint of a patient's journey requires estimating the carbon footprint of the various procedures that make up this journey.

3. Detailed methodology

The different steps considered in this method are listed below. Note that staff travel is not a separate category/step as it is already taken into account in the calculation of different procedures, at the consultation and hospitalization levels.

a. Consultation

Consultations refer to various hospital consultations conducted by healthcare professionals throughout the patient pathway. Consultations conducted outside the hospital setting are excluded. The tool offers two types of "standard" consultations, lasting 30 minutes and one hour, respectively. The greenhouse gas emissions for consultations have been calculated using the "Medical Procedure" tab of the "Carebone" tool and are detailed in "Emission Factors & Sources > Consultation".

b. Imaging

This category corresponds to imaging procedures conducted as part of the patient pathway. The carbon footprint of an imaging procedure can be calculated using the methodology for calculating the carbon footprint of a procedure (refer to Assessing the carbon footprint of medical procedure) and added to the emission factor database in the "Procedure EF" tab.

c. *Laboratory tests*

This category corresponds to **laboratory tests** conducted as part of the patient pathway. The carbon footprint of a laboratory test can be calculated using the methodology for calculating the carbon footprint of a procedure (refer to Assessing the carbon footprint of a medical Procedure) and added to the emission factor database in the "Procedure EF" tab. Some emission factors from scientific publications are also provided in the tool (refer to Emission Factors & Sources > Biology Tests).

d. *Operating room*

This category corresponds to surgical procedures conducted as part of the patient pathway. The carbon footprint of a surgical procedure can be calculated using the methodology for calculating the carbon footprint of a procedure (refer to Assessing the carbon footprint of a medical procedure) and added to the emission factor database in the "Procedure EF" tab.

e. *Other Procedures*

This category includes emissions related to other medical procedures (e.g., endoscopy, colonoscopy, etc.). The carbon footprint of another procedure can be calculated using the methodology for calculating the carbon footprint of a procedure (refer to Assessing the carbon footprint of a medical procedure) and added to the emission factor database in the "Procedure EF" tab.

f. *Patient transportation*

Patient transportation corresponds to the journeys made by the patient and their relatives between home and the hospital. The **round-trip distance in kilometers** and the **mode of transportation** are to be provided. Users can use Google Maps or equivalent tools to estimate the round-trip distance in kilometers. In the absence of actual data, default assumptions are provided in the "Assumptions & Sources > Patient Transportation" section.

g. *Treatment*

This category includes all **treatments** and **medications** taken by the patient throughout the journey, excluding those already included in the calculations for different procedures. Medications and treatments taken by the patient after their hospital stay are accounted for within the scope.

h. *Hospitalization*

This category accounts for emissions related to the patient's **hospitalization**. The number of hospitalization days planned for the patient's pathway is required, along with the type of service accommodating them (Intensive Care Unit, Medical and Surgical Unit, etc.).

The tool automatically calculates the greenhouse gas emissions for a hospitalization day, broken down into four sub-categories to be filled in by the user:

- **Energy consumption** in the patient's room in kWh/m2/year,
- **Number of meals** consumed by the patient
- **Number of healthcare professionals** caring for the patient during their hospitalization (meals + commute)
- Quantity of **flat linen** in kg per hospitalization day (assuming the same bedding is used overnight)

Default assumptions are provided in the "Assumptions & Sources > Hospitalization" section. The methodology for calculating greenhouse gas emissions related to **meals and personnel** is detailed in "Assessing the carbon footprint of a medical procedure > Staff" and in "Emission Factors & Sources > Personnel". The same emission factor is applied for both **day and night** shifts, which is 6.74 kgCO2e/person/day or night. The tool also takes into account greenhouse gas emissions related to the day and night **personnel's work clothing** using the same methodology as described in "Assessing the carbon footprint of a medical procedure > Laundry".

i. *Staff commuting*

There is no dedicated category for staff commuting in the "Patient pathway" tab as the associated emissions are already accounted in the following categories:

- Consultation: Travel expenses for staff are included in the emission factor
- Procedure: Emissions related to staff travel are taken into account in the calculated emission factor in the "Procedure" tab (refer to the section "Assessing the carbon footprint of a medical procedure > Staff").
- Hospitalization: The emission factor for a hospitalization day also includes the staff's commuting involved in the patient's care during hospitalization (refer to Detailed Methodology > Hospitalization).

4. Assumptions & Sources

a. *Patient transportation*

The following table summarizes the default assumptions provided:

Type of Travel	Type of Journey	Default Travel Assumption
Patient- Paris - round trip	Without hospitalization	5 km round trip by subway – Île-de-France
	With hospitalization	5 km round trip by car – average motorization
Patient- Île-de-France - round trip	Without hospitalization	20 km round trip by RER and Transilien – Île-de-France
	With hospitalization	20 km round trip by car – average motorization
Patient- region - round trip	All cases	500 km round trip by car – average motorization
Patient- abroad - round trip	All cases	1000 km round trip by plane + 20 km round trip by car – average motorization

b. *Hospitalization*

Several assumptions are provided in the tool in the absence of real data.

Energy:

The average size of a hospital room is estimated at 13 m^2.

Regardless of the type of service, the proposed energy consumption ratio is based on tertiary hospital areas.

- ⇨ Electricity: 120 kWh/m^2/year
- ⇨ Natural gas (heating): 152 kWh/m^2/year
- ⇨ These ratios are converted to daily consumption by dividing by 365 days.

Staff:

Staff-related emissions are calculated based on the average number of Full-Time Equivalents (FTE) per hospitalization day and the average daily carbon footprint of an AP-HP employee.

For the average number of FTEs per hospitalization day or night, the ratios are derived from standardized ratios summarized in the document " Qualité et sécurité des soins dans les

établissements de santé : quels ratios d'effectifs dans les services de soins et comment sont-ils calculés ?" from EHESP in 2016.

Laundry:

As a first estimation, the default assumption provided in the tool to estimate the quantity of flat linen is as follows:

- Sheet: 500 g
- Fitted sheet: 200 g
- Pillowcase: 160 g
  - ⇨ Totaling 860 g of flat linen per hospitalization day (it is assumed that the same bedding is used at night).

UNCERTAINTY ⟩⟩

In its "Method for the realization of greenhouse gas inventories in accordance with Article L.229-25 of the Environmental Code – Version 5 – 2020," ADEME defines uncertainty as follows: "a parameter associated with the result of quantification that characterizes the dispersion of values that can reasonably be attributed to the quantified magnitude. Uncertainty thus measures the potential deviation between the value allocated to the quantified magnitude and its actual value.

Numerous sources of uncertainty can impact the accuracy of calculations in estimating a carbon footprint. This methodology considers uncertainty as the result of a combination of uncertainties of emission factors and corresponding activity data.

Uncertainty related to emission factors:

"In accordance with various recommendations and best practices of international standards, emissions are typically estimated using emission factors obtained from references and institutional databases. These factors will have been measured under particular circumstances deemed typical. Uncertainties will therefore be associated both with the original measurements and with the use of factors in circumstances other than those associated with the original measurements. For example, the use of average emission factors for excipients constitutes a significant source of uncertainty since they were not originally calculated for this purpose.

Emission databases and sources typically provide a level of uncertainty with the emission factor. If this information is not provided, uncertainty is automatically estimated at 50%.

The uncertainty of the emission factor is automatically applied in the tool following the user's choice of emission factor.

Uncertainty related to activity data:

The reliability of estimates is also linked to the robustness of activity data and how they were collected. Some are derived from very precise measurements provided by manufacturers of drugs or medical devices. Others may have been estimated when data was not available. Based on the recommendations of ADEME and ABC methodology, the following rules have been defined in the tool:

Type of Collection	Uncertainty
Technical Data / Supplier Data	5%
Weighing	20%
Default Estimation	40%
Consumption Ratio	100%

For each emission category, when the user enters data into the tool, they must also select how they obtained this information in the "Collection Methodology" column. The "Default

Estimation" collection type refers specifically to the methodologies proposed in the " **HELP – Estimation of Excipient Qty** " and " - " **HELP - MD Material weigh** " tabs, and for default packaging estimation. The "Consumption Ratio" collection primarily refers to ratios used to estimate energy consumption related to production and packaging. Indeed, these estimates are very approximate because the original data is imprecise, and the sources are not tailored to each drug or medical device.

Combining uncertainties and calculating total uncertainty

For each emission category, the tool calculates a combined uncertainty and a weighted combined uncertainty using the following formulas:

Combined uncertainty of the category = $= c = \sqrt{a^2 + b^2}$

Where a = uncertainty related to emission factor

and b = uncertainty related to activity data

Weighted combined uncertainty = $= \mathrm{i} = c \times D \div \sum D$

Where D = GHG emissions of the category in gCO2e

And $\sum D =$ sum of emissions from all categories in gCO2e / total carbon footprint

Total uncertainty corresponds to the square root of the sum of squares of uncertainties from all categories and is therefore calculated using the following formula:

Total uncertainty $= \mathrm{I} = \sqrt{\sum i^2}$

EMISSION FACTORS & SOURCES ⟩⟩

Sources and other factors are presented in the following paragraphs.

a. Active substances

To properly use an emission factor, it is necessary to understand its scope. In the context of this methodology, we have selected emission factors in " from production to disposal " format to the extent of available information. The "from production to disposal" format corresponds only to emissions related to the production process. Greenhouse gas emissions related to upstream (raw materials, etc.) or downstream of the plant (transportation, distribution, use, end-of-life) are not included in the scope of these emission factors.

We have chosen this format since the upstream and downstream aspects are already considered elsewhere in our methodology.

a) List of used EF sources

The sources for emission factors are as follows:

- Carbon footprint of the Austrian health sector - klima energie fonds

B670168-ACRP9-HealthFootprint-KR16AC0K13225-EB.pdf (klimafonds.gv.at)

⇨ The emission factors from this source were later corrected. Indeed, the provided values concern emissions associated with the energy consumption of the process. The following correction: the process's share in total emissions is estimated at 10%. This assumption comes from the report " Évaluation de l'empreinte carbone de l'ibuprofène " by EcovaMed, which shows that the process represents 10% of ibuprofen emissions.

https://uploads-ssl.webflow.com/6151b650ce4cd9198b1fd7e8/6176e0cb1ac57152bc572efd_Ibuprofen_Carbon_footprint_Ecovamed_May_2021.pdf

- Life cycle analyses conducted by pharmaceutical laboratories as part of submissions to Indian authorities to obtain the necessary environmental approvals for their activities:

⇨ SunPharma: Annexure-XVII – Life Cycle Analysis for M/s Sun Pharmaceutical Industries Limited (Starting from the page 1043)

DownloadPfdFile.aspx (environmentclearance.nic.in)

⇨ Solvay: Annexure-XVII – Life Cycle Analysis for M/s Solvay Specialities India Private Limited (p 925)

DownloadPfdFile.aspx (environmentclearance.nic.in)

⇨ BEC Chemicals: ENVIRONMENTAL IMPACT ASSESSMENT(EIA) REPORT FORAN EXPANSION OF ACTIVE PHARMACEUTICAL INGREDIENT (API) MANUFACTURING UNIT by BEC Chemicals (p 146)

DownloadPfdFile.aspx (environmentclearance.nic.in)

- ACS Sustainable Chemistry & Engineering [16] : onglet summary

  https://ndownloader.figstatic.com/files/14573810

- Combined simulationeoptimization methodology to reduce the environmental impact of pharmaceutical processes: application to the production of Penicillin V [17]

  Combined simulation-optimization methodology to reduce the environmental impact of pharmaceutical processes: application to the production of Penicillin V | Elsevier Enhanced Reader

- Technical Potential for Energy and GWP Reduction in Chemical–Pharmaceutical Industry in Germany and EU—Focused on Biologics and Botanicals Manufacturing (Table 1 & 2)

  Processes | Free Full-Text | Technical Potential for Energy and GWP Reduction in Chemical–Pharmaceutical Industry in Germany and EU—Focused on Biologics and Botanicals Manufacturing (mdpi.com)

- EcovaMed (ACV Juin 2022, fabrication en Chine – API Metformine) : https://uploads-ssl.webflow.com/6151b650ce4cd9198b1fd7e8/62c9be879749a0293c862949_METFORMIN_Life_Cycle_Assessment_ECOVAMED_June-2022.pdf

- EcovaMed (ACV Mai 2021 – API Ibuprofène) : https://uploads-ssl.webflow.com/6151b650ce4cd9198b1fd7e8/62c9be879749a0293c862949_METFORMIN_Life_Cycle_Assessment_ECOVAMED_June-2022.pdf

b) Methodology in case of missing EF

If the EF for the API is not yet in the tool's database, the user can choose an emission factor estimate using the " **HELP – Choice of API EF** " tab.

The average emission factors are as follows:

- ⇨ **API – Low**: 600 kgCO2e / kg API
- ⇨ **API – Medium**: 1500 kgCO2e / kg API
- ⇨ **API – High**: 7000 kgCO2e / kg API

These EFs are derived from the ABPI Blister Pack Carbon Footprint Tool:

https://www.abpi.org.uk/media/1rdb3sno/carbon_blister_pack.xlsm

However, the ABPI tool does not clearly specify how to choose between the three factors. Another methodology of this tool, labeled as "calculated," allows for estimating an EF based on the molecule's chirality, production volume, and number of manufacturing steps. Since these data are rarely available, we have proposed a simplified methodology for selecting the API EF. This is inspired by the methodology of the ABPI tool and other sources cited below.

The methodology proposed in the " **HELP – Choice of API EF** " tab is based on the average score of 4 criteria. For each API, these criteria are evaluated from 1 (low energy consumption and greenhouse gas emissions) to 3 (high energy consumption and greenhouse gas emissions). The following table assigns the average API EF based on the obtained score:

Average Score > 2	API - High
1,5 < Average Score =< 2	API - Medium
Average Score =< 1,5	API - Low

- **Criterion 1:** Molecule complexity

The chemical structure, number, and types of atoms or functional groups in a molecule influence the production process of the active substance. This will notably affect the number of steps required for manufacturing, each of which may require specific and potentially energy-intensive reaction conditions. Complex active substances such as polysaccharides, peptides, or recombinant proteins will be assigned a score of 3, while simple molecules like paracetamol (a benzene ring substituted with a hydroxyl group and an amide) are scored 1. The molecule's chirality contributes to increasing the score.

- **Criterion 2:** Origin of the active substance

Different types of manufacturing impact the energy consumption required for API production. The list below outlines the main types of manufacturing (source: Annex 2, WHO Technical Report Series 957, 2010) and suggests a recommended score. This score was determined based on the number of required steps and their complexity (sources cited below).

Type of Manufacturing	Recommended Score	Comments
Chemical Manufacturing	2	Chemical manufacturing processes can vary in terms of energy consumption depending on the complexity of synthesis, the exothermic or endothermic reactions involved, and the efficiency of the technologies used.
Active Substances from Animal Sources	3	Extracting active substances from animal sources may require complex and energy-intensive extraction processes, especially for purifying substances from biological tissues.
Active Substances Extracted from Plant Sources	2	Extracting active substances from plant sources may require processing and purification steps, but they are assumed to be less energy-intensive than for animal sources (less stringent safety requirements, less impactful raw materials, etc.).
Plant Extracts Used as Active Substances	1	This type of manufacturing involves fewer steps, including no purification, suggesting an overall lower energy consumption.
Active Substances Composed of Crushed or Pulverized Plants	1	This type of manufacturing involves fewer steps, including no purification, suggesting an overall lower energy consumption.
Biotechnology Fermentation / Cell Culture	3	The production process of biopharmaceuticals is very different from that of chemical drugs. Energy consumption includes, among other things, the operation of cold rooms, heat required for steam and pharmaceutical water production, heat production for culture medium (temperature between 25 and 35°C), sterile culture medium.....[12]
Classic Fermentation for the Production of an Active Substance	2	Fermentation is a process that requires specific temperature and pressure conditions, but it is an ancient process widely mastered in industries other than the pharmaceutical sector.

- **Criterion 3:** Special Conditions

Some substances may require specific reaction conditions, such as high temperatures or pressures, which can lead to increased energy usage to maintain these conditions. Some active substances may also be produced by exothermic reactions, meaning reactions that release heat. Temperature control and cooling can also result in higher energy consumption. In the absence of information on this criterion, a default score of 2 is assigned.

- **Criterion 4:** Production Volumes

The energy efficiency of production processes is often proportional to production volumes (economies of scale, investment in energy-efficient technologies, etc.). Thus, drugs

[12] In a future version, it would probably be pertinent to develop a methodology specific to biotechnologies.

produced in very large quantities (e.g., paracetamol) will receive a score of 1, while rare drugs will be assigned a score of 3 on this criterion. AP-HP sometimes relied on its own data on drug purchase and usage to evaluate this criterion.

For the medication "emission factors" evaluated by AP-HP, the list of scores assigned to each active substance and their justifications are available upon request.

Sources used:

- LEEM : 2022-12-16 – « Rapport final Impact de la transition écologique sur les métiers et compétences des industries de santé »
- Good Manufacturing Practices for Pharmaceutical Active Substances (Annex 2, WHO Technical Report Series 957, 2010)

b. Excipients

To properly use an emission factor, it is necessary to understand its scope. In the context of this methodology, we have selected emission factors in " from production to disposal " format to the extent of available information. The " from production to disposal" format corresponds only to emissions related to the production process. Greenhouse gas emissions related to upstream (raw materials, etc.) or downstream of the plant (transportation, distribution, use, end-of-life) are not included in the scope of these emission factors. We have chosen this format since the upstream and downstream aspects are already considered elsewhere in our methodology.

a) List of Used EF Sources

The sources for excipient emission factors are as follows:

The ABPI Blister Pack Carbon Footprint Tool - Original Excipient EFs Tab : https://www.abpi.org.uk/r-d-manufacturing/abpi-blister-pack-carbon-footprint-tool

Carbon Footprint Database (version 22.0), ADEME
https://base-empreinte.ademe.fr/

- Greenhouse Gas Emissions Inventory applied to the Spirits Sector through the Carbon Assessment Method® - SECTOR GUIDE - Carbone 4 - June 2011

  https://librairie.ademe.fr/changement-climatique-et-energie/3545-inventaire-des-emissions-ges-applique-au-secteur-spiritueux-au-travers-de-la-methode-bilan-carbone.html

- Methodological Guide for Conducting Carbon Footprints for Industrial Bakeries, Pastry Shops, and Pastry Making Companies - January 2011 (pages 69 to 72) https://librairie.ademe.fr/changement-climatique-et-energie/3345-guide-methodologique-pour-la-realisation-de-bilan-carbone-des-entreprises-de-boulangerie-patisserie-viennoiserie-industrielles.html

- Solvay : Annexure-XVII – Life Cycle Analysis for M/s Solvay Specialities India Private Limited (p 925)

- Methodological Guide for Assessing Greenhouse Gas Emissions from Water and Sanitation Services - ASTEE - Updated 2018 https://www.astee.org/publications/guide-methodologique-des-emissions-de-gaz-a-effet-de-serre-des-services-de-leau-et-de-lassainissement/

  The Carbon Footprint of Titanium Dioxide Pigment – December 2023 – Titanium Dioxide Manufacturers Association https://tdma.info/wp-content/uploads/2017/09/The-carbon-footprint-of-titanium-dioxide.pdf

- EcovaMed (LCA July 2023, Manufactured in China - PVP) https://uploads-ssl.webflow.com/6151b650ce4cd9198b1fd7e8/64d00de2347c14534e5be458_PVP_Life_Cycle_Assessment_ECOVAMED_July-2023.pdf

Currently, a single emission factor is provided in the tool for purified water and water for injection preparations. It corresponds to the average of the two production processes in the study below, which is 0.00155 kgCO2e / L.

- Yuan Yuan, Jiaqi Lu, Dungang Gu, Yuhang Lou, Na Xue, Guanghui Li, Wenjie Liao, Nan Zhang - Deduction of carbon footprint for membrane desalination processes towards carbon neutrality: A case study on electrodeionization for ultrapure water preparation, Desalination, Volume 559, 2023, 116648, ISSN 0011-9164

  https://doi.org/10.1016/j.desal.2023.116648

For monoclonal antibodies, an automated calculation provides an estimate of the water footprint for injectable preparations. The Cataldo study, conducted in 2020 [18], offers a range of 16 to 89 kgCO2e per kilogram of monoclonal antibodies. For our tool, we've utilized an average of 52.5 kgCO2e per kilogram of monoclonal antibodies.

b) Methodology in the absence of emission factors

If the exact emission factor is not yet available in the tool's database, estimates are provided in the " **HELP – Choice EF Excipient** " tab. These estimates are derived from

averages of emission factors in the database based on the nature and/or manufacturing process of the excipient.

Excipient Categories:	Average EF (kg CO2e/ kg)
Basic Heavy Chemistry Excipients:	**4,20**
Fatty Acids (oleic acid, stearic acid, etc.)	*23,66*
Alcohols (ethanol, glycol, glycerol, etc.)	*1,21*
Other Sugars (mannitol, carmelloses, croscarmelloses, hypromellose, etc.)	*3,06*
Cellulose and its derivatives	*3,74*
Hydrocarbons (vaseline, paraffin, etc.)	*0,83*
Polyethylene Glycols (PEG, POEG, or macrogols)	*2,10*
Povidone, crospovidone, PVP	*21,70*
Mineral Products (silica, talc, titanium dioxide, etc.)	*2,13*
Basic Mineral Compounds	*1,19*
Naturally Sourced Excipients:	**7,96**
Starches and their derivatives	*1,43*
Naturally Sourced Flavors	*20,64*
Gelatin	*1,78*
Glycerins and Vegetable Oils	*12,62*
Gums	*1,47*
Iron Oxides	*0,03*
Sugars and their derivatives (sucrose, lactose, glucose, etc.)	*1,78*
Substances Extracted from Algae (sodium alginate, carrageenans, agar-agar, etc.)	*6,77*
Specialty Fine Chemistry Excipients:	**231,09**
Amino and Phenolic Antioxidants	*324,07*
Synthetic Flavors	*9,21*
Synthetic Colorants	*2,33*
Anionic Surfactants (soaps and sulfated derivatives)	*308,42*
Cationic Surfactants (quaternary ammonium halides, etc.)	*341,10*

These averages have enabled us to provide approximations for excipients of similar nature (see table above), as well as estimates for categories not covered in the database:

Products	**Choice of EF (kgCO2e/kg)**	**Explanation**
Waxes and Butters - Estimation	12,62	Same as Vegetable Oils
Semi-synthetic and Synthetic Glycerides - Estimation	23,66	Same as Fatty Acids
Fatty Alcohols (cetyl alcohol, stearyl alcohol, etc.) - Estimation	4,20	Basic Heavy Chemistry Excipient

Non-Glyceride Esters (polystates B, PEG stearates, cetiols, etc.) - Estimation	231,09	Specialty Fine Chemistry Excipient
Silicones - Estimation	231,09	Specialty Fine Chemistry Excipient
Natural Surfactants (cholesterol, lecithin, saponin, etc.) - Estimation	7,96	Naturally Sourced Excipient
Alkylolamines, Alkanolamines, and Ethanolamines - Estimation	231,09	Specialty Fine Chemistry Excipient
Natural Colorants - Estimation	7,96	Naturally Sourced Excipient
Amino Acid - Bacterial Fermentation - Estimation	7,96	Naturally Sourced Excipient
Amino Acid - Chemical Synthesis - Estimation	231,09	Specialty Fine Chemistry Excipient
Parabens - Estimation	231,09	Specialty Fine Chemistry Excipient
Specialty Fine Chemistry Excipient - Estimation	231,09	Average of Known EFs (TCD)
Basic Heavy Chemistry Excipient - Estimation	4,20	Average of Known EFs (TCD)
Naturally Sourced Excipient - Estimation	7,96	Average of Known EFs (TCD)

c. *Energy*

The sources of emission factors are:

Carbon Footprint Database (version 22.0), ADEME

https://base-empreinte.ademe.fr/

- IEA - Emissions Factors 2022

  https://www.iea.org/data-and-statistics/data-product/emissions-factors-2022

d. *Materials & Packaging*

The sources of emission factors are:

- Carbon Footprint Database (version 22.0), ADEME

  https://base-empreinte.ademe.fr/

- Impacts Database, ADEME

  https://base-empreinte.ademe.fr/

- PlasticsEurope

  http://www.inference.org.uk/sustainable/LCA/elcd/external_docs/petb_31116f00-fabd-11da-974d-0800200c9a66.pdf

https://www.pedagogie.ac-aix-marseille.fr/upload/docs/application/pdf/2015-11/4-_eco-profile_pe_2014-04.pdf

- Guide to Carbon Footprint Emission Factors for Businesses and Communities Version 6.1 published by ADEME in June 2010: http://23dd.fr/images/stories/Documents/PV/Ademe_Metro_Chapitre_2_Energie.pdf

- Silicon-chemistry carbon balance: an assessment of greenhous gas emissions and reductions

  https://www.silicones.eu/wp-content/uploads/2019/05/SIL_exec-summary_en.pdf

- Ecoinvent (BEGES Bouygues 2015)

  https://www.bouygues-tp.com/uploads/page/21/Rapport_BEGES_2015_BYTP_SA.pdf

- France Stratégie – How to evaluate the carbon externality of metals

  https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/fs-2020-na96-externalite-carbone-metaux-octobre.pdf

- Buitrago-Tello, Rodrigo; Venditti, Richard A.; Jameel, Hasan; Yao, Yuan; Echeverria, Darlene (2022): Carbon Footprint of Bleached Softwood Fluff Pulp: Detailed Process Simulation and Environmental Life Cycle Assessment to Understand Carbon Emissions. ACS Publications. Collection.

  https://doi.org/10.1021/acssuschemeng.2c00840

- Total Producers Association - Rapport Trucost Clarity - Diamond

  https://collectif-diamant.fr/uploads/607e9d4f726d0_DPA_TotalClarity_Report_FR.pdf

- Biosourced Materials - Arcanne - 07/04/2020:

  https://associationarcanne.files.wordpress.com/2020/04/arcanne-bs.2020.04.pdf

- The emission factors related to the packaging materials transformation processes are drawn from the BEE Citeo tool v 3.04:

https://bee.citeo.com/Produits chimiques

e. Chemical Products

- Footprint Database, ADEME

  https://base-empreinte.ademe.fr/donnees/jeu-donnees

- Formaldéhyde: Review and environmental footprint assessment of various formalin production pathways, Jan Puhar, Damjan Krajnc, Lidija Čuček, Annamaria Vujanović,

  https://www.sciencedirect.com/science/article/pii/S0959652622041099

f. Reagents

- Labos 1 point 5

  https://apps.labos1point5.org/purchases-simulator

g. Transport & round-trip

The emission factors' sources are:

- Carbon Footprint Database (version 22.0), ADEME

https://base-empreinte.ademe.fr/

h. End of Life

The emission factors' sources are:

- Carbon Footprint Database (version 22.0), ADEME

  https://base-empreinte.ademe.fr/

i. Consumables & Personal Protective Equipment

The emission factors' sources are:

- Carbon Footprint Database (version 22.0), ADEME

  https://base-empreinte.ademe.fr/

Some emission factors may also have been calculated using the "Carebone" tool, specifically through the "Medical Devices" tab.

j. *Hygiene & Cleaning*

The emission factors' sources are:

Carbon Footprint Database (version 22.0), ADEME

https://base-empreinte.ademe.fr/

It's important to note that these emission factors are not specific to the healthcare sector and have been calculated based on standard products that do not meet the hygiene standards of hospital environments. In case of uncertainty about an emission factor, it is recommended to use the most conservative factor, "Disinfectant."

k. *Surgical Instruments*

The emission factors for surgical instruments have been calculated using the "Carebone" tool, specifically through the "Medical Devices" tab. By default, the instruments are assumed to be made of stainless steel in Pakistan. The following assumptions were used for material weights:

- Small Surgical Instrument - Medium - 50 uses: 80 grams of stainless steel
- Medium to Large Surgical Instrument - Medium - 50 uses: 150 grams of stainless steel

These factors were calculated for an average of 50 uses (likely a conservative assumption). The results are as follows:

- Small Surgical Instrument - Medium - 50 uses: 19.8 gCO2e / unit / use
- Medium to Large Surgical Instrument - Medium - 50 uses: 36.2 gCO2e / unit / use

l. *Sterilization Containers*

The emission factors for sterilization containers have been calculated using the "Carebone" tool, specifically through the "Medical Devices" tab. By default, the containers and baskets are assumed to be made of stainless steel in Pakistan. The following assumptions were used for material weights:

- Small Sterilization Container and Basket - 13 L - 200 uses:
  - ⇨ Basket: 646 grams
  - ⇨ Container: 2086 grams
- Medium Sterilization Container and Basket - 20 L - 200 uses:
  - ⇨ Basket: 949 grams
  - ⇨ Container: 3067 grams
- Large Sterilization Container and Basket - 25 L - 200 uses:
  - ⇨ Basket: 1300 grams
  - ⇨ Container: 4200 grams

These factors were calculated for an average of 200 uses (likely a conservative assumption). The results are as follows:

- Small Sterilization Container and Basket - 13 L - 200 uses: 158.7 gCO2e / unit / use
- Medium Sterilization Container and Basket - 20 L - 200 uses: 233 gCO2e / unit / use
- Large Sterilization Container and Basket - 25 L - 200 uses: 319.3 gCO2e / unit / use

m. Equipment

The emission factor related to the upstream/production of equipment is derived from the Carbon Footprint Database (version 22.0), ADEME

https://base-empreinte.ademe.fr/

It corresponds to the "Machinery - Manufacturing" factor: 5.5 kg CO2e / kg.

n. Laundry

The emission factors related to textile production were calculated as part of the 2022 Carbon Assessment of the AP-HP (Public Assistance - Hospitals of Paris) based on emission factors from the ADEME's Footprint Database in kgCO2e / kg and the weights of textile references purchased by the AP-HP's Central Laundry Service (SCB).

https://base-empreinte.ademe.fr/

Averages were obtained from multiple references as follows:

- Flat Linen: 15,955 kgCO2e / unit
  - ⇨ Average use of 33 times, resulting in **0.483 kgCO2e/kg/use**
- Workwear:
  - Tunic: 7.851 kgCO2e / unit
  - Pants: 11.131 kgCO2e / unit
  - Fabric shoes: 17.3 kgCO2e / unit
    - ⇨ Average use of 59 times, resulting in **0.615 kgCO2e/kg/day**

The average usage data was estimated based on laundry data (see "Assumptions & Sources > Laundry").

o. Water Consumption

Network water (consumption and treatment): 0.394 kgCO2e / m3

The source is the Carbon Footprint Database (version 22.0), ADEME, and the emission factor is the sum of:

- Purchases of goods > Water, water treatment and distribution: 0.132 kgCO2e / m^3
- Waste treatment > Wastewater > Wastewater, Potable water, Network water: 0.262 kgCO2e / m^3

p. Digital Data Storage

The emission factors related to the storage of digital imaging data have been calculated from three sources:

- Activity data from the PACS of the AP-HP
- The volumes of data hosted on the PACS by exam type and the number of exams allowed for obtaining the weight in megabytes (MB) of data stored for each type of exam.
- The legal storage period of data on the PACS: 20 years
- The annual electricity consumption of storing one byte of data (kWh / byte / year) from The Shift Project's work, [Lean ICT Materials] QuantiLev, "Lev4" tab

Consumption = 1 E-09 kWh / byte / year

https://theshiftproject.org/wp-content/uploads/2019/10/Lean-ICT-Materials-Liens-%C3%A0-t%C3%A9l%C3%A9charger-r%C3%A9par%C3%A9-le-29-10-2019.pdf

- The emission factor of electricity in France (see Emission Factors & Sources > Energy)

This results in the following table:

Type of Imaging Data	MB / unit	kgCO2e / unit
Computer Radiography	1.8	1.79E-03
Scanner / CT Scan	46.7	4.77E-02
Digital Radiography	1.6	1.62E-03
Electrocardiogram	70.8	7.24E-02
Endoscopy	4.2	0.00431866
Mammography	23.7	0.024200789
MRI	24.8	0.025328442
Nuclear Medicine	9.0	0.009152476

Others	1.4	0.001430536
Positron Emission Tomography	58.1	0.059345036
Panoramic Radiography	0.5	0.000526837
Fluoroscopy	3.5	0.00355022
Structured Document	0.2	0.000212368
Ultrasound	6.1	0.01
Angiography	18.0	0.018379176

q. *Staff*

- Average annual emissions from **home-to-work trip** per employee: 901 kgCO2e / employee

The average annual emissions from home-to-work travel per employee are from the AP-HP's 2019 Carbon Assessment. Home-to-work travel is carried out by all employees between their place of residence and their workplace. This emissions category was quantified in the AP-HP's 2019 Carbon Assessment based on the distances traveled between home and the hospital for each employee and a set of assumptions about modal shares of transportation.

- Average emissions **per meal** at the AP-HP: 2.77 kgCO2e / meal

The average emissions per meal are from the AP-HP's 2019 Carbon Assessment and were calculated across the entire scope of the AP-HP (patient meals, healthcare workers, etc.) based on food purchases.

r. *Consultation*

The emission factors for hospital consultations were calculated using the "Procedure" tab of the "Carebone" tool:

- 30-minute hospital consultation: 0.62 kgCO2e / consultation
- One-hour hospital consultation: 1.14 kgCO2e / consultation

s. *Biology tests*

Emission factors are provided in the tool for certain biochemical tests; they are derived from a Canadian study: "Patient, hospital and environmental costs of unnecessary bloodwork: capturing the triple bottom line of inappropriate care in general surgery patients" by Spoyalo K, Lalande A, Rizan C, et al. [19].

CROSS-CUTTING PROTOCOLS USED

1. Nomenclature

To ensure clarity and consistency of emission factors calculated by this tool, the following paragraphs describe the adopted nomenclature. Emission factors are all titled in French, in lowercase with capital letters only at the first letter or after a hyphen.

a. *Medicines*

Ideally, the FE wording is taken from the commercial label of the drug as described on the AGEPS website.

http://informations-marches-ageps.ap-hop-paris.fr/index.php?id=6034e106c616d332ccf3b10b7d2577d0

The mandatory information and the preferred order are as follows:

Name - Quantity [Unit] - Galenic Form - CIP 13

The SAP reference, the manufacturer, the name of the person responsible for the calculation, and the date are to be filled in the general data and will thus be recorded in the dedicated columns of the FE database.

b. *Medical device*

Ideally, the FE wording is taken from the commercial label of the drug as described on the AGEPS website or AP-HP purchase website.

http://informations-marches-ageps.ap-hop-paris.fr/index.php?id=6034e106c616d332ccf3b10b7d2577d0

https://webacha.aphp.fr/accueil

The mandatory information and the preferred order are as follows:

Name - Size [Unit] - Supplier Reference

The SAP reference, the manufacturer, the name of the person responsible for the calculation, and the date are to be filled in the general data and will thus be recorded in the dedicated columns of the FE database.

2. Archiving

Recording emission factors for reuse in a patient's pathway carbon footprint is done at two levels:

- The tool allows copying and pasting the emission factor line (medical procedure, medicines, medical device) calculated and inserting it into the emission factor database. It is then recorded and available in the new version of the tool. The name of the person responsible for the calculation, the date, the manufacturer, and the SAP reference are traced.
- The calculation file for this emission factor is saved and recorded on the shared AP-HP network, so that calculation assumptions and input data can be retrieved / modified / updated at any time.

ACRONYMES ››

Acronyms	Definition
AGEPS	Equipment and Health Products Markets
AP-HP	Public Assistance - Hospitals of Paris
API	Active Principal Ingredient ou substance active
CHU	University Hospital Centers
CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
CPCU	Connection to the Parisian Urban Heating Company
CSR	Corporate Social Responsibility
FE	Emission factor
FTE	Time Equivalents
GHG	Greenhouse gas
HCW	Healthcare Waste
LCA	Life Cycle Assessment
MD	Medical device
PACS	Picture Archiving and Communication System
PE	Polyethylene
PEF	Polyethylene 2,5-furandicarboxylate
PEG	Polyethylene glycol
PP	Polypropylene
PUI	Inpatient Pharmacy
SAD	Procurement and Distribution Service
SPC	The Summary of Product Characteristics
WFI	Water for injection purposes

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