Methodology Of Life Cycle Assessment For The Electronics Industry

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About Me

Managing sustainability and environment for the last 18 years in global chemical, electronics and energy industries

Owner of **Enviroet GmbH** providing a holistic approach for sustainability solutions and strategic plans to support acceleration of our journey to carbon neutrality

Conducting LCAs and EPDs over the last 5 years

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Today we will understand

BASICS OF A LIFE CYCLE ASSESSMENT METHODOLOGY

ECO INDICATORS

EPD - ENVIRONMENTAL PRODUCT DECLARATION

LCA IN THE ELECTRONIC INDUSTRY – STUDY CASE

REE LCIA – RARE EARTH ELEMENTS LIFE CYCLE IMPACT ASSESSMENT

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Basics of a Life Cycle Assessment Methodology

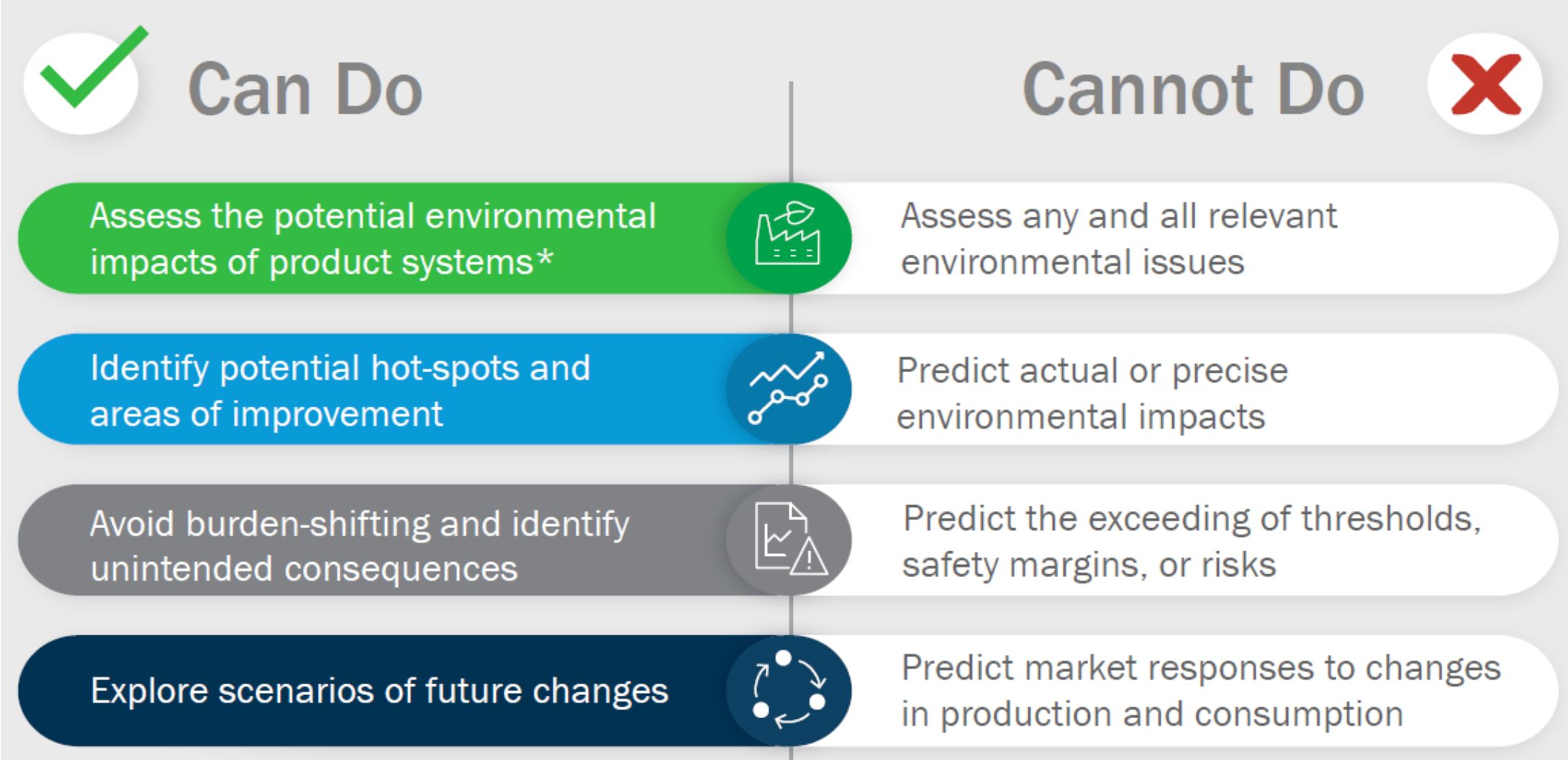
Main LCA Reporting Standards

- ISO. (2006). ISO 14044: Environmental management - Life cycle assessment - Requirements and guidelines
- ISO. (2009). ISO 14040: Environmental management - Life cycle assessment - principles and frameworks
- ISO 14067 on the carbon footprint of products
- ISO 14020, ISO 14021, ISO 14024, ISO 14025, and ISO 14026 on environmental labels
- ILCD (EU) on life cycle assessment
- PAS 2050 (UK) on greenhouse gas emissions
- BP X30-323 (France) on environmental foot printing
- EcoLeaf Environmental Labeling Program (Japan)
- Carbon Footprint of Products and Environmental Product Declaration (Korea)

What is LCA?

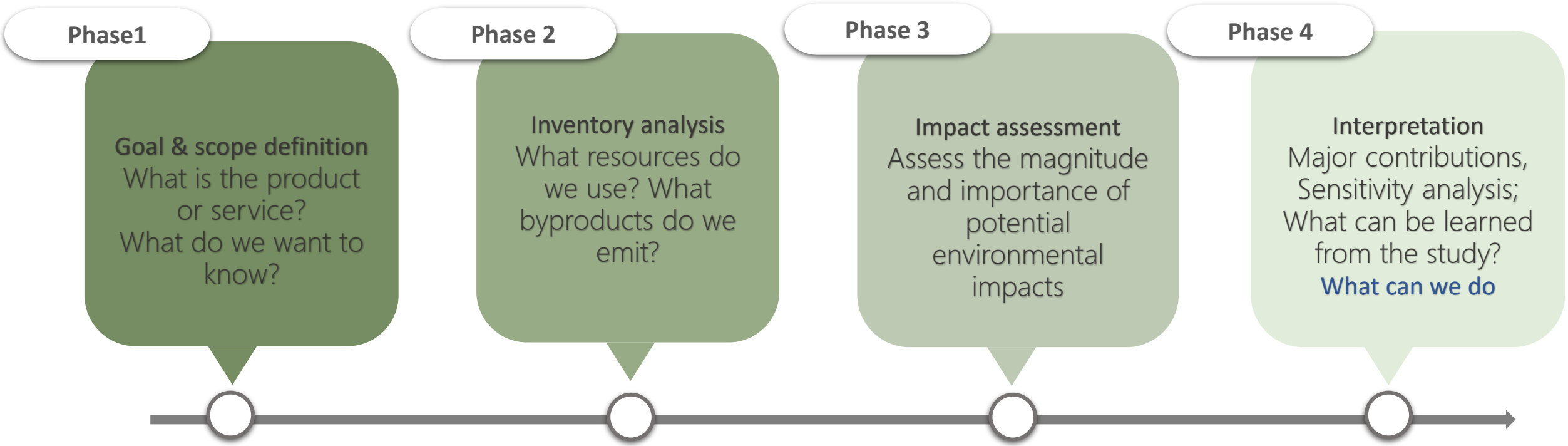
LCA is a **methodology** to assess the potential **environmental impacts** of **products**, **systems**, or **service** at all **stages** in their **life cycle**

Capabilities and Limitations of LCA



*Limited by availability of data and methodology

Phases of an LCA study



Phase 1: Scope definition of the LCA study

Geographical scope

Production phase: Country.
Manufacturing & Distribution center: Country

Functional unit

1 kg /1 Unit/1 MJ of material used.

System boundary

"**Cradle-to-grave**" - All **processes** from **extraction** of natural **resources** to the **disposal** of the product

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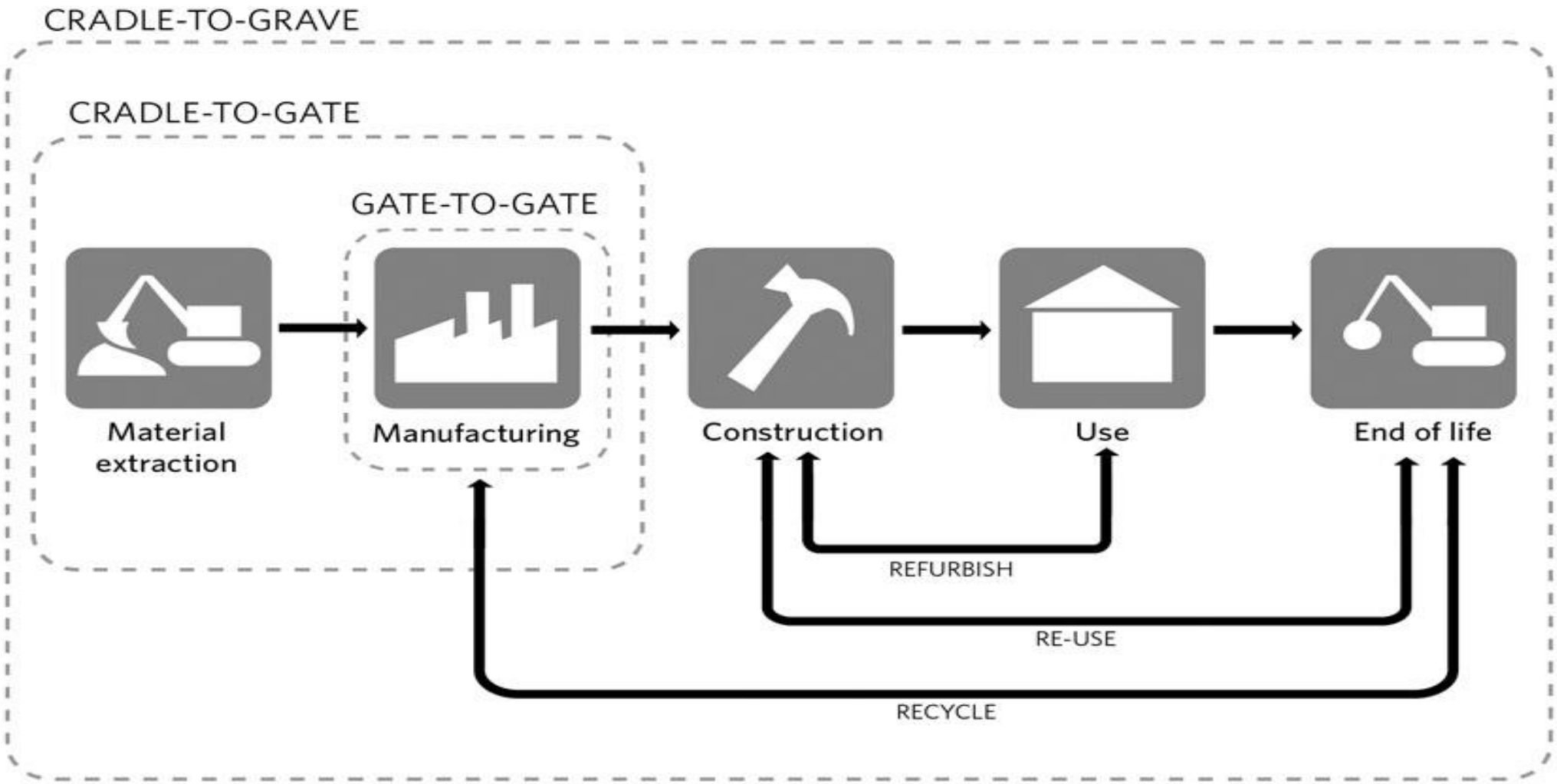
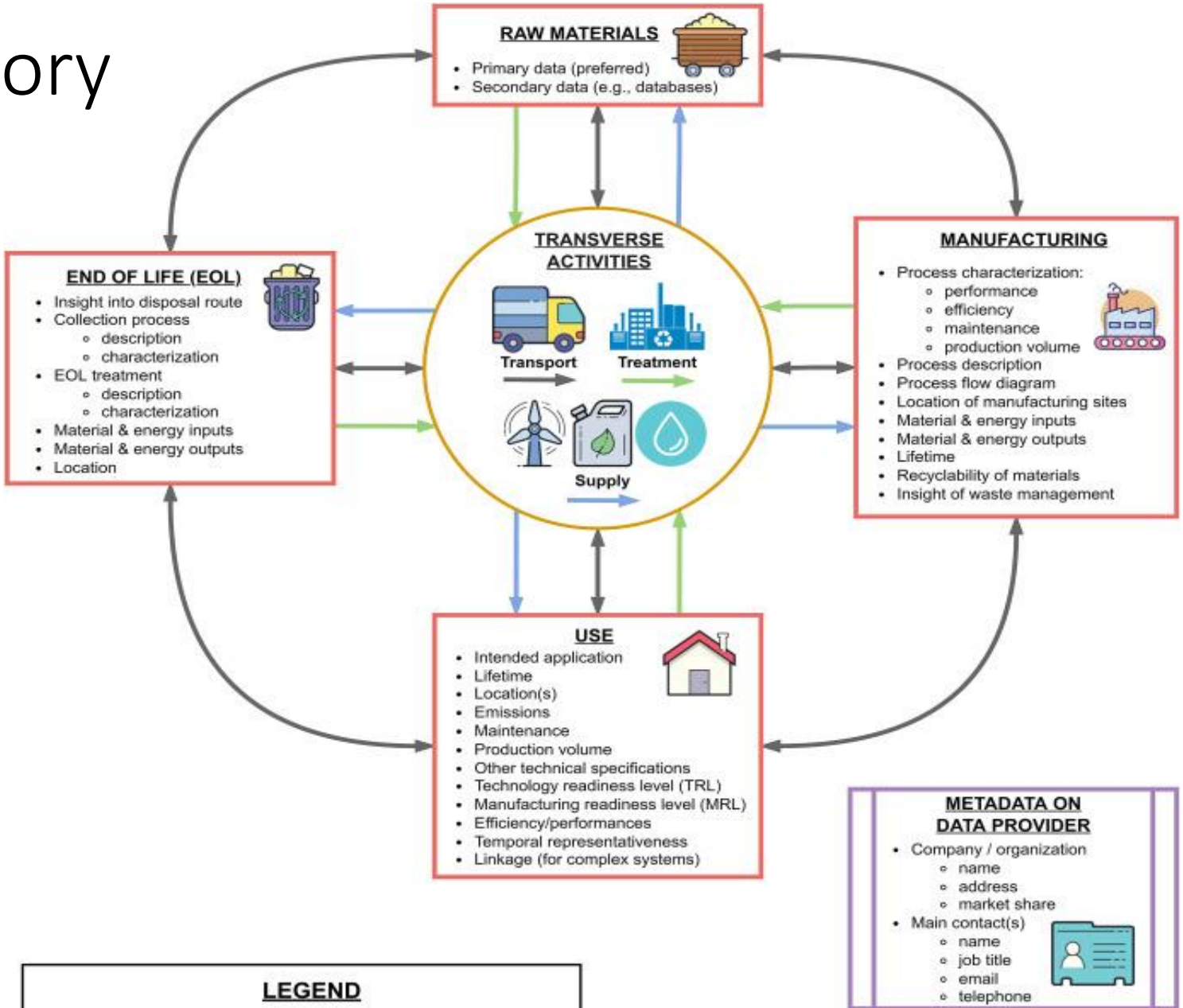
Boundaries system



Phase 2: LCI - Inventory analysis



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Eco Indicators

Phase 3: Impact assessment

Climate Change

Global warming potential (GWP)

*The **heat** absorbed by any **greenhouse gas** in the **atmosphere**.*
GWP-fossil
GWP-biogenic
GWP-land use
GWP- Total

Acidification of Land and Water Resources

Acidification potential (AP)

*Affects **aquatic** and **terrestrial** ecosystems by changing the **acid-basic-balance***

Eutrophication

Eutrophication potential (EP)

*The **excessive** supply of **nutrients** and can apply to both **surface** waters and soils*

- *Freshwater*
- *Marine*
- *Terrestrial*

Formation of Photochemical Oxidants

Photochemical oxidant formation potential (POFP)

*also known as **smog** is the **photochemical creation** of **reactive** substances (mainly **ozone**)*

Use of Energy and Resources

1- Abiotic depletion potential (ADP Elements)
2- Abiotic depletion potential (ADP Fossil)
3- Water scarcity footprint (WSF)

*1- represents the **extraction** of **natural elements** from earth*
*2- represents the **use** of **fossil-based** energy.*
*3- used to **measure** the amount of **water** utilized*

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Life Cycle Impact Assessment (LCIA) methods

CML 2001-2016

Indicator	Unit
GWP-total	kg CO_2 eq.
GWP-fossil	kg CO_2 eq.
GWP-biogenic	kg CO_2 eq.
GWP-luluc	kg CO_2 eq.
ODP	kg CFC 11 eq.
AP	mol H+ eq.
EP-freshwater	kg P eq.
EP-freshwater	kg N eq.
EP-terrestrial	mol N eq.
POCP	kg NMVOC eq.
ADP-minerals&metals	kg Sb eq.
ADP-fossil	MJ
WDP	m3

CML (Used worldwide - except North America)
from the Institute of Environmental Sciences of the University of Leiden in the Netherlands. Required by the European EN 15978 and EN 15804 standards

TRACI (Used in North America)
stands for Tool for the Reduction and Assessment of Chemical and other environmental Impacts. It is a method published by the U.S. Environmental Protection Agency (US EPA)

PEF (Used worldwide - except North America)
EN15804 standard became mandatory in July 2022. Environmental Product Declaration (EPD)

ReCiPe (Used in Europe)
Developed by the Dutch research institute of RIVM (National Institute for Public Health and the Environment), Radboud University Nijmegen, Leiden University and Pré Consultants in 2008.

Which is the most important environmental impact indicator?

- Analogous to nutrition information.

- Are biscuits with low fat, low sugar or high protein the healthiest?
- Different people will focus on different things depending on their health needs.

- It is the same for environmental impacts. Different industries focus on different problem areas.
- **All are important!**

Nutrition Facts

Serving Size 2 biscuits (30g)
Servings Per Container about 14

Amount Per Serving

Calories 140	Calories from Fat 60
	% Daily Value*
Total Fat 6g	**10 %**
Saturated Fat 3g	**15 %**
Trans Fat 0g	
Polyunsaturated Fat 0.5g	
Monounsaturated Fat 2.5g	
Cholesterol 0mg	**0 %**
Sodium 160mg	**7 %**
Total Carbohydrates 20g	**7 %**
Dietary Fiber 1g	**4 %**
Sugars 5g	
Protein 2g	

Vitamin A 0%	• Vitamin C 0%
Calcium 2%	• Iron 0%
Thiamin 2%	• Niacin 0%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g

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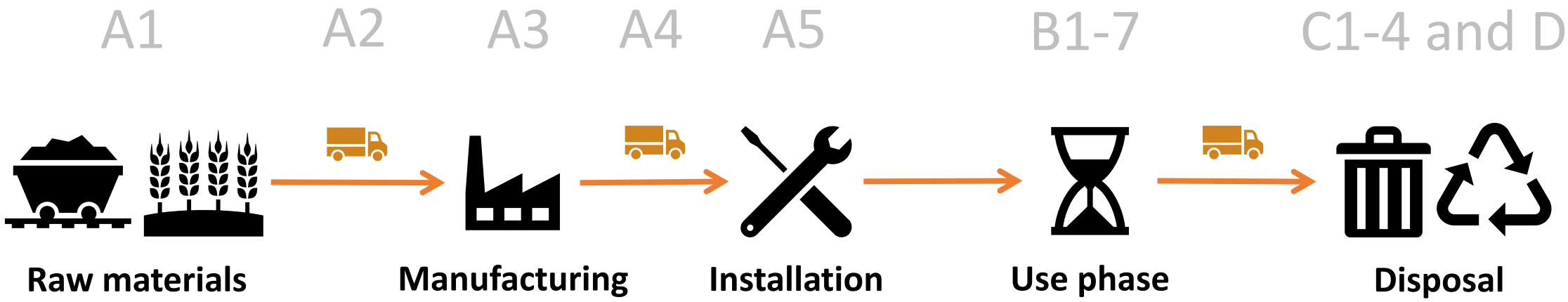
EPD – Environmental Product Declaration

EPD – Environmental product declaration

An EPD is a **declaration document** that discloses the life cycle **environmental performance** of **products** and **services** during their **life cycle.**

What part of my product is included in an EPD?

EPDs look at the full life cycle of the product or service, from cradle to grave.



Details of A, B, C and D modules

Product stage			Assembly stage		Use stage							End of life stage				Benefits & loads beyond system boundary
Raw materials	Transport	Manufacturing	Transport	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy	Operational water	De-construction	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D

LCA for Meter Connectivity Module

LCA for Meter Connectivity Module

- Understand the environmental impacts of their products and make this information **publicly available** as an EPD (Environmental Product Declaration).
- The aim of the LCA report is to specify all environmental impacts downstream and upstream through all life cycle of the production of the product - **workplan to reduce the environmental impacts**

Steps Involved in Completing a LCA Study

Data collection

- BOM Materials
- BOM Packaging
- Energy Consumption
- Distances
- Distribution Logistics
- Calculation for 1 FU (functional unit)

*BOM (Bill Of Material)

Product specification

Product components	Weight, g	Weight-% (versus the product)
PCB	8.3	58.00
Connector	2.13	14.88
NB-IoT modem	1.124	7.85
Capacitor	0.6688	4.67
Flash	0.653	4.56
Header	0.586	4.10
MAHDA	0.13	0.91
Led	0.096	0.67
Solder Paste	0.09	0.63
Load Switch	0.069	0.48
IC TRNSLTR	0.04	0.28
Inverter	0.02	0.14
Transistor	0.012	0.08
Resistor	0.0104	0.07
Diode	0.009	0.06
Clamp for SIM Card Interface	0.007	0.05
Power, Signal Line Ferrite Bead	0.004	0.03
NFC Forum Type	0.0034	0.02
ESD Suppressor	0.0002	0.00
TOTAL	14.01	
Packaging materials	Weight, g	Weight-% (versus the Packed product)
Cardboard	5.19	25.71
Foam - Expanded Polyethylene	1.02	5.07
TOTAL	6.21	

System Phases and Boundaries

A1-A3 Manufacturing

Components Manufacturing	Circuit board Assembly	Test and inspection	Packaging
Various Sites in China	Incoming inspection (components) Screen-printing Pick and place Reflow soldering Hand mounting Optical inspection	Programming Visual inspection Functional inspection Rework	Carton, ESD foam

A4 Transport

Transport to Warehouse	Inbound goods	Transport to Customers
Road transport from Poland to Sweden	Incoming inspection Storage	Road transport to Germany and Sweden

A5 Install

Install Smart Model in meter
Install MCM in meter

B1, B6, C1 Use Phase

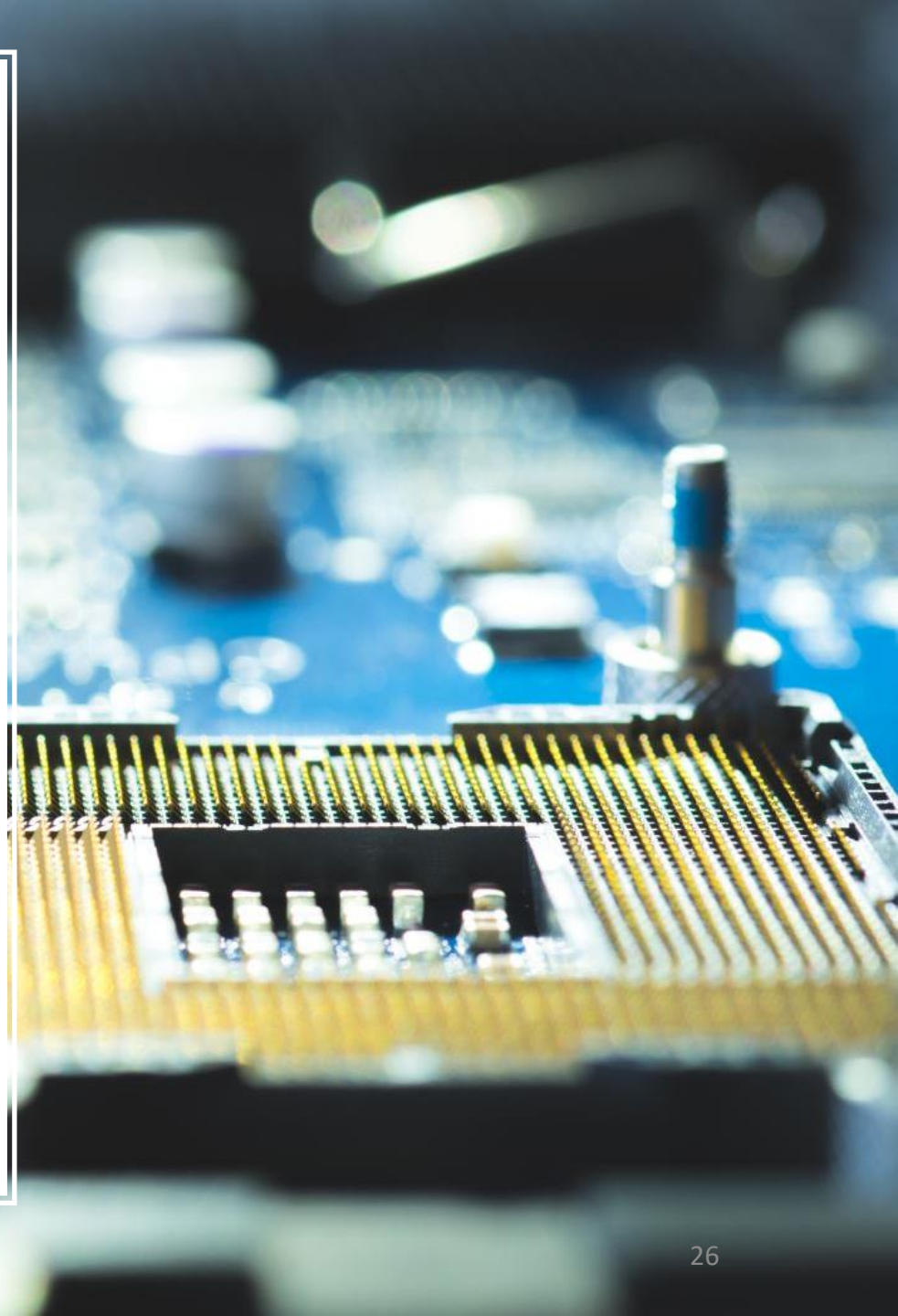
B1 Use Phase	B6 Operational Use	C1 Demolition
Meter Connectivity Module in Meter RSL -10 years	Meter Connectivity Module in Meter RSL -10 years	Disassemble of the Meter Connectivity Module

C2-C4, D End Of Life

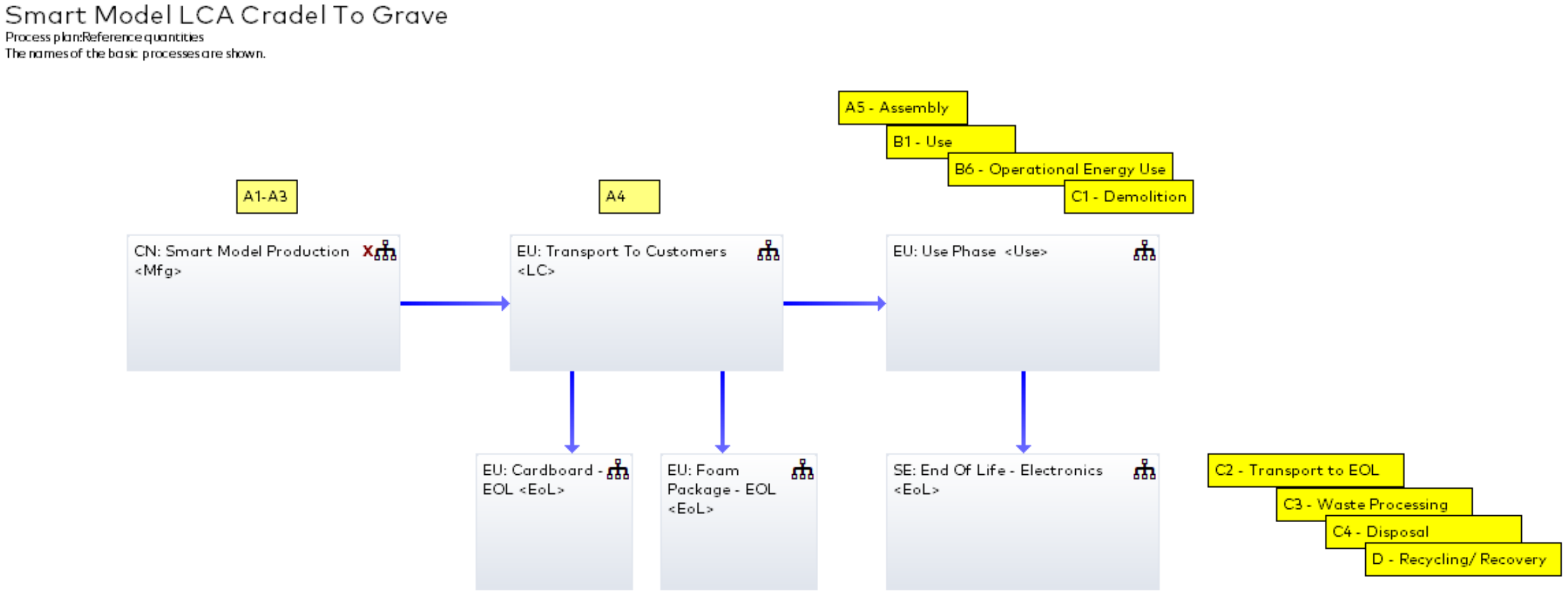
C2 Transport of Waste	C3 Waste Processing	C4 Disposal	D Recovery/ Recycling
Transport of Electronic waste and Packaging waste	Waste Processing Cardboard and Foam packaging waste	Disposal of Electronic waste and Packaging waste	Recycling of Cardboard and Electronic Waste. Incineration of Foam packaging

Database and PCR (Product Category Rules)

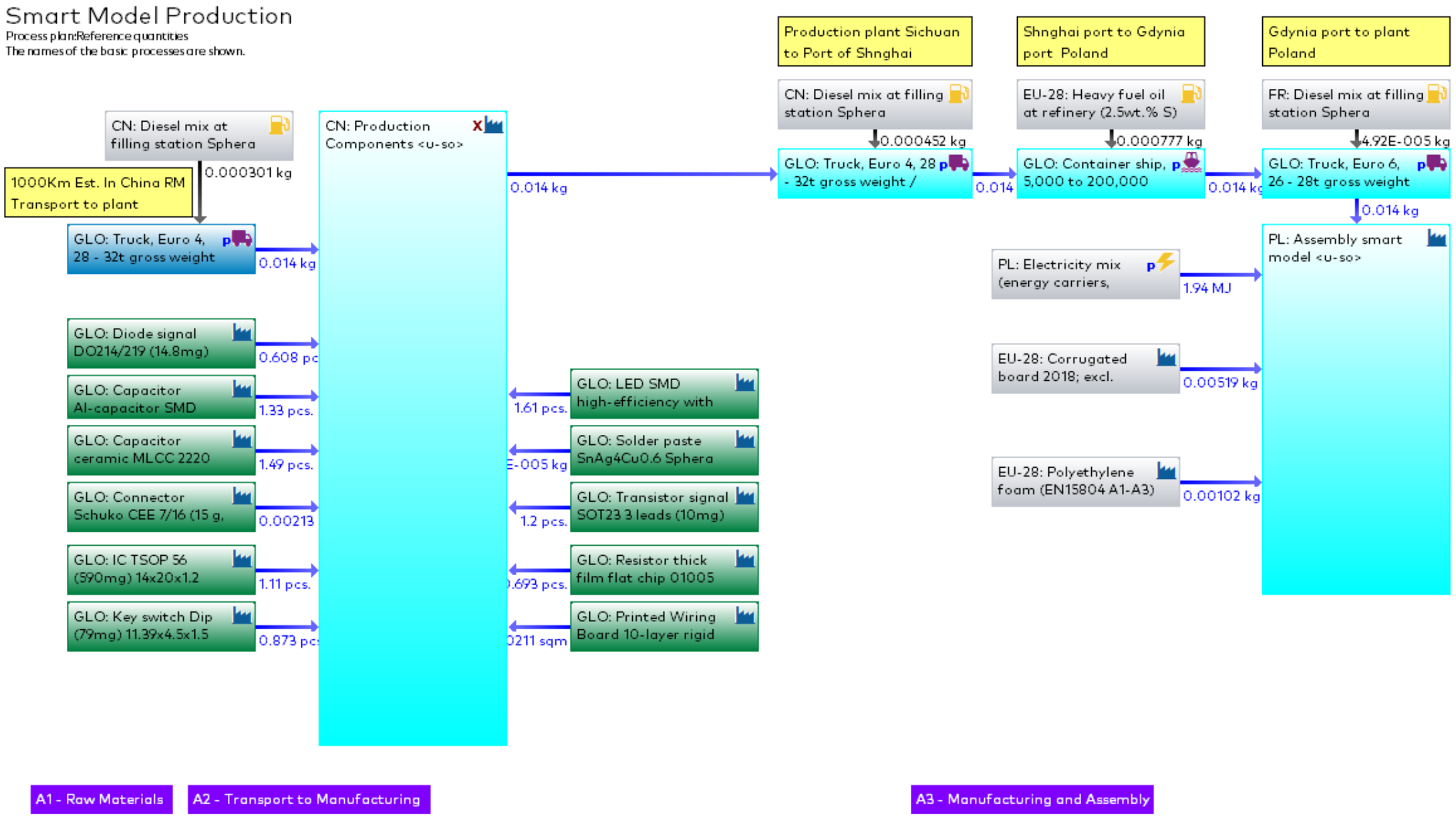
- Database at GaBi LCA software - Extension Electronics and ECOINVENT 3.8
- Decide on the available relevant Product Category Rule – PCR at EPDItaly
  - PCR EPDitaly007 - Electronic and Electrical Products and Systems
  - Sub PCR EPDitaly011 – Electronic and Electrical Products and Systems - Meters



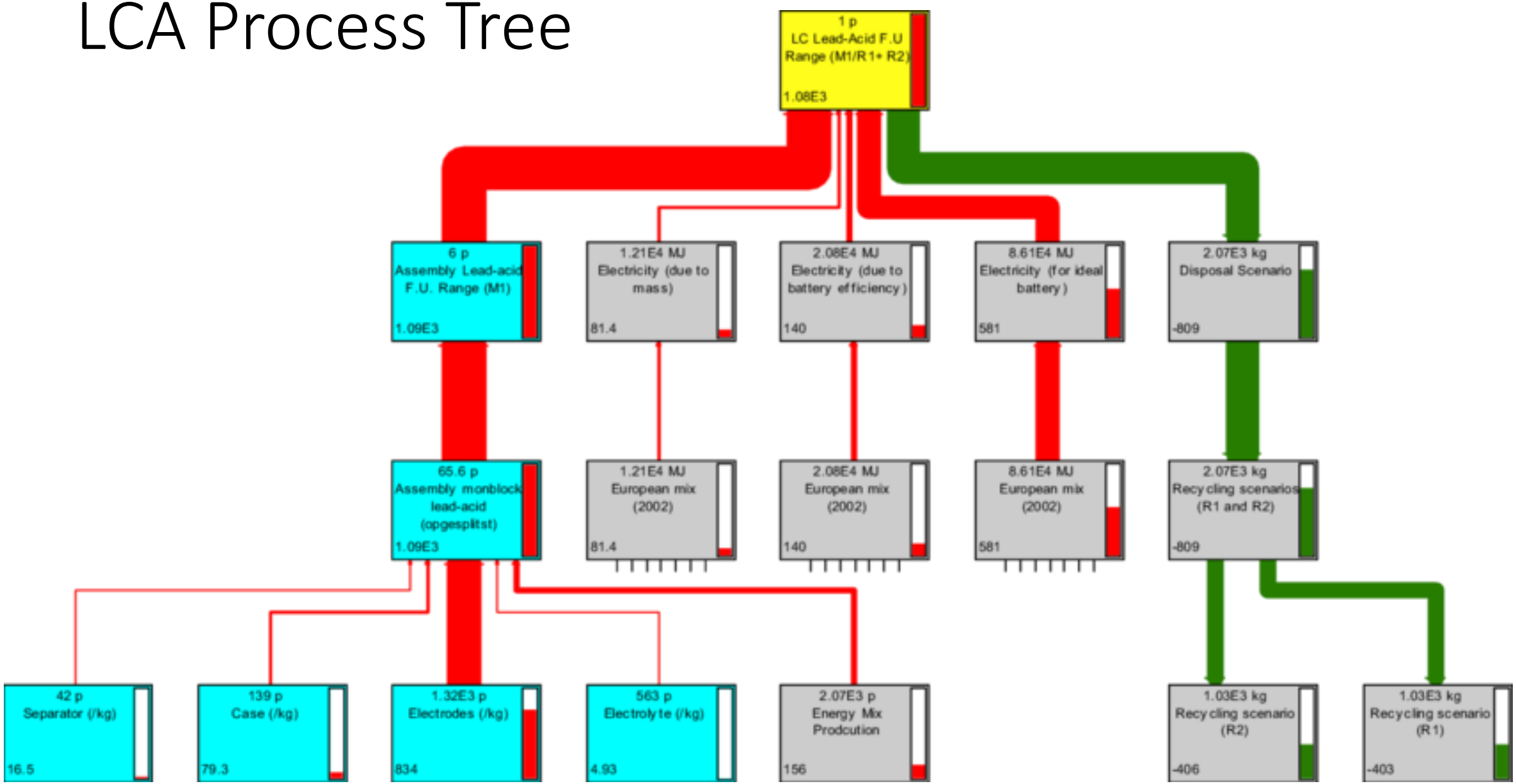
Overall plan - LCA Modelling on GaBi software

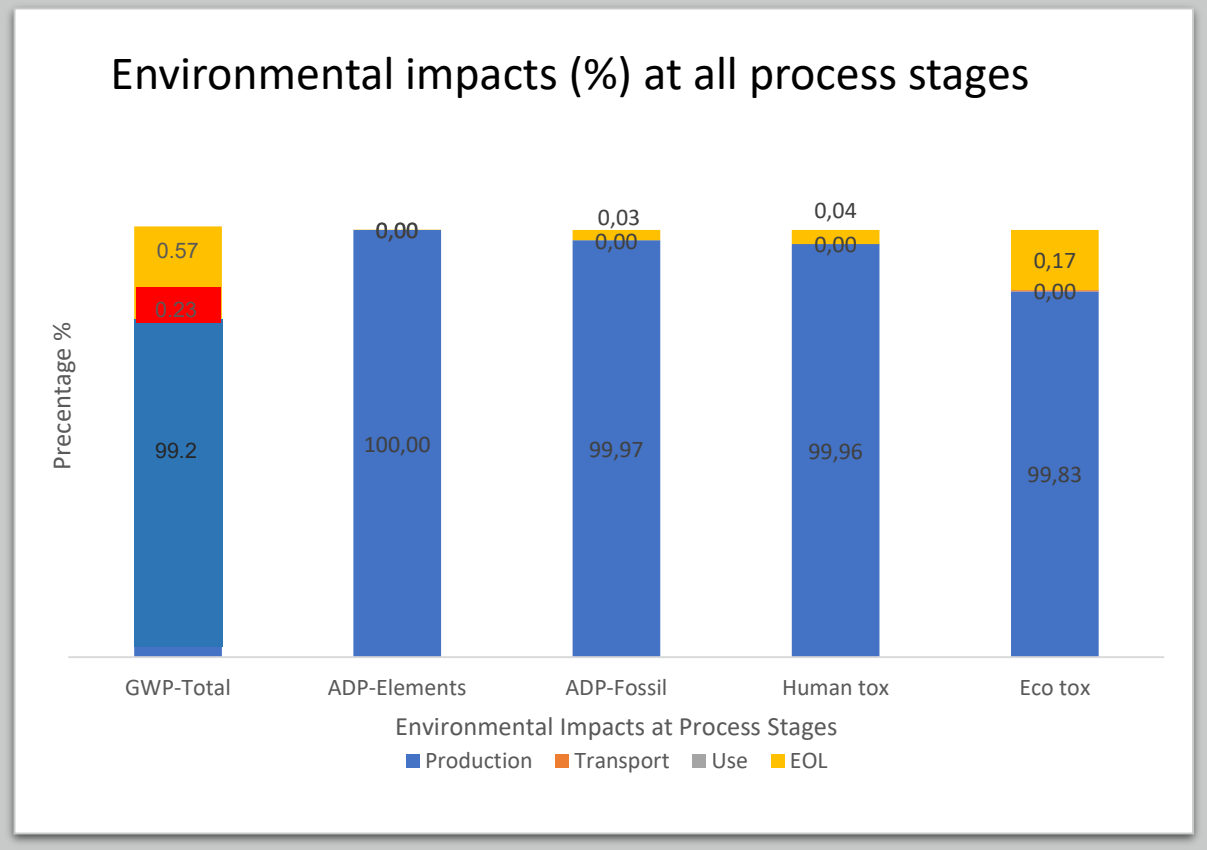


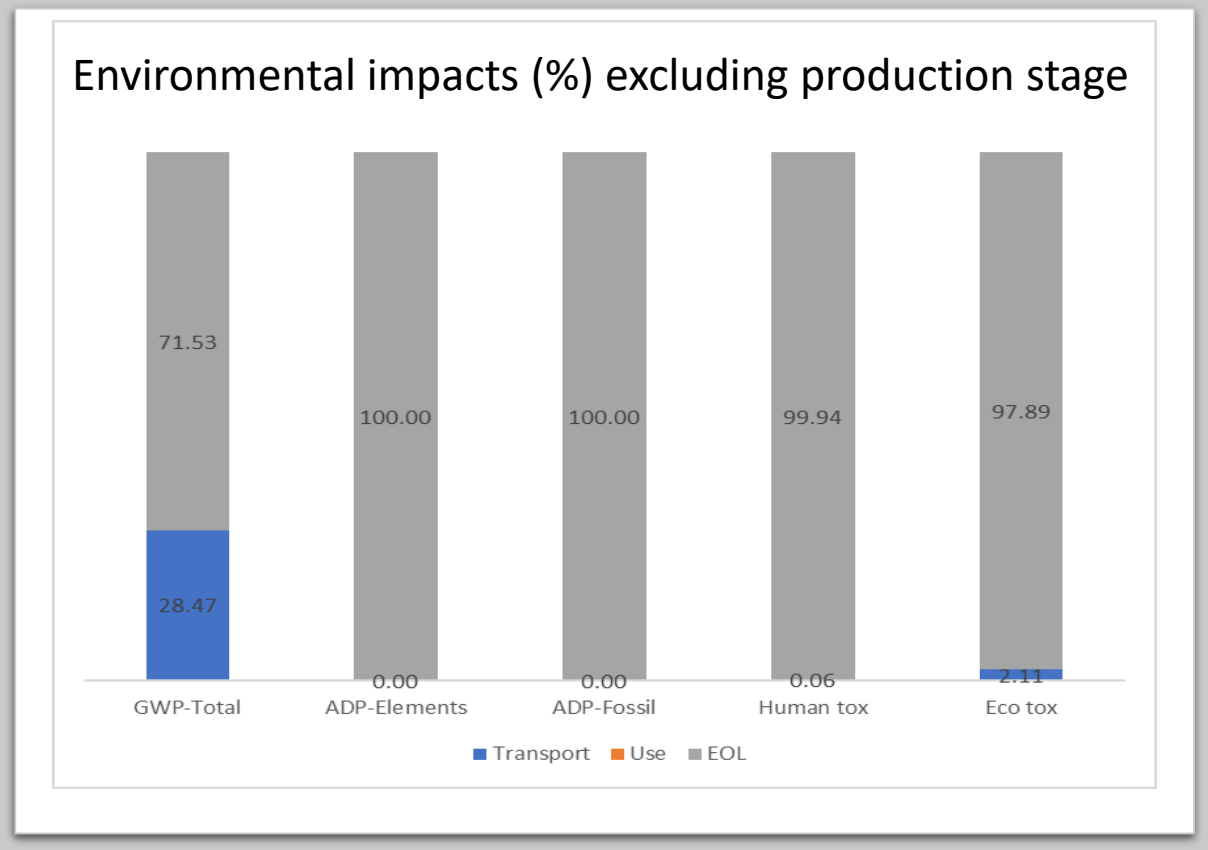
Production Process



LCA Process Tree







Results of 1 unit at process stages

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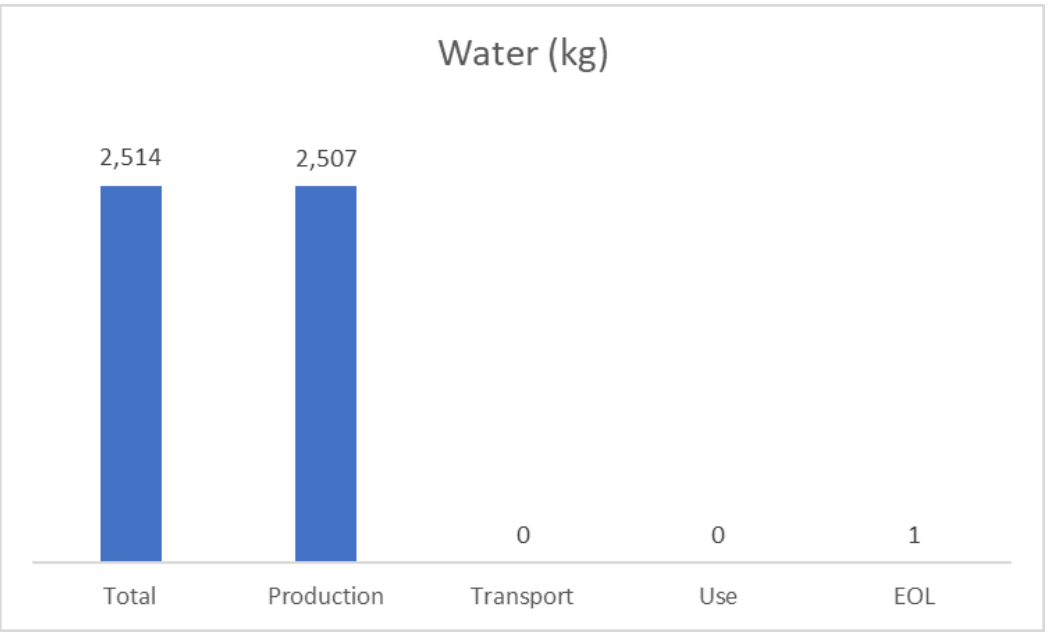

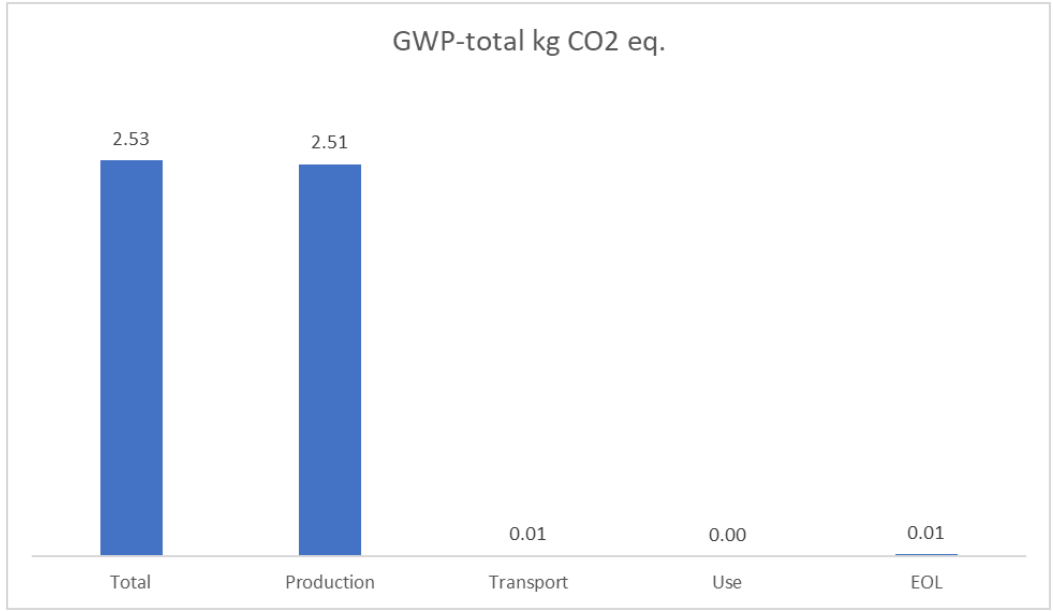

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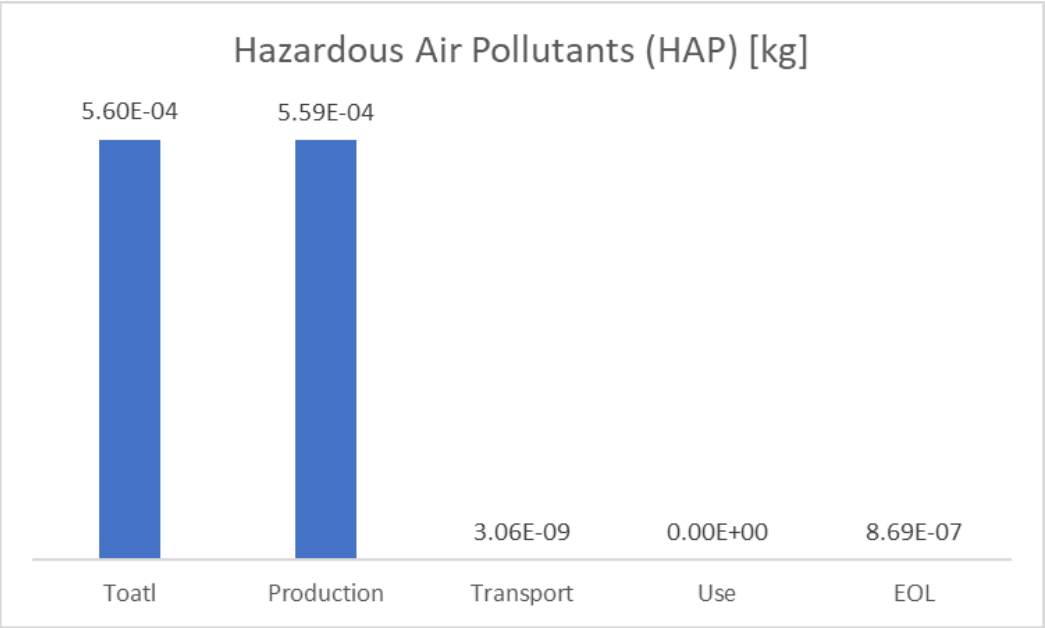

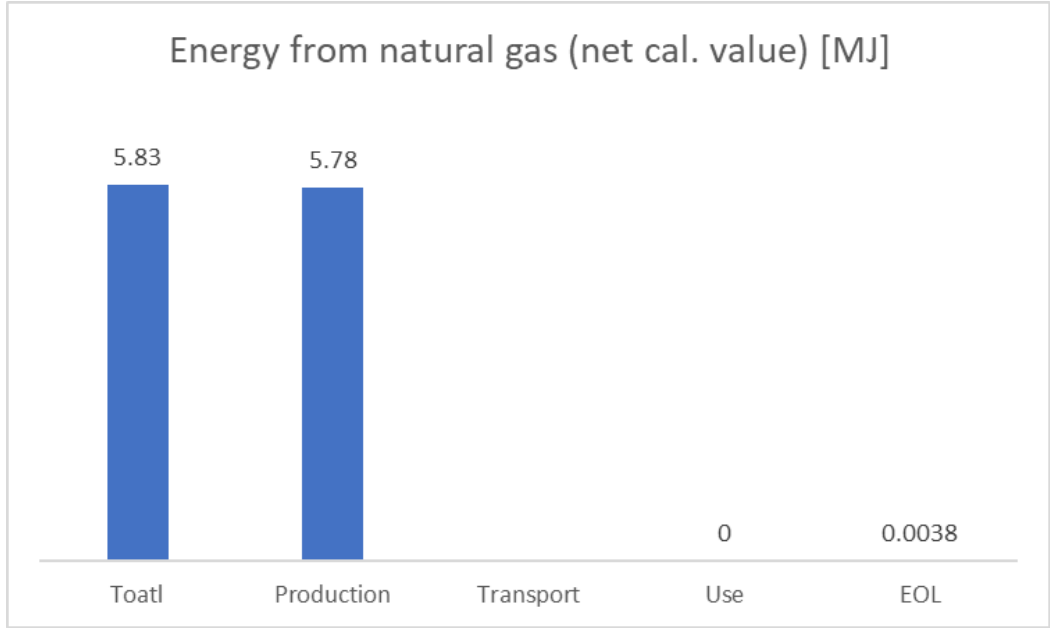

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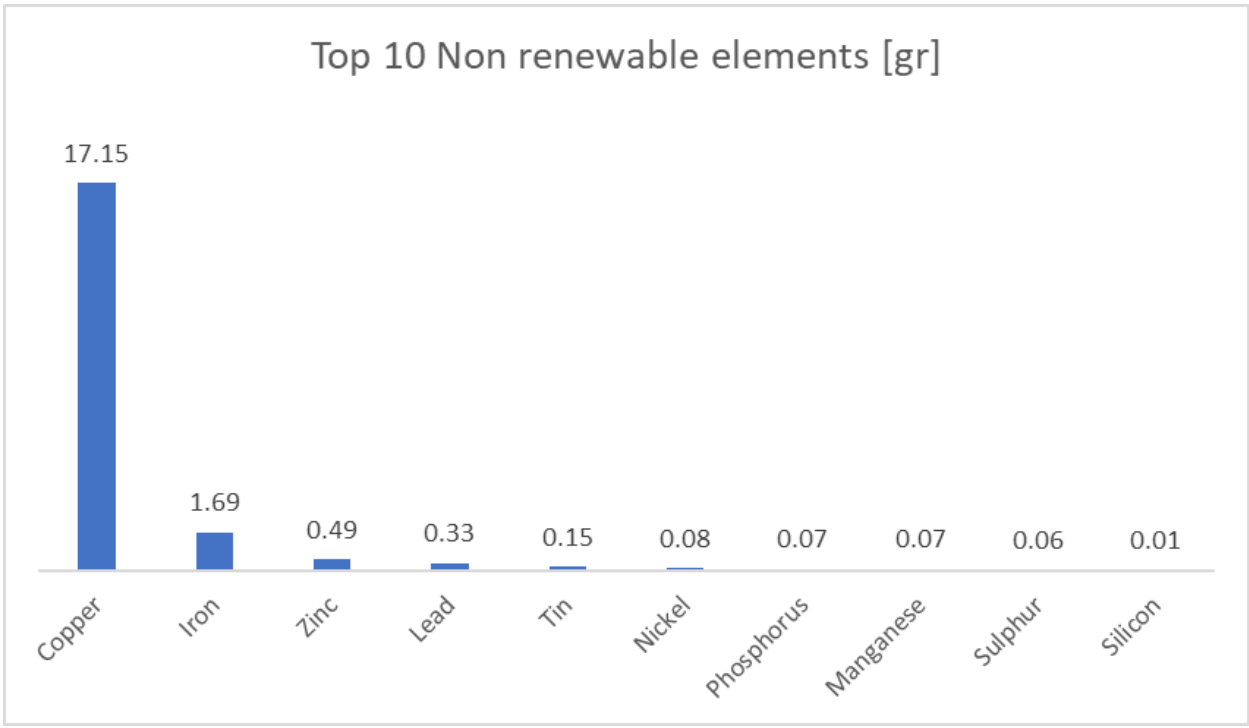

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Main Interpretations

- Raw materials in supply stage account for around 95-99% of the total impacts
- The EOL (End Of Life) stage is second most important with 99% of all environmental impacts occurring then. Only at the GWP, transportation percentage increases to 28% and EOL is 71%.
- The total GWP value is 2.53 kg CO_2 eq. per product. **For 1 year of production of 1 unit there are 253 tons of CO_2**
- The total water use is 2,514 kg per product. **For 1 year of production of 1 unit there are 251,400 tons of water**

Main Recommendations

Change transportation route - using direct route from Poland to Germany

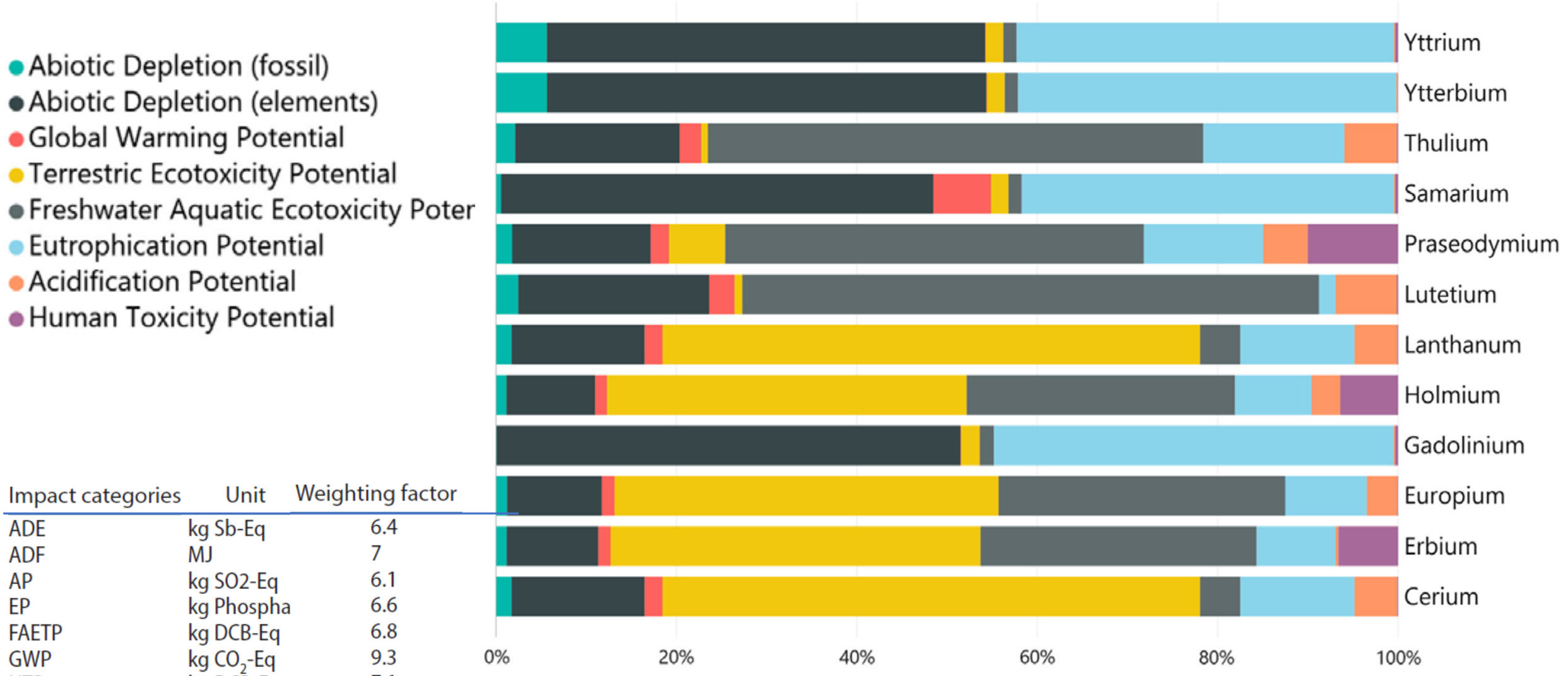
Decrease Polyethylene packaging

- Reduce using 50% less foam packaging per product
- Reuse foam packaging for at least 4 times
- Replace the foam packaging with recycled plastic

Every change to the weight of the components will have huge effects on all environmental impact especially at **PCB, Modem, Flash components**

Environmental impact categories of REE

Results of weighted environmental impact categories of extraction, processing, and production 1 Kg of each REE



Impact categories	Unit	Weighting factor
ADE	kg Sb-Eq	6.4
ADF	MJ	7
AP	kg SO2-Eq	6.1
EP	kg Phospha	6.6
FAETP	kg DCB-Eq	6.8
GWP	kg CO_2-Eq	9.3
HTP	kg DCB-Eq	7.1
TETP	kg DCB-Eq	6.8

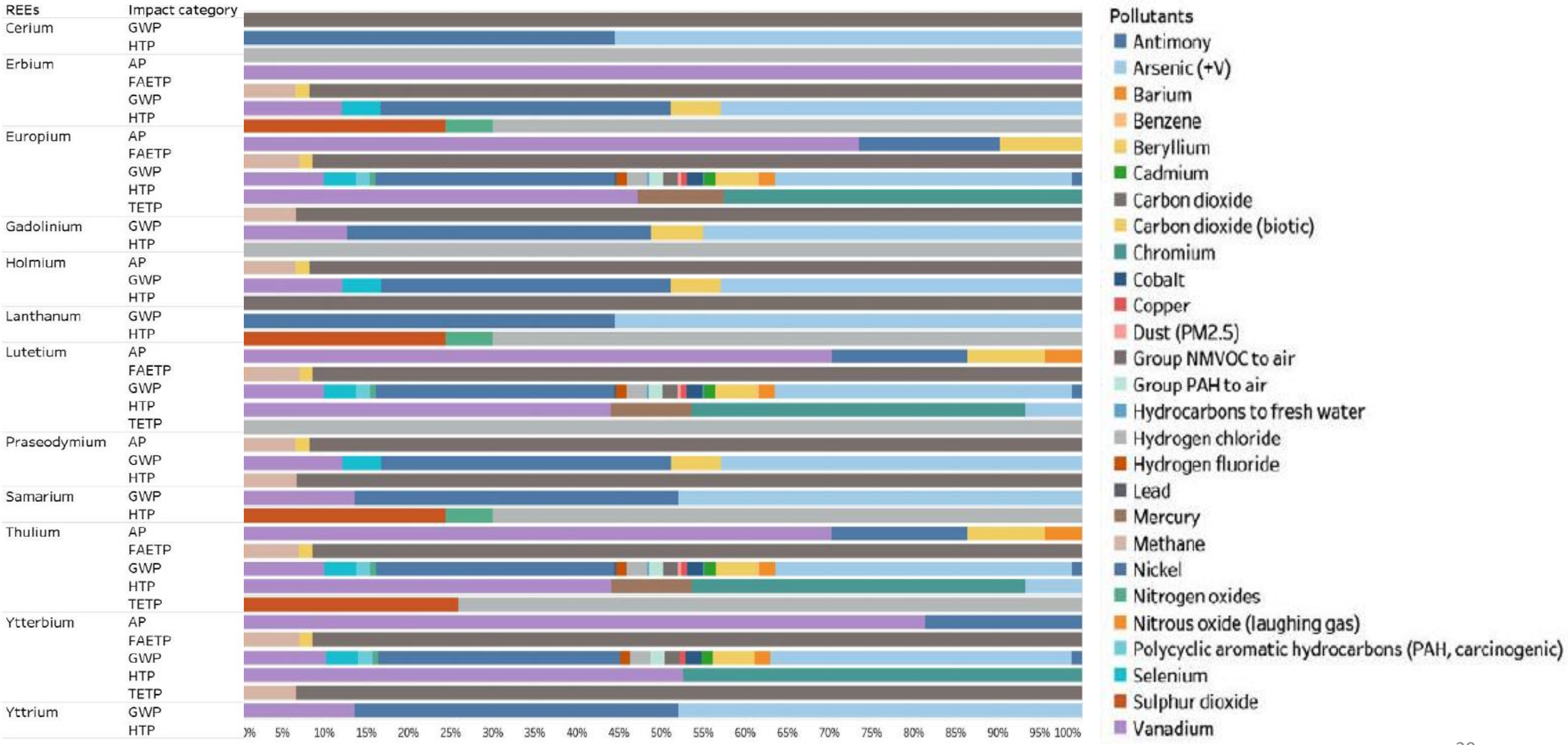
CML 2001 impact categories of **REEs** expressed in kg-Eq per functional unit

	REEs											
Impact categories	Cerium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Praseodym-ium	Samarium	Thulium	Ytterbium	Yttrium
ADE	1.23E-05	8.62E-05	1.16E-03	5.55E-05	7.51E-05	1.23E-05	1.57E-03	7.40E-05	2.97E-05	1.59E-03	4.76E-04	4.34E-05
ADF	1.38E+02	9.62E+02	1.30E+04	6.20E+02	8.39E+02	1.38E+02	1.76E+04	8.26E+02	3.31E+02	1.78E+04	5.31E+03	4.84E+02
AP	2.75E-01	1.92E+00	2.59E+01	1.24E+00	1.67E+00	2.75E-01	3.51E+01	1.65E+00	6.61E-01	3.55E+01	1.06E+01	9.66E-01
EP	4.51E-03	3.15E-02	4.26E-01	2.03E-02	2.75E-02	4.51E-03	5.76E-01	2.70E-02	1.08E-02	5.83E-01	1.74E-01	1.59E-02
FAETP	2.29E-01	1.60E+00	2.16E+01	1.03E+00	1.40E+00	2.29E-01	2.93E+01	1.37E+00	5.51E-01	2.96E+01	8.83E+00	8.06E-01
GWP	1.32E+01	9.24E+01	1.25E+03	5.95E+01	8.06E+01	1.32E+01	1.69E+03	7.93E+01	3.18E+01	1.71E+03	5.10E+02	4.65E+01
HTP	5.18E+00	3.62E+01	4.89E+02	2.33E+01	3.15E+01	5.18E+00	6.61E+02	3.11E+01	1.25E+01	6.69E+02	2.00E+02	1.82E+01
TETP	1.42E-01	9.90E-01	1.34E+01	6.38E-01	8.64E-01	1.42E-01	1.81E+01	8.50E-01	3.41E-01	1.83E+01	5.47E+00	4.98E-01

CML 2001 impact categories of **non-REEs** expressed in kg-Eq per functional unit.

	Base metals					Precious metals				
Impact categories	Aluminium	Copper	Steel	Nickel	Zinc	Gold	Palladium	Platinum	Rhodium	Silver
ADE	4.07E-06	8.42E-03	2.28E-05	2.12E-05	1.22E+00	5.20E+01	4.92E-01	2.14E+00	5.05E+00	8.19E-02
ADF	1.05E+02	4.69E+01	2.51E+01	1.56E+02	3.04E+04	6.29E+05	1.44E+05	4.47E+05	9.83E+05	4.66E+03
AF	3.51E-02	2.10E-02	7.31E-03	1.05E-01	2.16E+01	6.07E+02	1.94E+02	5.75E+02	1.25E+03	8.29E+00
EP	2.37E-03	1.67E-03	6.46E-04	3.49E-03	2.39E+00	4.19E+01	7.10E+00	2.33E+01	5.21E+01	1.07E-01
FAETP	5.69E-02	1.60E-01	4.40E-03	1.42E+00	1.09E+02	6.63E+01	3.43E+02	4.77E+02	7.27E+02	3.06E+00
GWP	9.62E+00	3.69E+00	2.21E+00	1.30E+01	3.13E+03	6.16E+04	1.23E+04	4.24E+04	9.56E+04	3.36E+02
HTP	3.29E+01	3.33E+00	2.47E-01	6.25E+01	4.78E+03	4.45E+03	1.05E+04	1.57E+04	2.54E+04	8.61E+02
GWP	1.56E-02	1.69E-02	1.20E-02	2.98E-01	2.40E+01	7.53E+01	1.06E+02	1.73E+02	2.97E+02	6.30E+00

The major emissions that contribute to AP, FAETP, GWP, HTP, and TET P for each REE.
Percentage of emissions measured in kg-eq greater than 1 kg-eq.



REE Environmental impact categories

- Environmental loads associated with the production of REEs, which might help **provide a baseline for cleaner production, alternative metal choices, and advances in technologies for primary metal production**.
- The results show that the worst weighted environmental impacts are those from the **production of gadolinium, yttrium, cerium, lanthanum, and samarium**. The production of lutetium and thulium has the lowest impacts of the REEs examined.
- The most significant emissions for all REEs are **radium, carbon dioxide, and chloride**.
- The greatest heavy metal emissions from the REEs are **manganese, tin, copper, vanadium, zinc, and nickel.**

Sources

- LCA for Meter Connectivity Module - Done by Amit Lotan ‘Enviroet GmbH’
- Impact Assessment Methods and Categories – Ecoinvent website: https://ecoinvent.org/
- Environmental impact categories of REE - Mahdi Ikhlayel (2017) **Evaluation of the environmental impacts of rare earth elements production**, International Journal of Environmental Studies. link to this article: https://doi.org/10.1080/00207233.2017.1341737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