CIRAIG[MC]

Centre interuniversitaire de recherche sur le cycle de vie des produits, procédés et services

ENV-510 – Week 1

Introduction to life cycle assessment, presentation of the course

POLYTECHNIQUE MONTRÉAL

WORLD-CLASS ENGINEERING

ENV-510 – LIFE CYCLE ASSESSMENT IN ENERGY SYSTEMS

Title: **Life Cycle Assessment in energy systems**

Teachers:	**Professor Manuele Margni,** HES-SO Valais Wallis Polytechnique Montréal manuele.margni@hevs.ch	**Professor François Maréchal,** EPFL IPESE (SCI-STI-FM) EPFL Valais Wallis ferancois.marechal@epfl.ch
Teaching Assistants:	**Jonas Schnidrig** EPFL IPESE (SCI-STI-FM) HES-SO & EPFL Valais Wallis jonas.schnidrig@epfl.ch	**Xinyi Wei** EPFL IPESE (SCI-STI-FM) EPFL Valais Wallis xinyi.wei@epfl.ch
	Gabriel Magnaval HES-SO & EPFL Valais Wallis gabriel.magnaval@hevs.ch	**Jocelyn Roth** EPFL SB ISIC LFIM EPFL Valais Wallis jocelyn.roth@epfl.ch

3 credits
(presence in class/online attendance: 2 h./week)
(practical work through tutorial sessions: 1 h./week)
(personal work: 3 h./week)

Contextual information about the course

This course will be taught in a dual-mode: it will be held face-to-face and broadcasted via the zoom web platform.

The Moodle platform is used as a repository of course documents. The access to the Zoom platform will be accessible on Moodle.

The courses will also be recorded so that participants can also follow up in asynchronous mode (although not always guaranteed).

The final exam will requires physical presence

On the agenda today

- Presentation of teachers and participants
- Presentation of the syllabus
- Introduction to the LCA project

BREAK 1

- Why LCA?
- IPAT equation

BREAK 2

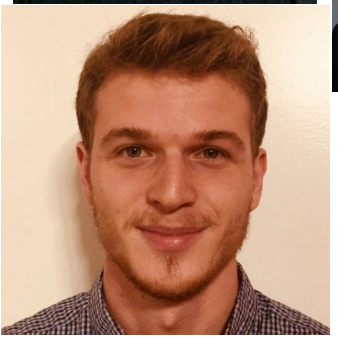
- Conceptual model of LCA
- LCA framework according to ISO 14040
- Group exploration of LCA concepts
- Conclusion

Professors / teachers

- **François Maréchal,** Prof. EPFL, IPESE
- Process and Energy Systems Engineering
- Co-responsible of the course

- **Manuele Margni,** Prof. HES-SO Valais, Polytechnique Montréal, CIRAIG, academic guest EPFL
- Life cycle assessment and sustainability metrics
- Co-responsible of the course

Teaching assistants: Lab mgmt, LCA project coach, Q&A



- **Xinyi Wei:** PhD student at EPFL VS (IPESE) :
- **Gabriel Magnaval:** PhD student at Polytechnique Montréal & HES-SO Valais
- **Jocelyn Roth**: PhD student at SB ISIC LFIM, EPFL VS
- **Dareen Dardor:** PhD student at EPFL (IPESE) & HES-SO Valais Wallis
- **Soline Corre:** PhD student at EPFL VS (IPESE)
- **Sai Ravi:** PhD student at EPFL (IPESE)

Syllabus

GENERAL OBJECTIVES of the course (summary – complete list in the syllabus)

- Gather a theoretical understanding of LCA
- Analyze, interpret and criticize results of an LCA
- Perform an LCA from A to Z

Pedagogical organisation of the course

- Lectures on LCA theory
- Labs (calculations using software and by hand)
- LCA project in a team of students

Syllabus – Learning assessment

LCA PROJECT = 50%

PRELIMINARY DELIVRABLE: Oral & Report (10%)

FINAL DELIVRABLE: Oral & Report (40%)

IMPORTANT: The overall evaluation of the LCA project by the teaching team will be tailored to each team member based on peer evaluation (from team members)

FINAL EXAM = 50%

IMPORTANT: A minimum grade of 3.5 over 6 is required in the final exam, otherwise, the grades for the project will not be considered and a failing grade is assigned

Moodle and syllabus

- *Show how the course is organized on the Moodle platform*
- *Present the syllabus and how the course plan is organized throught the 14 weeks*

Readings

NORME INTERNATIONALE

ISO 14040

Deuxième édition
2006-07-01

Management environnemental — Analyse du cycle de vie — Principes et cadre

Environmental management — Life cycle assessment — Principles and framework

NORME INTERNATIONALE

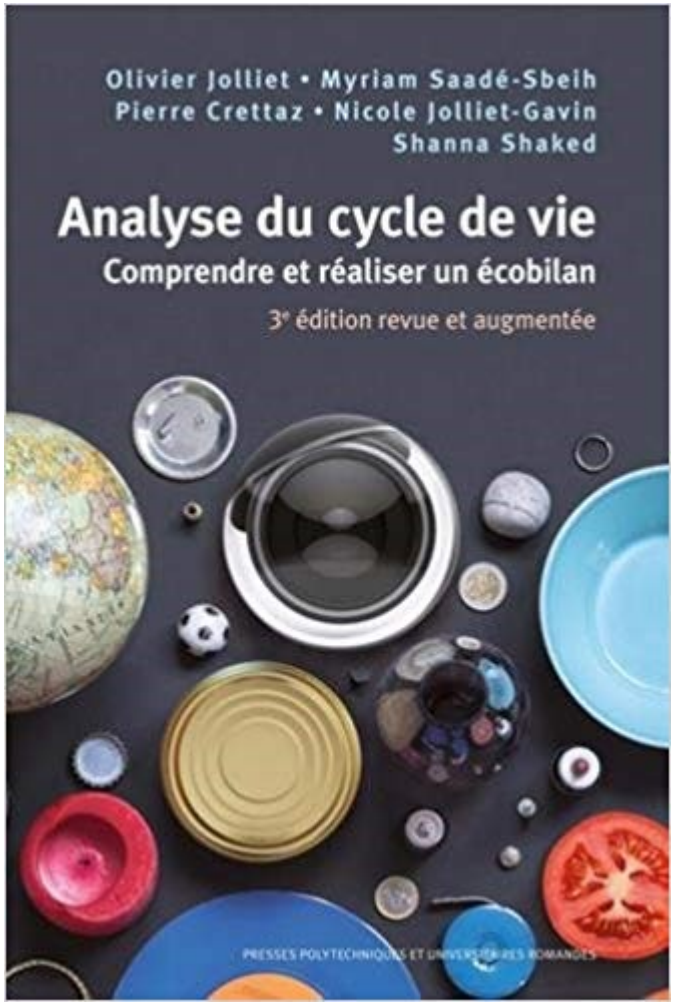
ISO 14044

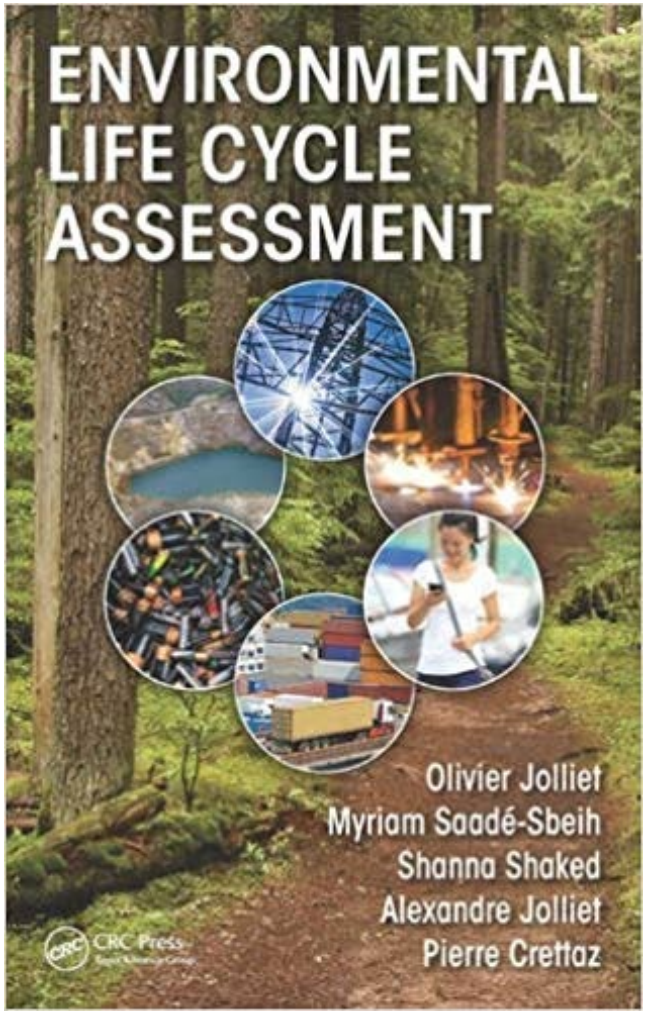
Première édition
2006-07-01

Management environnemental — Analyse du cycle de vie — Exigences et lignes directrices

Environmental management — Life cycle assessment — Requirements and guidelines

LCA textbooks



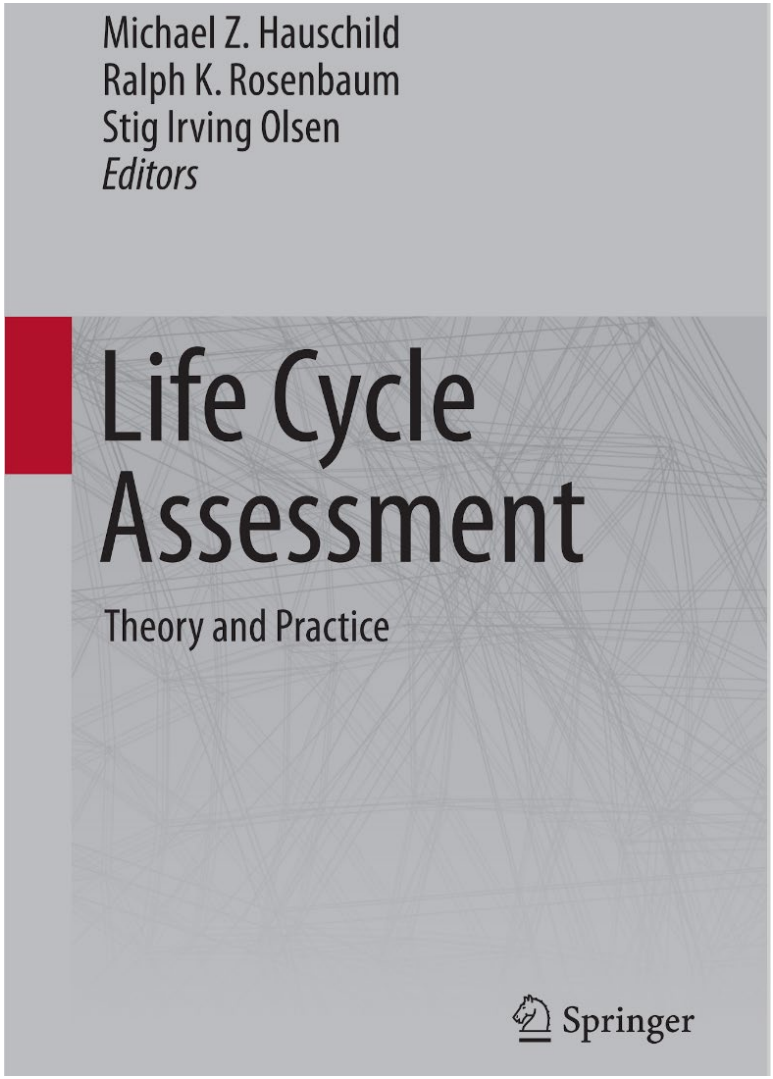


https://doi.org/10.1201/b19138

MOOC: introduction à l'analyse du cycle de vie

https://www.edx.org/course/cycle-de-vie

LCA textbooks



Readings

And any other document suggested during the session

Tools

Software: OpenLCA (http://openlca.org/)

Life cycle inventory database: ecoinvent v3.6

Communication tool / document transfer: Moodle

Zoom for video lectures

Support

Questions? Doubts?

Step 1: Ask the question to your colleagues on Moodle Forum (we also answer)

Step 2: Teaching assistants by appointment

Step 3: Teachers

LCA project

- Groups (max 6 students) formed and project proposals approved by the end of the course on week 3.

- Submit your project proposal:
  - **Register your project in the « LCA project » section of Moodle "Registation of LCA group projects"**
  - **Ask teachers to validate the project**

- Use course breaks and Moodle forum to select and create a group / suggest a project topic

Choosing the subject of your LCA project

- Comparison of products / services
- Prioritize subjects…
  - **That you are passionate about**
  - **For which you have access to data**
  - **That are important to you and on which you already have some knowledge**
- Avoid subjects…
  - **With obvious conclusions**
  - **That were already studied many times**
  - **That are too complicated or complex**

- We will validate the subjects with you

BREAK1

CIRAIG

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BREAK 1

- Why LCA?
- IPAT equation

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Why LCA?

What does life cycle mean?

Evaluate a situation through a life cycle thinking: take into account all life cycle stages of the product or service studied

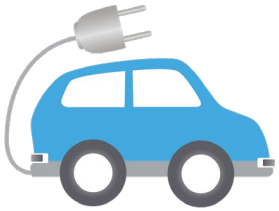
What does assesment mean?

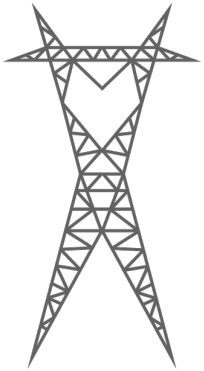
Assess the environmental impacts of a product or service. It usually takes into account multiple environmental indicators.

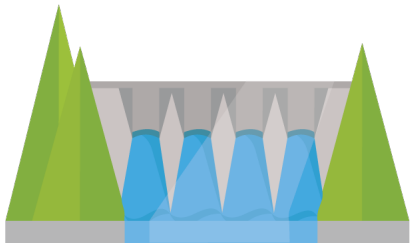
It is possible to assess other things like cost or social impact with a life cycle thinking but those type of assessment are outside the scope of this class

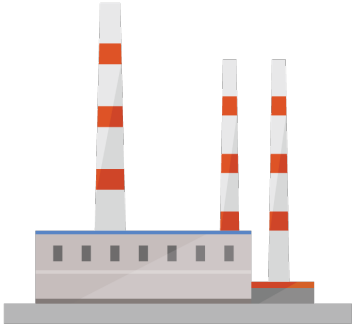
Unexpected impacts

Zero emission?









Or rather occurs elsewhere?

Life cycle thinking makes it possible to:

- Identify unexpected impacts
- Avoid shift of environmental problems

Why LCA?

RESEARCH AND ANALYSIS

Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles

Troy R. Hawkins, Bhawna Singh, Guillaume Majeau-Bettez, and Anders Hammer Strømman

Journal of Industrial Ecology, Volume 17, Number 1, (2012)

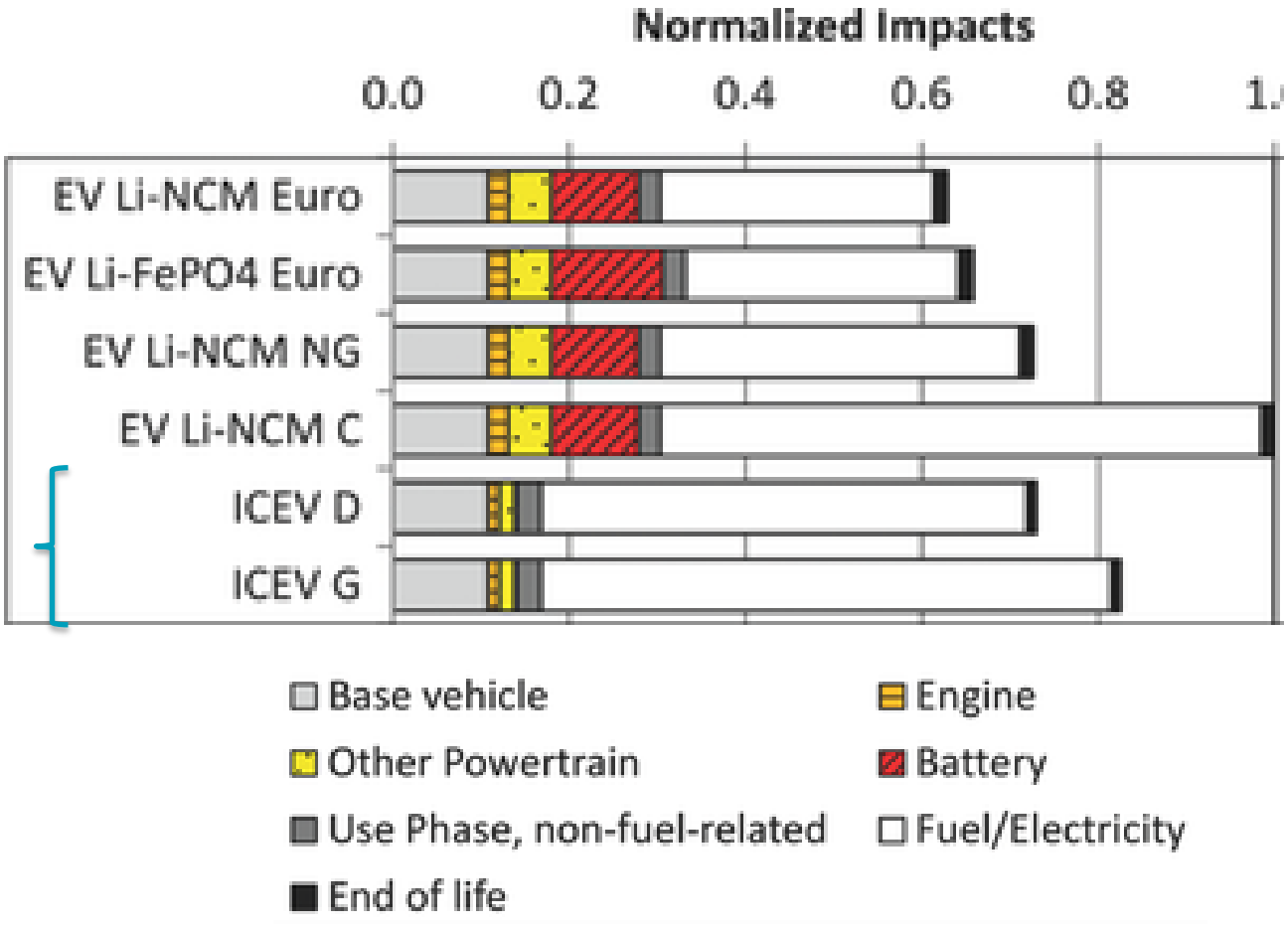
Summary

Electric vehicles (EVs) coupled with low-carbon electricity sources offer the potential for reducing greenhouse gas emissions and exposure to tailpipe emissions from personal transportation. In considering these benefits, it is important to address concerns of problem-shifting. In addition, while many studies have focused on the use phase in comparing transportation options, vehicle production is also significant when comparing conventional and EVs. We develop and provide a transparent life cycle inventory of conventional and

Global Warming Potential for electric vs. conventional vehicles

Electric Vehicle (EV) powered by EU electricity (EURO), coal (C) and natural gaz (NG)

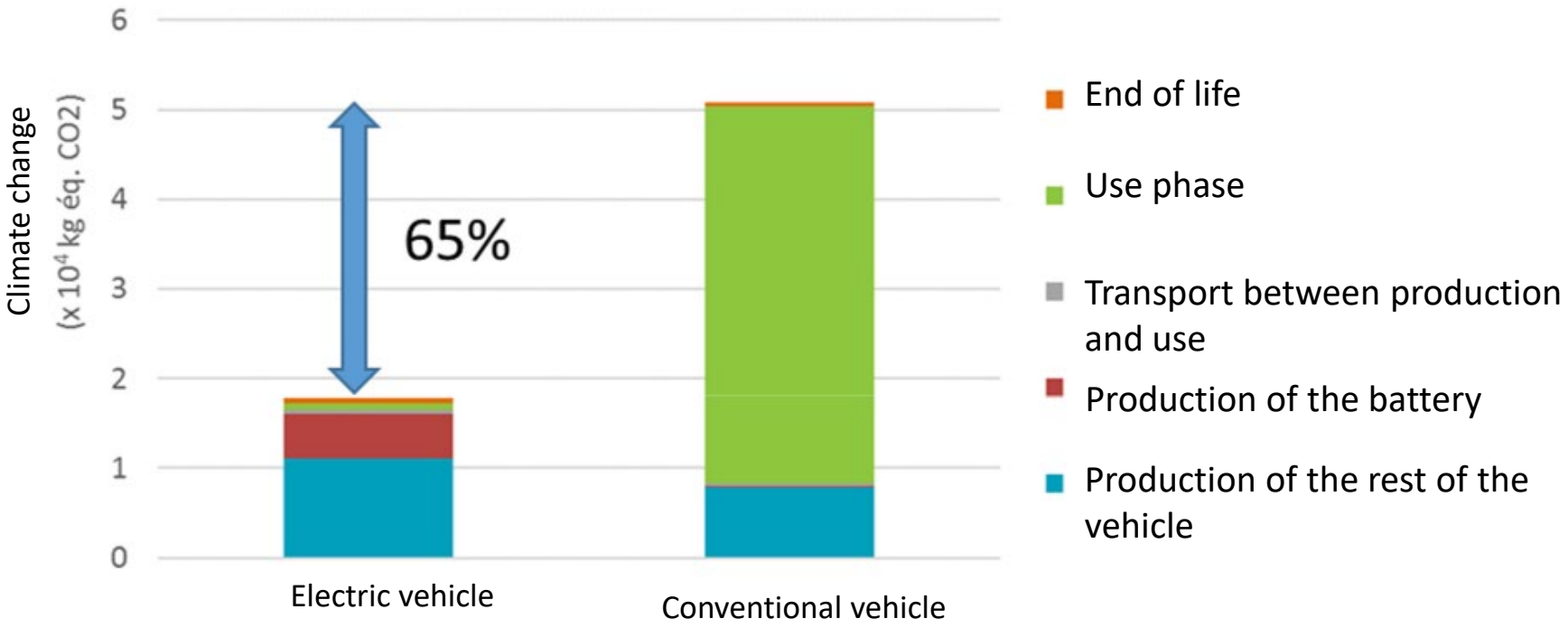
Conventional vehicles poweved by Diesel (D) and gasoline (G)



(Troy et al., 2012)

Electric vehicles vs conventional vehicles (QC)

Quebec context (> 95% hydroelectricity)



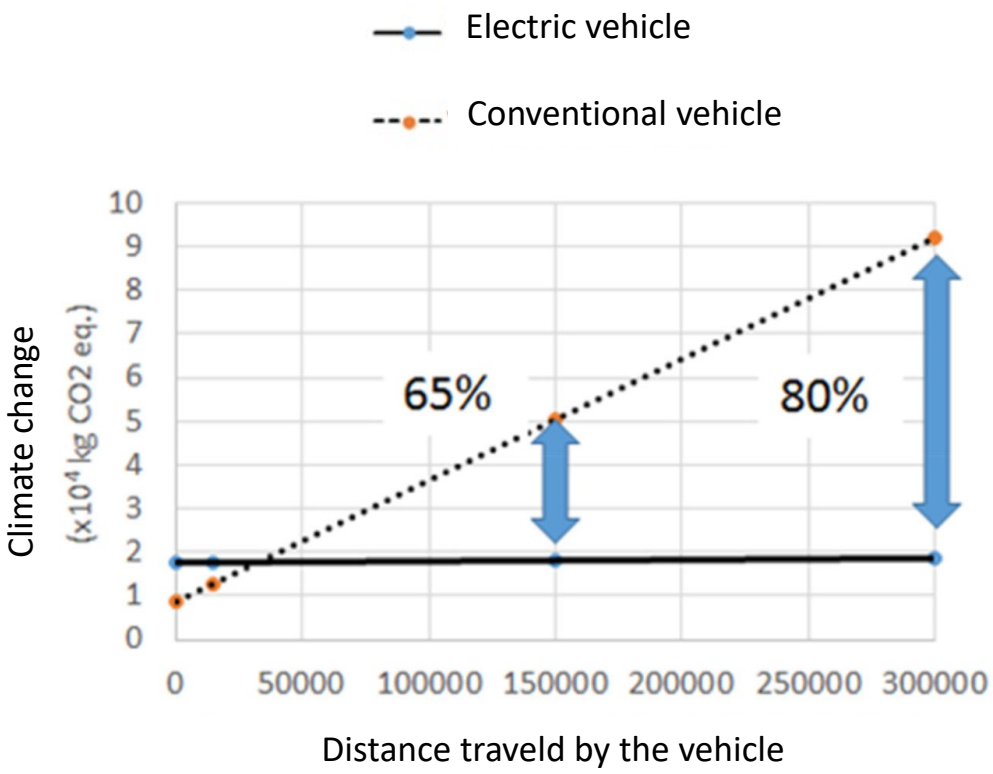
(CIRAIG, 2016)

Electric vehicles vs conventional vehicles (QC)

EV more impactful than CV at purchase (x 1.5 – 2)

Breakeven point ~ 30,000 km

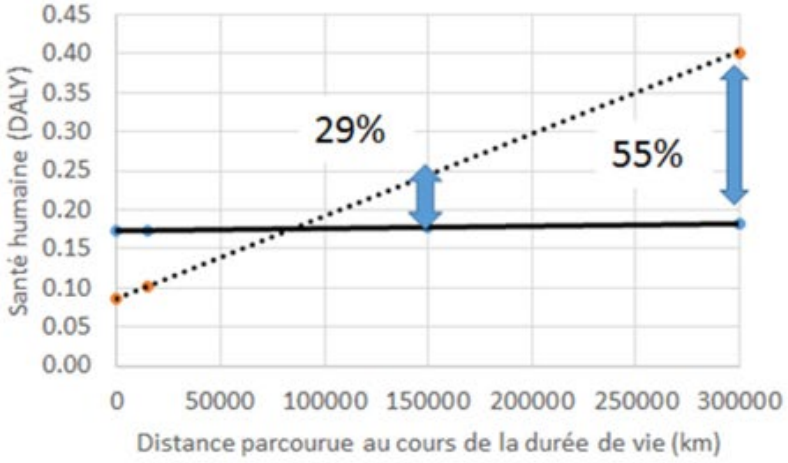
Gap increases with vehicle lifetime

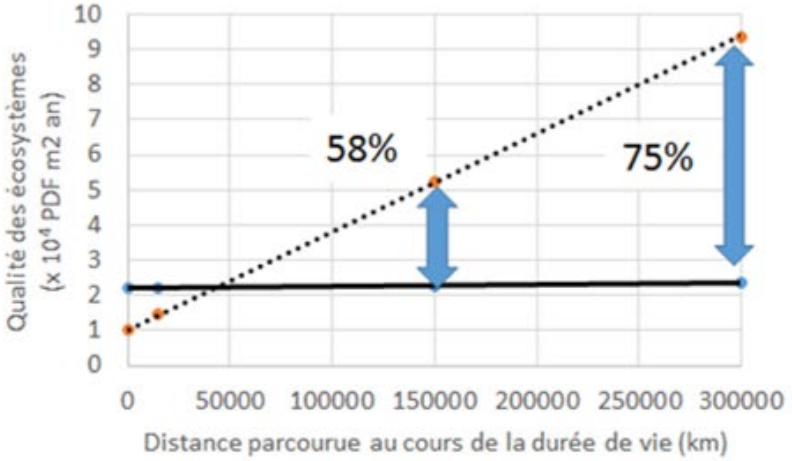


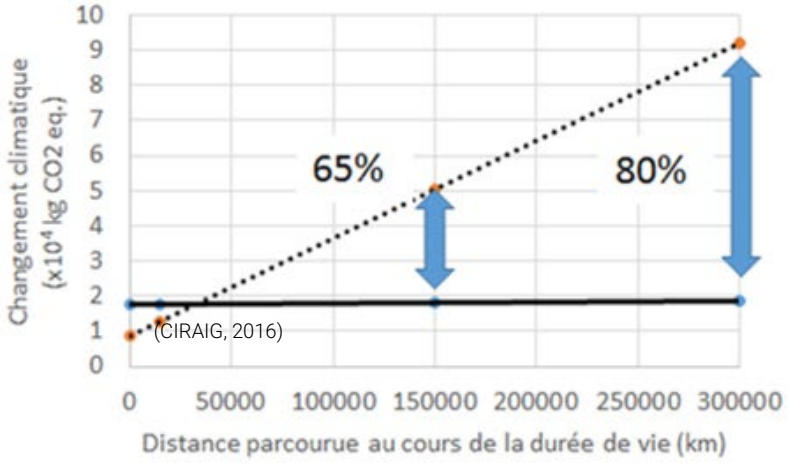
(CIRAIG, 2016)

Electric vehicles vs conventional vehicles (QC)

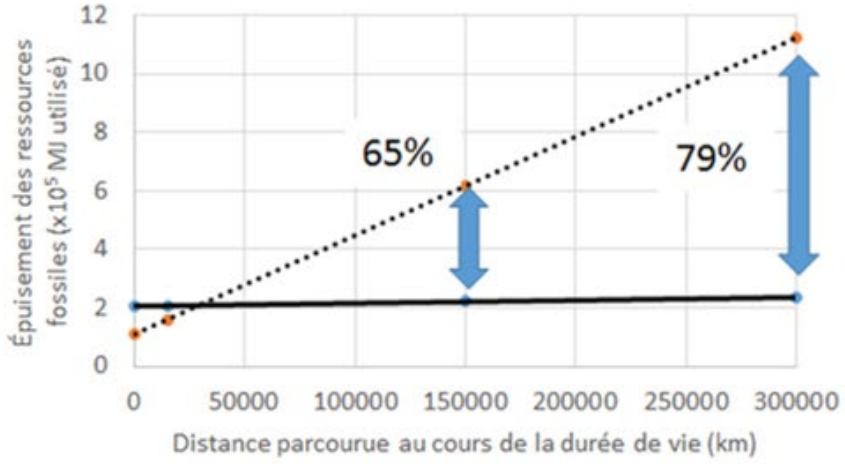
Similar trend for the « human health », « ecosystem quality » and « resource depletion – non renewable»





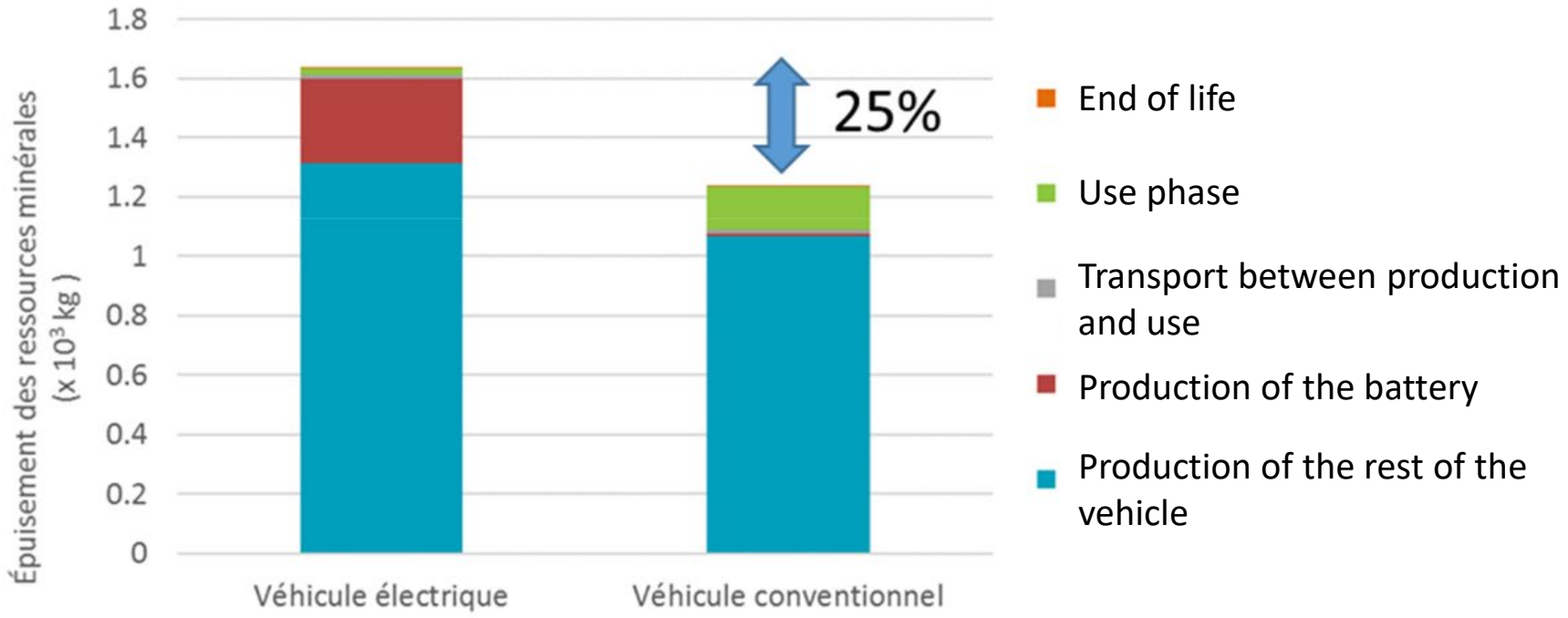


(CIRAIG, 2016)



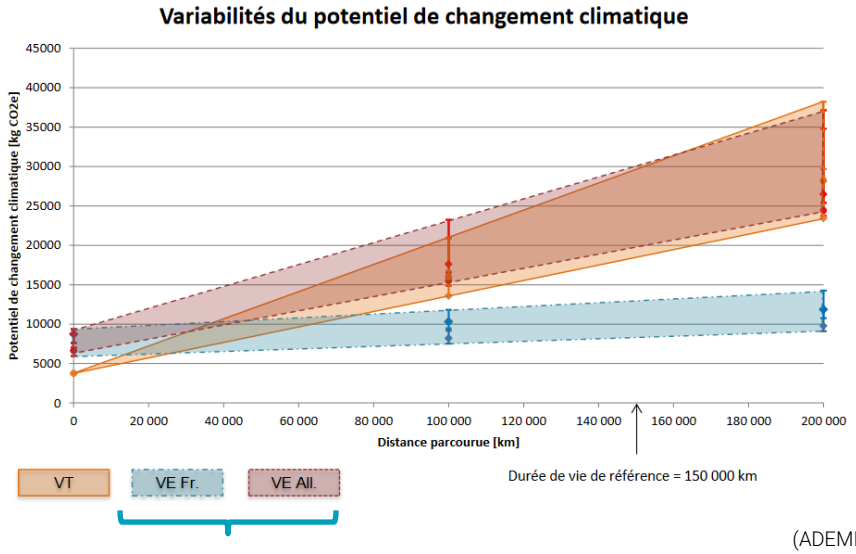
Electric vehicles vs conventional vehicles (QC)

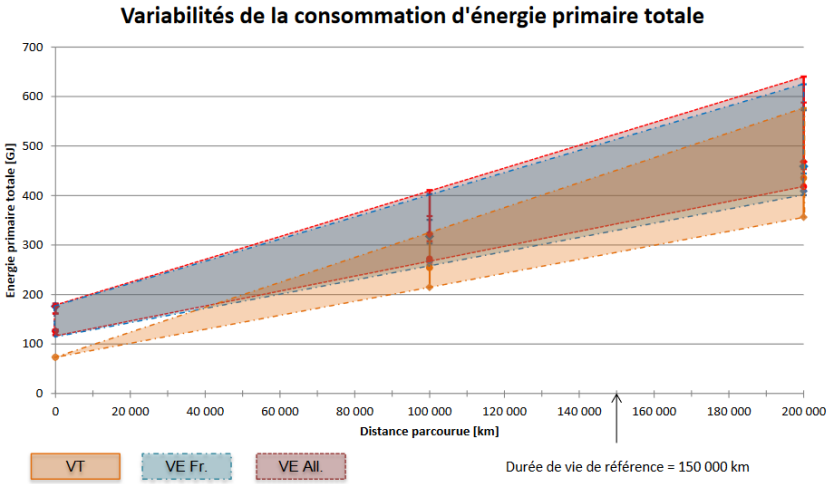
Trends are reversed for the indicator « depletion of mineral resources»



(CIRAIG, 2016)

Electric vehicles vs conventional vehicles in other context (FR and DE)





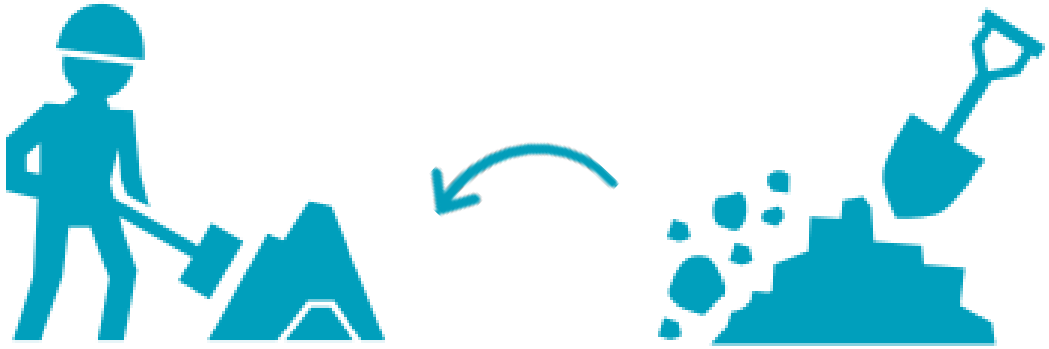
Conventional vehicle

Electric vehicle

(ADEME, 2013)

The life cycle approach

The life cycle approach makes it possible to anticipate a potential impact shift

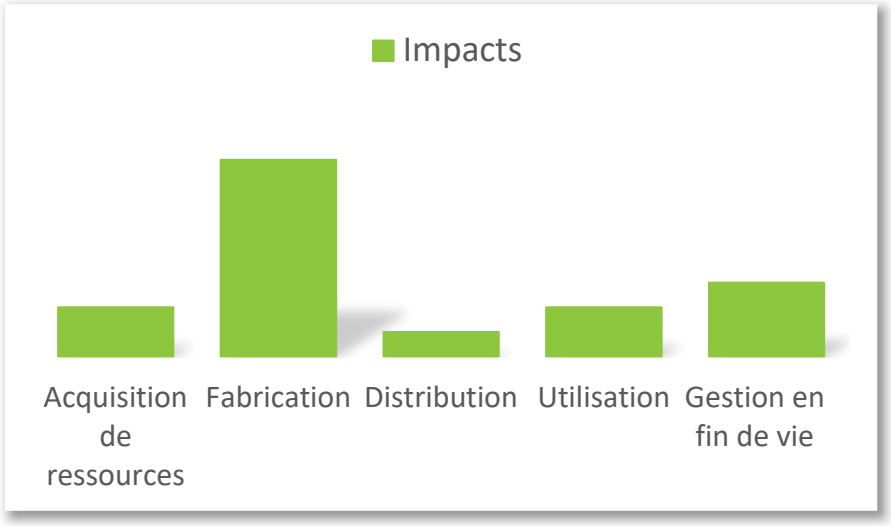


Two principles to avoid impact shift:

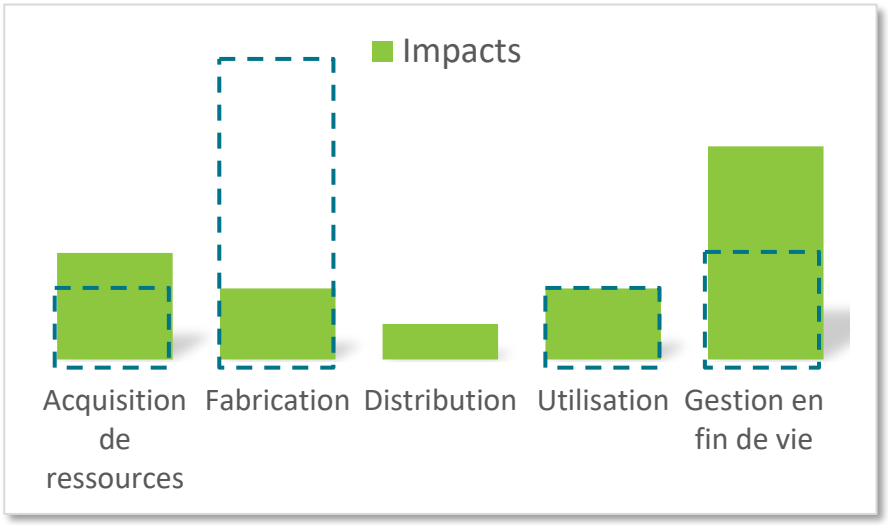
- Global or life cycle approach
- Multi-criteria or multi-indicator approach

1st principle to avoid impact shift

Global or life cycle approach



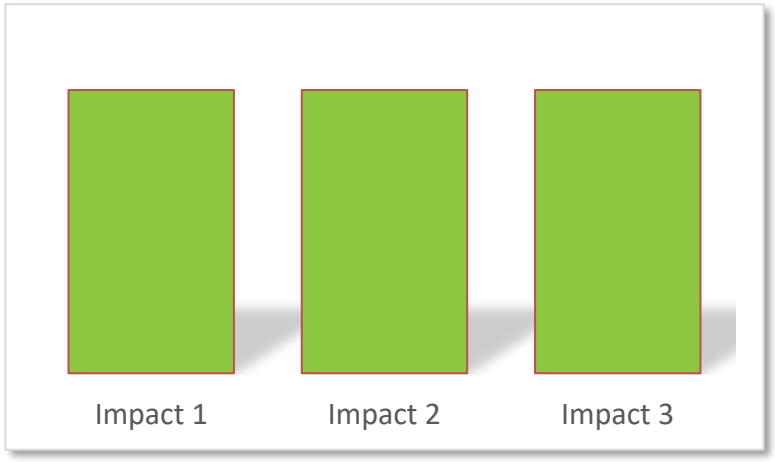
Before



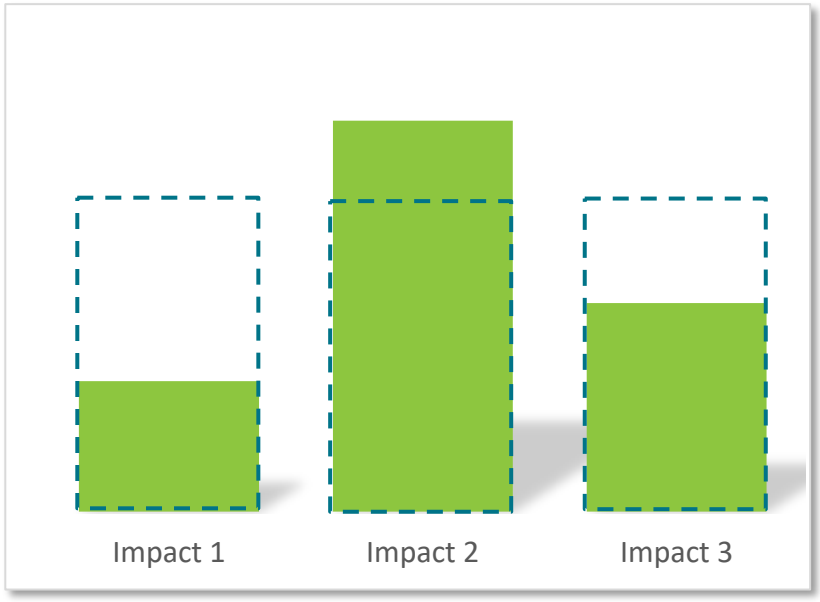
After

2nd principle to avoid impact shift

Multi-criteria or multi-indicator approach



Before



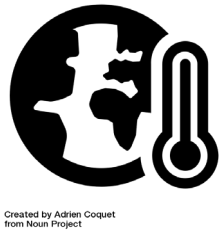
After

Example of impact shift

Refrigeration systems are a concrete example of impact shift

Chloromethane,
Sulfur dioxide,
Ammonia

CFC



HCFC

1 kg of HCFC corresponds to 10 000 kg of CO_2

1950

1987

Provide an example of burden shift

Across life cycle stages

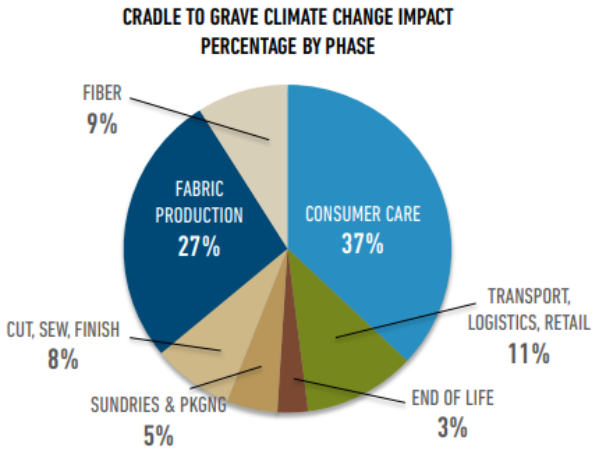
Between environmental problems

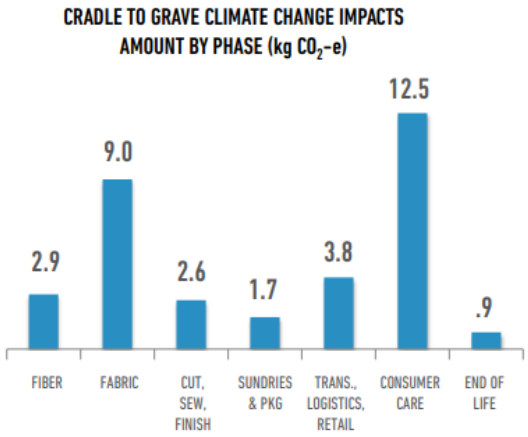
Identification of « hotspots »

Quantify the scores of several types of environmental impact over the entire life cycle

Identification of activities and life cycle stages with the greatest contribution to impacts

Consumer Care phase dominates the climate change impact area (driven by high use of non-renewable energy).





http://levistrauss.com/wp-content/uploads/2015/03/Full-LCA-Results-Deck-FINAL.pdf

Eco-design

« Systematic integration of environmental aspects in the design and development of products (goods and services, systems) with the objective of reducing negative environmental impacts throughout their life cycle for equivalent or superior service […] ».

Norme NF X 30-264

A bad example of design

« Nestlé abandons Cailler packaging: […] sales of the redesigned chocolate […] dropped by 31% »

Quotidien Le Temps, 27 January 2007

« The *Consumers' Federation of French-speaking Switzerland notes that they have a five times greater impact on the environment in terms of* CO_2 *when burned* »

A good example: eco-design of new packaging

December 2008

Design of a new baby food packaging

Int J Life Cycle Assess
DOI 10.1007/s11367-008-0052-6

CASE STUDY

Life cycle assessment of two baby food packaging alternatives: glass jars vs. plastic pots

Sebastien Humbert · Vincent Rossi · Manuele Margni · Olivier Jolliet · Yves Loerincik

Received: 21 August 2008 / Accepted: 28 November 2008

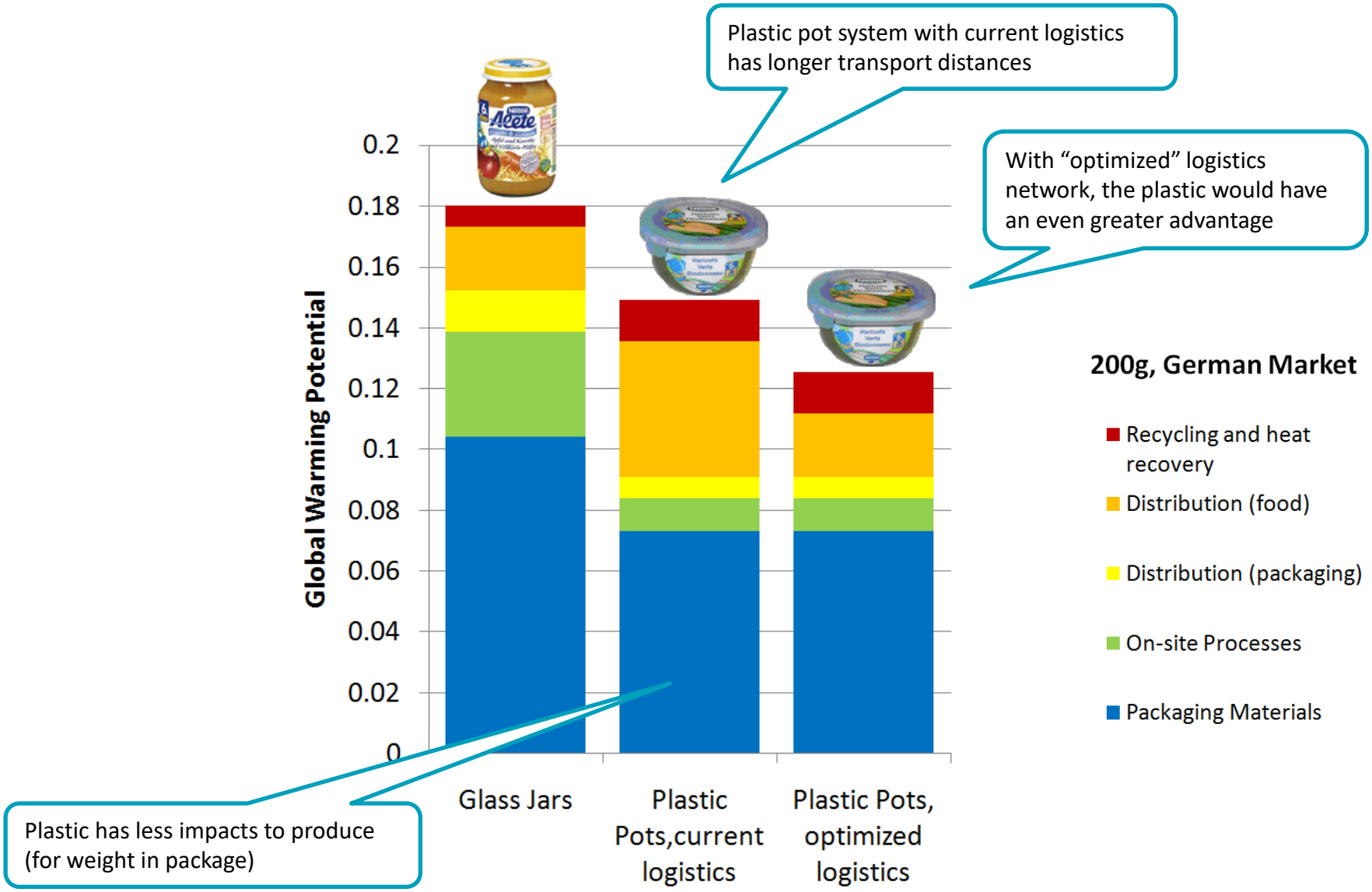
Abstract
Background, aim, and scope This paper compares the life cycle assessment (LCA) of two packaging alternatives used for baby food produced by Nestlé: plastic pot and glass jar. The study considers the environmental impacts associated with packaging systems used to provide one baby food meal in France, Spain, and Germany in 2007. In addition, alternate logistical scenarios are considered which are independent of the two packaging options. The 200-g packaging size is selected as the basis for this study. Two other packaging sizes are assessed in the sensitivity analysis. Because results are intended to be disclosed to the public, this study underwent a critical review by an external panel of LCA experts.
Materials and methods The LCA is performed in accordance to the international standards ISO 14040 and ISO 14044. The packaging systems include the packaging production, the product assembly, the preservation process, the distribution, and the packaging end-of-life. The production of the content (before preservation process), as well as the use phase are not taken into account as they are considered not to change when changing packaging. The inventory is based on data obtained from the baby food producer and the suppliers, data from the scientific literature, and data from the ecoinvent database. Special care is taken to implement a system expansion approach for end-of-life open and closed loop recycling and energy production (ISO 14044). A comprehensive impact assessment is performed using two life cycle impact assessment methodologies: IMPACT 2002+ and CML 2001. An extensive uncertainty analysis using Monte Carlo as well as an extensive sensitivity study are performed on the inventory and the reference flows, respectively.
Results When looking at the impacts due to preservation process and packaging (considering identical distribution distances), we observe a small but significant environmental benefit of the plastic pot system over the glass jar system. Depending on the country, the impact is reduced by 14% to 27% for primary energy, 28% to 31% for global warming, 31% to 34% for respiratory inorganics, and 28% to 31% for terrestrial acidification/nutrification. The environmental benefit associated with the change in packaging mainly results from (a) production of plastic pot (including its end-of-life; 43% to 51% of total benefit), (b) lighter weight of packaging positively impacting transportation (20% to 35% of total benefit), and (c) new preservation process permitted by the plastic system (23% to 34% of total benefit). The jar or pot (including cap or lid, cluster, stretch film, and label) represents approximately half of the life cycle impacts, the logistics approximately one fourth, and the rest (especially on-site energy, tray, and hood) one fourth.
Discussion The sensitivity analysis shows that assumptions made in the basic scenarios are rather conservative for plastic pots and that the conclusions for the 200-g packaging size also apply to other packaging sizes. The uncertainty analysis performed on the inventory for the German market situation shows that the plastic pot system has less impact than the glass jar system while considering similar distribution distances with a confidence level above 97% for most impact categories. There is opportunity for further improvement independent of the type of packaging used, such as by reducing distribution distances while still optimizing lot size. The validity of the main conclusions

Responsible editor: Walter Klöpffer

S. Humbert (✉) · V. Rossi · M. Margni · O. Jolliet · Y. Loerincik
Ecointesys—Life Cycle Systems Sàrl, PSE-A, EPFL,
CH-1015 Lausanne, Switzerland
e-mail: sebastien.humbert@ecointesys.ch

Published online: 20 January 2009

… and improvement of the new alternative



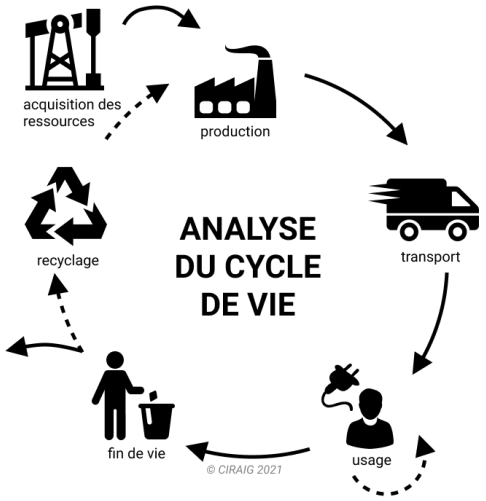
Biggest strength of LCA: holistic dimension

- Takes into account « all » economic activities associated to a product or to a decision.
  - **Extraction of raw materials**
  - **Transformation**
  - **Transport**
  - **use (consumable, energy)**
  - **End of life (recycling, landfill, incineration)**

« From cradle to grave »

Biggest strength of LCA: holistic dimension

- **Takes into account « all » economic activities associated to a product or to a decision.**
  - Extraction of raw materials
  - Transformation
  - Transport
  - use (consumable, energy)
  - End of life (landfill, incineration, recycling)



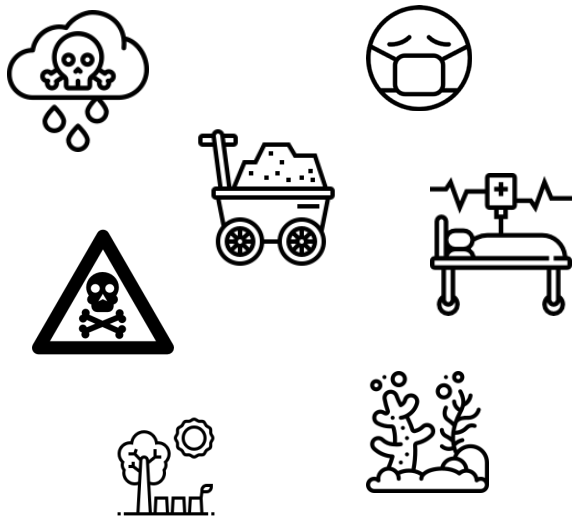
« From cradle to grave »

= the entire value chain

Biggest strength of LCA: holistic dimension

- **Takes into account « all » economic activities associated to a product or to a decision.**
- **Takes into account a comprehensive set of environmental impacts**

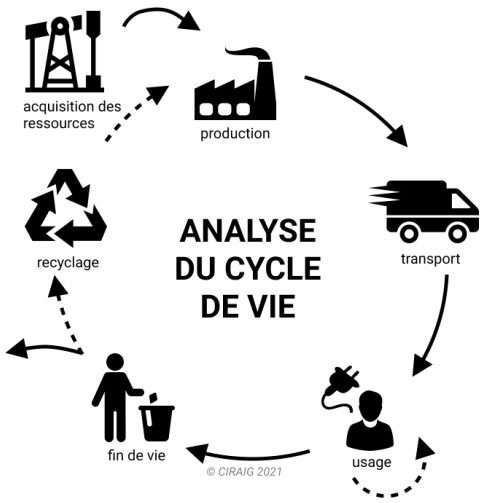
Multi indicators



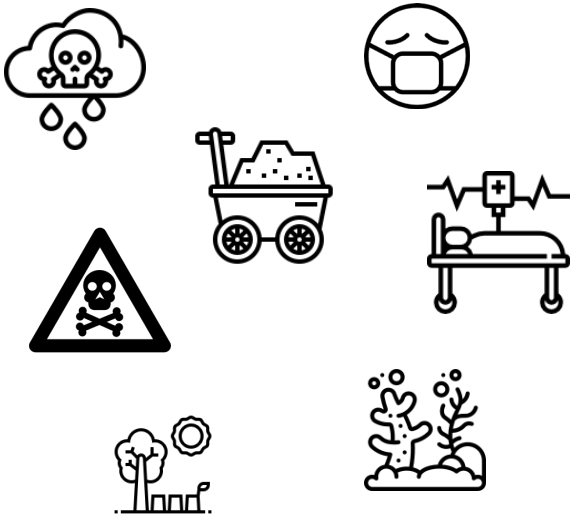
Biggest strength of LCA: holistic dimension

- Takes into account « all » economic activities associated to a product or to a decision.
- Takes into account a comprehensive set of environmental impacts
- This allows to avoid *burden shifting*

Value chain



Multi indicators



Life cycle thinking - Ethical question

- Who is responsible for the pollution?
- Why?
- What does it mean to be « responsible »?

Life cycle thinking - Ethical

« We produce products and these products are consumed by other countries, especially the developed countries. This share of emissions should be taken by the consumers but not the producers »

Li Gao, Chinas's chief climate negotiator, 2009

IPAT EQUATION

CIRAIG[MC]

Ehrlich equation (IPAT)

Impacts = Population x Affluence x Technology

[Number of inhabitants]

[Consumption per capita]

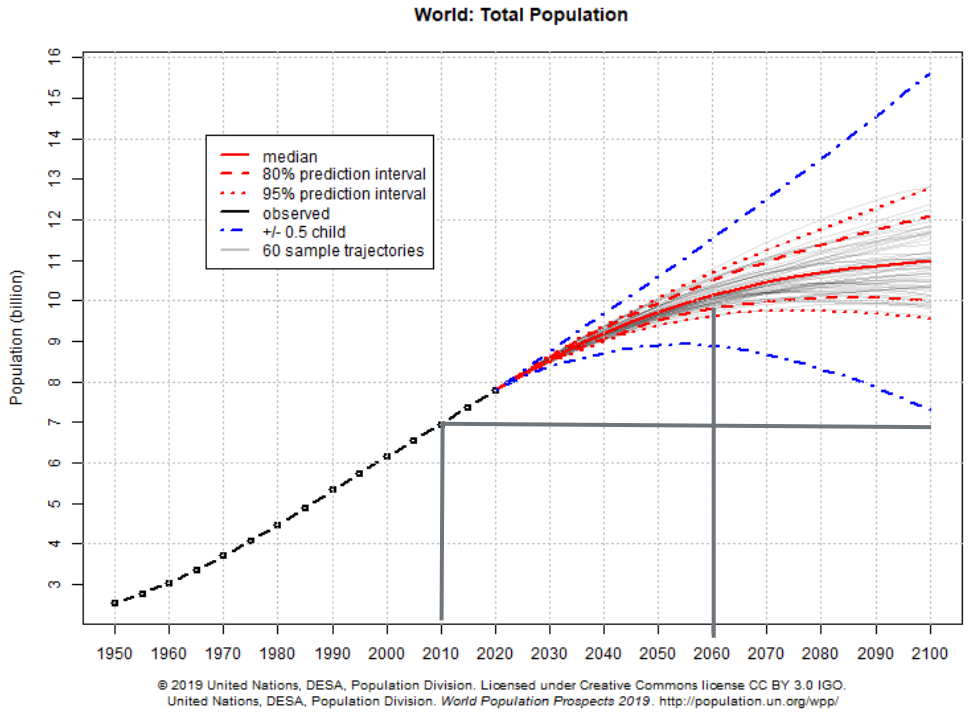
[Impacts to produce each unit of goods and services]

(Ehrlich et al., 1971; Chertow, 2000)

IPAT equation

Impacts = Population x Affluence x Technologie

The growth of the world population will necessarily lead to an increase in environmental impacts



+ 35% as compared to 2010, on average

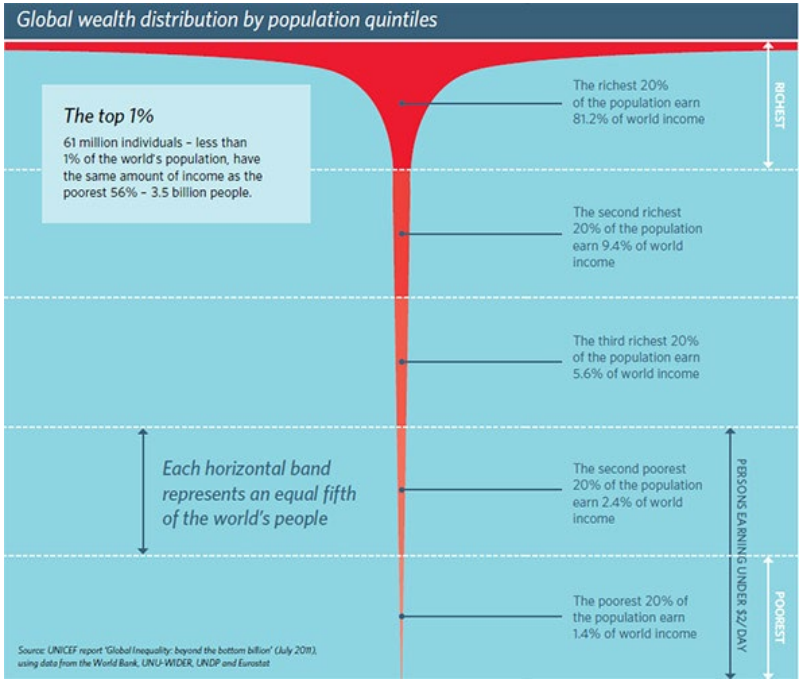
IPAT equation

Impacts = Population x Affluence x Technologie

A represents wealth per capita.

It can be expressed in GDP/capita.

Since our economic system is based on the principle of growth, we can predict a consistent increase in impact



Putting things in context: IPAT Equation: Finding levers: A

Contents of a middle class family home in California

Contents of a middle class family in Mali

Photographs by Peter Menzel, Material World (1994)

20% of the population is responsible for 90% of consumption
20% of the population lives with less than 1$ US per day

UN commission on sustainable development, 2002

IPAT Equation: Affluence projection

Impacts = Population x Affluence x Technologie

	Population	PIB / capita 2010	Annual increase of PIB / capita
Low income countries	817 million	1 980 $	2.8%
Middle income countries	4 920 million	3 979 $	4.6%
High income	1 123 million	38 293 $	1.0%

	PIB/ capita
Current Affluence (World Average)	9 358 $
Forecasted affluence in 2060 (World Average)	38 287 $

Factor 4 increase!

Source données : World Bank Statistics
Source diapositive : Urs Schenker, Nestlé Research Center

IPAT equation

Impacts = Population x Affluence x Technology

T: Represents the impact per unit of wealth produced

Impacts associated with emissions and consumption of resources for the production, transportation, use and end-of-life of products or services

So we can rewrite the equation like this:

$$\text{Impacts} = \text{population} \times \frac{\text{GDP}}{\text{capita}} \times \frac{\text{Impacts}}{\text{GDP}}$$

IPAT Equation : Technology

Impacts = Population x Affluence x Technologie

$$\text{Impacts} = \text{population} \times \frac{\text{GDP}}{\text{capita}} \times \frac{\text{Impacts}}{\text{GDP}}$$

LCA starts from a premise that a certain amount of “function” must be delivered; and assess / compare different ways of delivering this function (different products, different technologies, … etc)

IPAT Equation : Technology

Impacts = Population x Affluence x Technologie

To learn more about the IPAT equation:

Chertow (2000) The IPAT Equation and Its Variants: Changing Views of Technology and Environmental Impact. Journal of Industrial Ecology, Volume 4, Number 4, pp 13-29.

Critique of the IPAT equation → I = f(P,A,T)

Alcott, B. (2010). "Impact caps: Why population, affluence and technology strategies should be abandoned". Journal of Cleaner Production. 18 (6): 552–560. doi:10.1016/j.jclepro.2009.08.001

BREAK2

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On the agenda today

- Presentation of teachers and participants
- Presentation of the syllabus
- Introduction to the LCA project

BREAK 1

- Why LCA?
- IPAT equation

BREAK 2

- Conceptual model of LCA
- LCA framework according to ISO 14040
- Group exploration of LCA concepts
- Conclusion

CONCEPTUAL MODEL OF LCA

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Technosphere and Ecosphere

Technosphere

All human activities (production, consumption, processing, etc.)

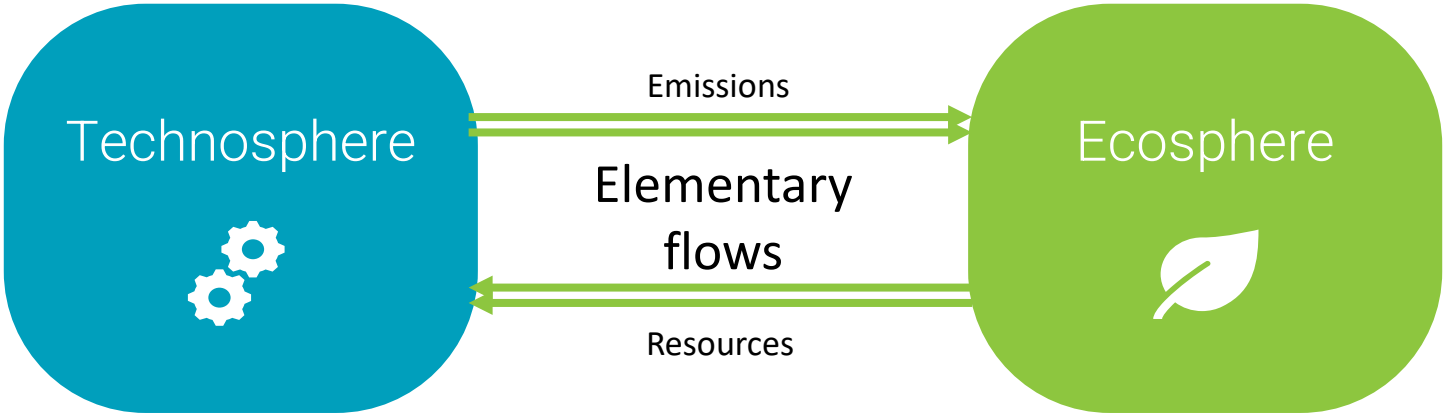
Ecosphere

The natural environment, including living organisms (biosphere), air, water, soil, and their natural resources (renewables or not)

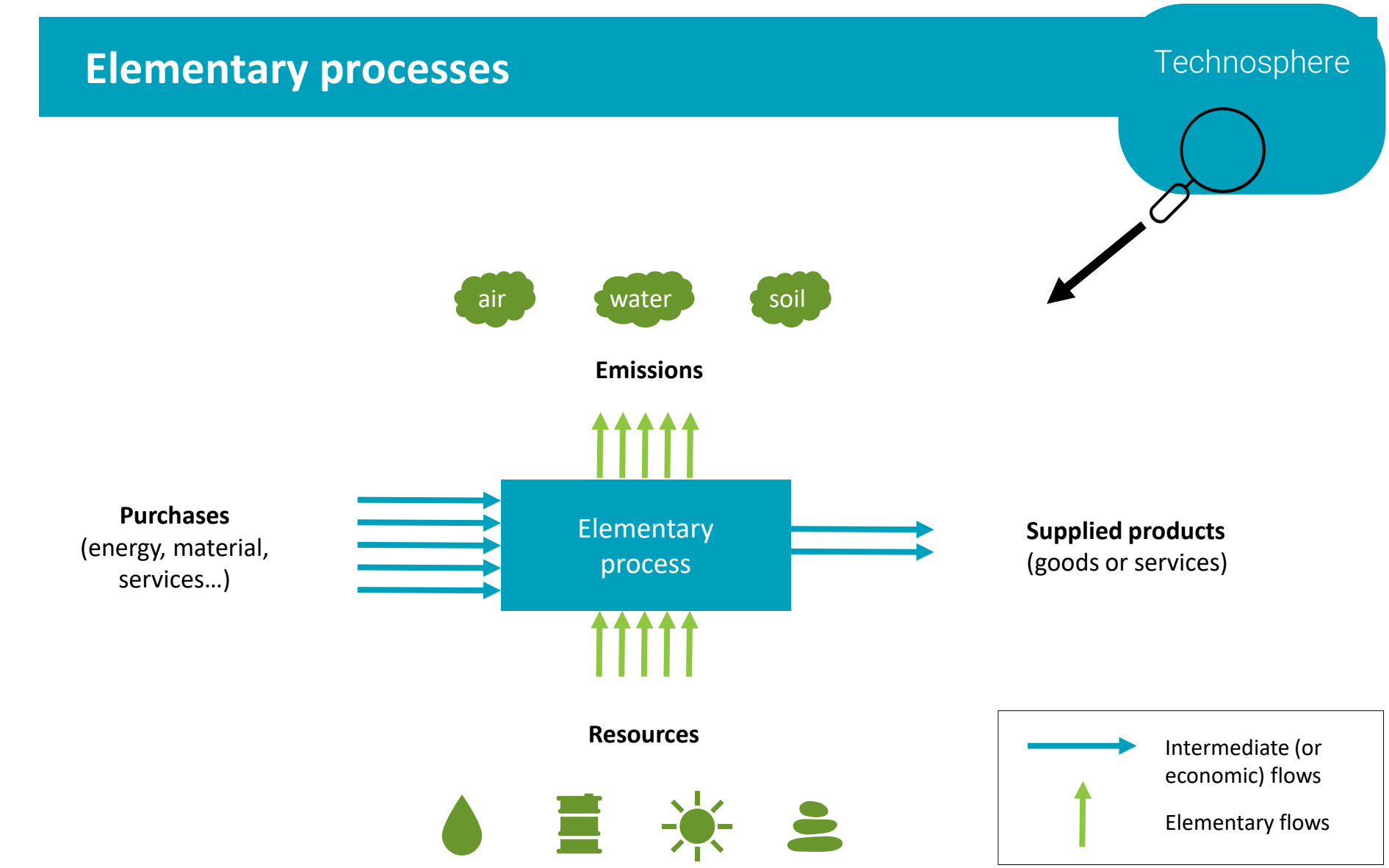
Elementary flows

- The ecosphere is the source of all raw materials used in the Technosphere
- The ecosphere is the sink for all the emissions from the Technosphere

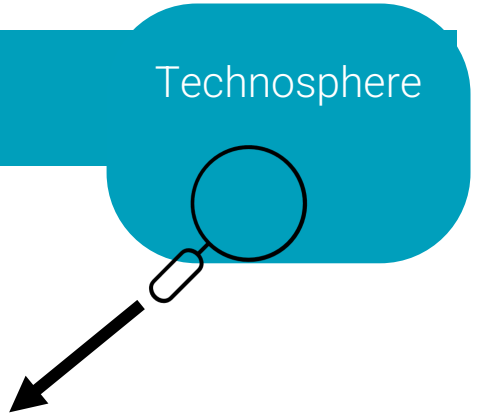
… these links or exchanges between the two spheres are called **Elementary flows** (or environmental interventions)



Elementary processes

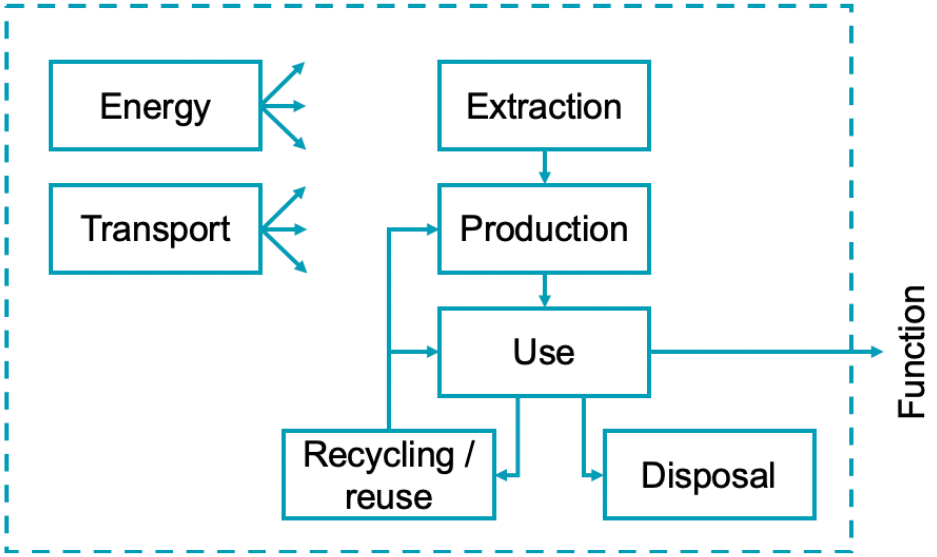


Product system– Simplified representation

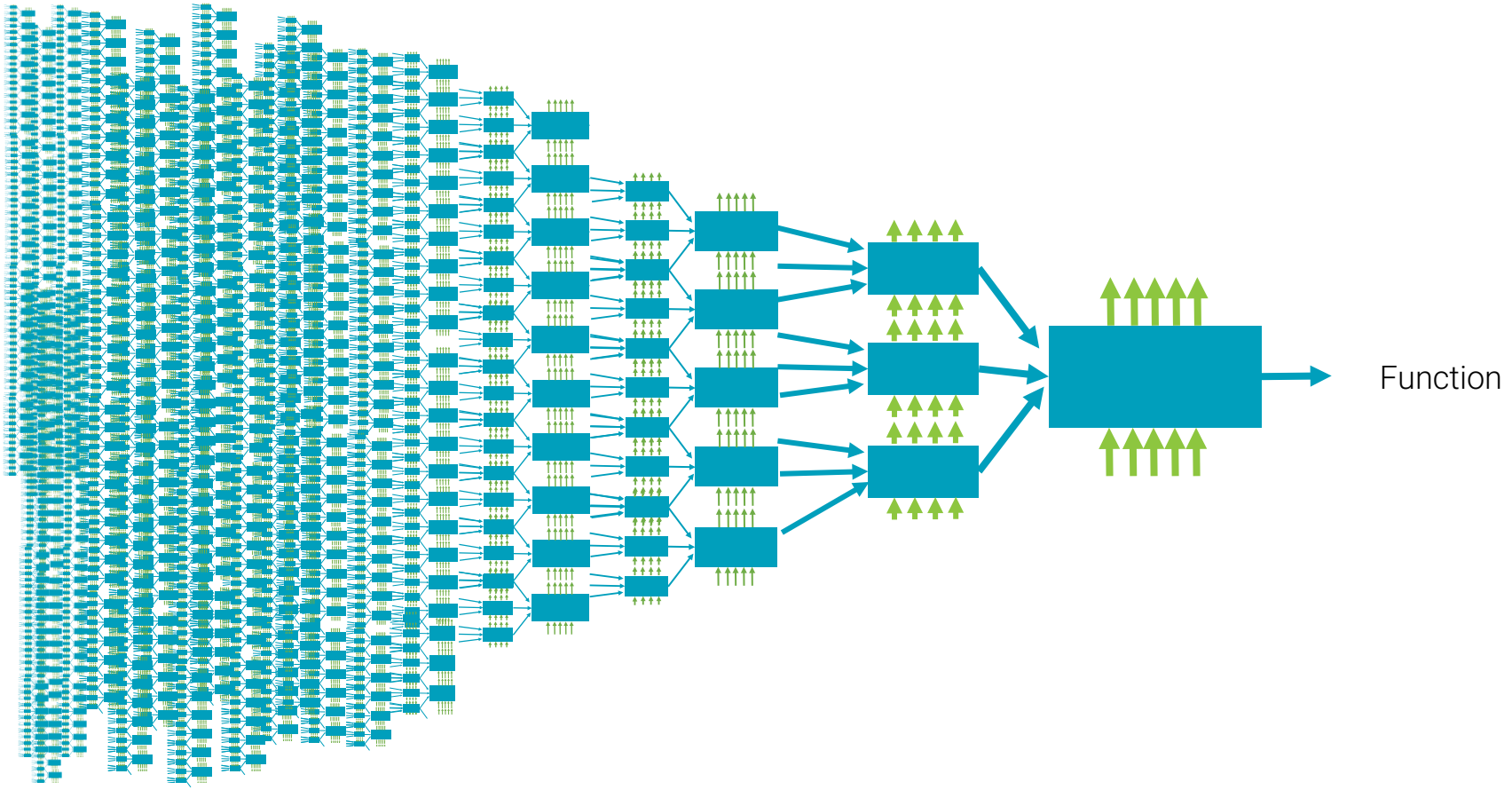


Definition (ISO 14040)

« Set of elementary processes comprising product flows […], fulfilling one or more defined functions, which serve as a model for the life cycle of the product»



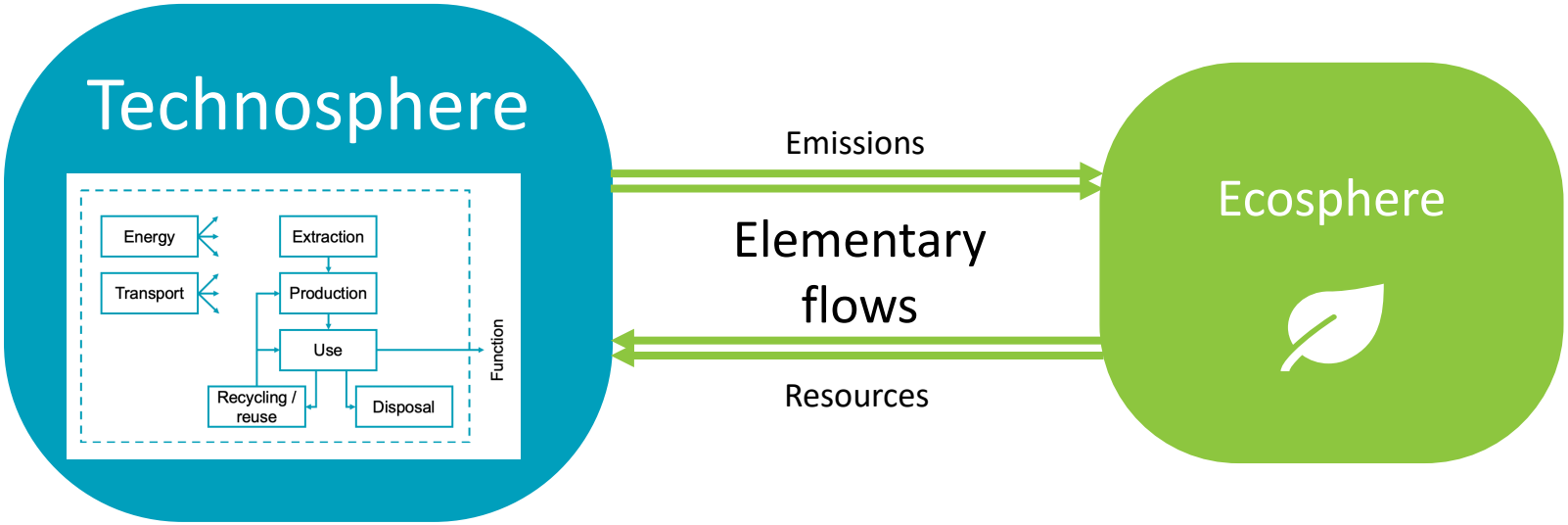
Product system– Realistic representation



Product system

The product system is an integral part of the Technosphere

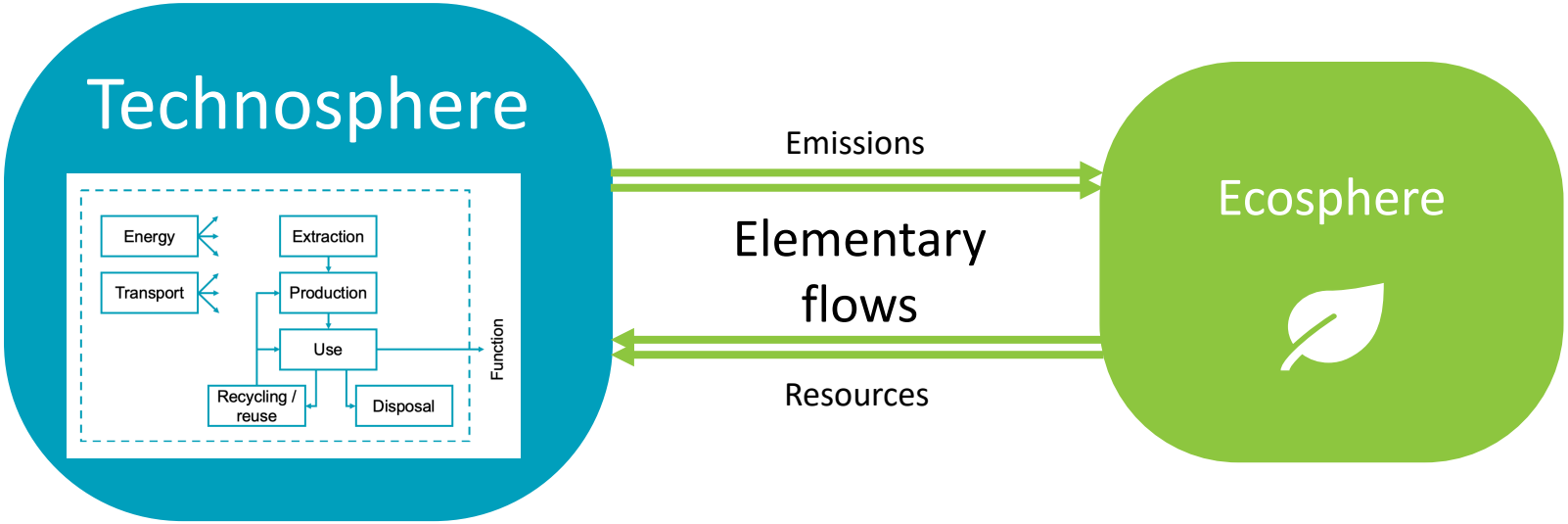
- **It mobilizes part of the activities of the Technosphere**
- **It exchanges elementary flows with the ecosphere**



Conceptual model - summary

In summary, an LCA consists of:

1. **Defining the product system (activities linked to a product / service)**
2. **Calculating all the exchanges between the product system and the environment (elementary flows)**
3. **Calculating the potential environmental impacts associated with these elementary flows**



LCA FRAMEWORK ACCORDING TO ISO 14040

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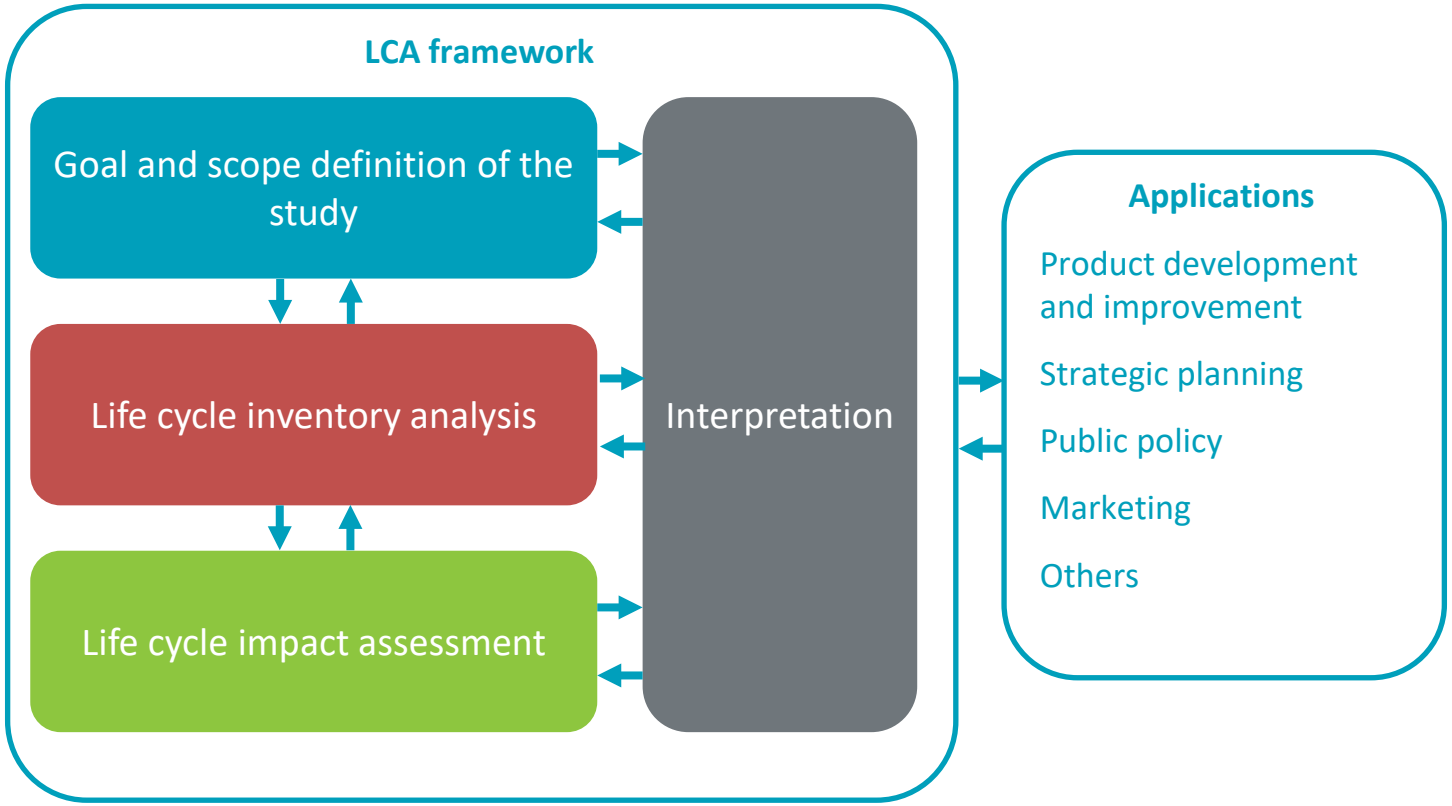
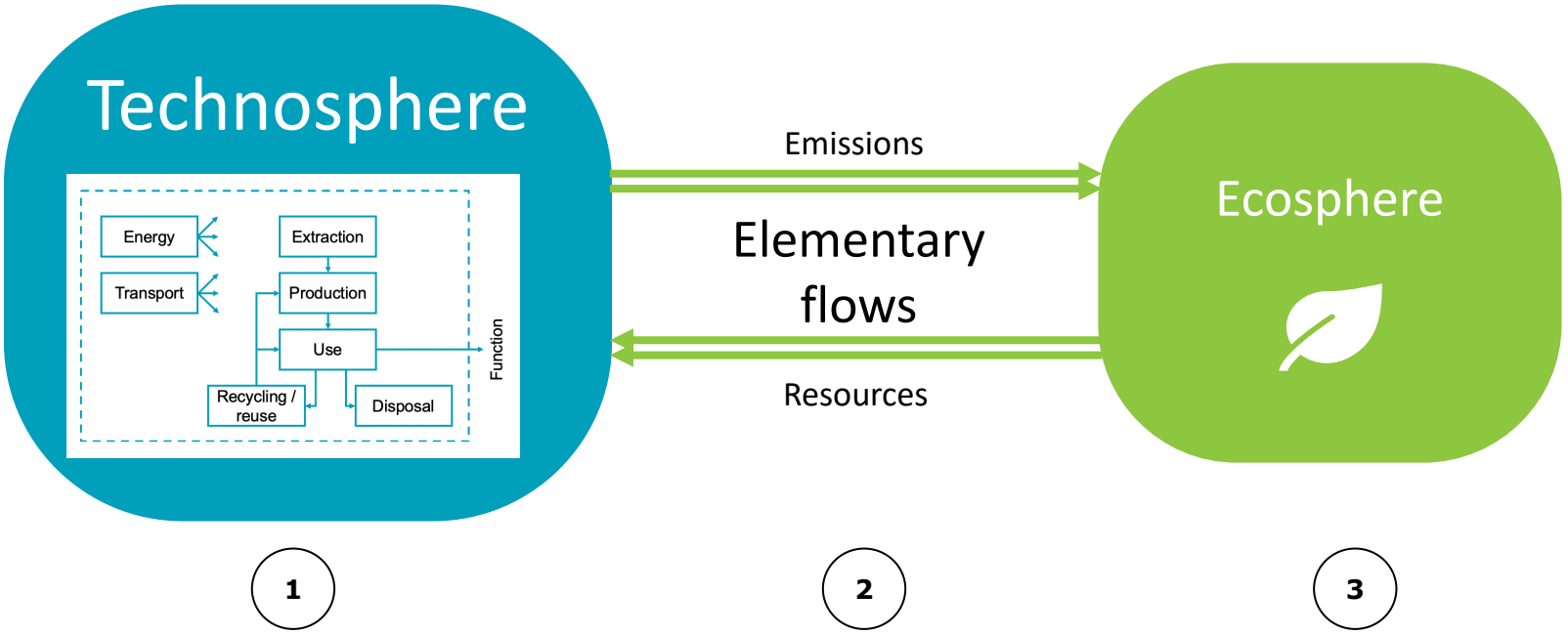
International standard ISO14040



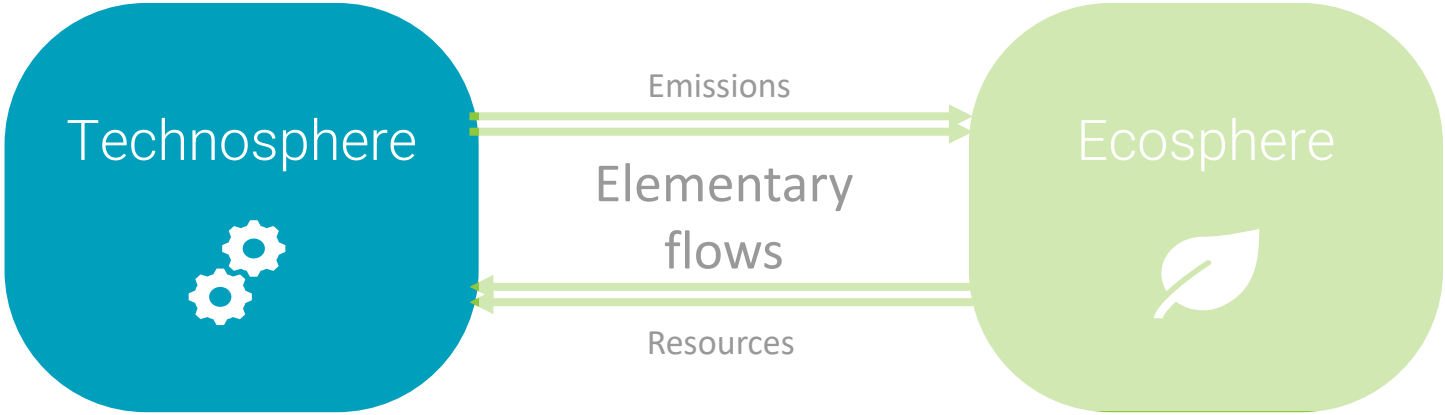
Reminder: Conceptual model

The world is divided into two sphere which interact through elementary flows

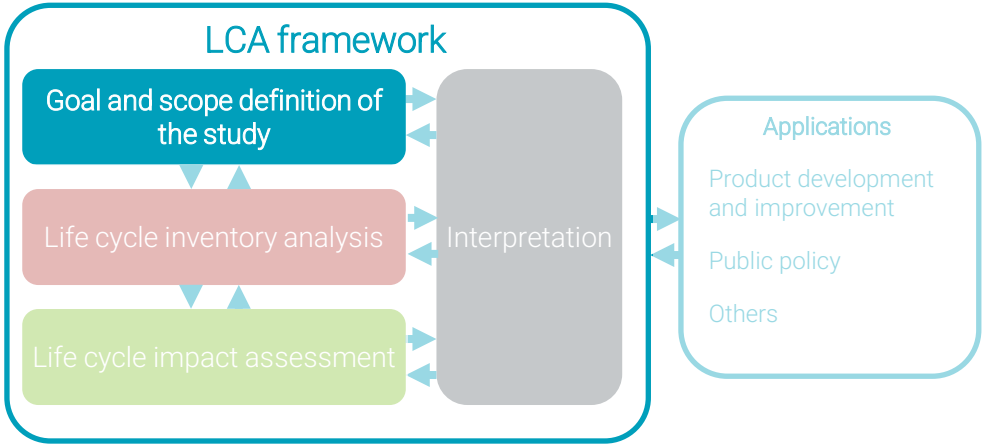


LCA deals with these elements in three distinct phases

1. Goal and Scope definition of the study



Within the Technosphere, LCA is intersted in a particular <u>product system</u>, which will be defined during the first phase of LCA

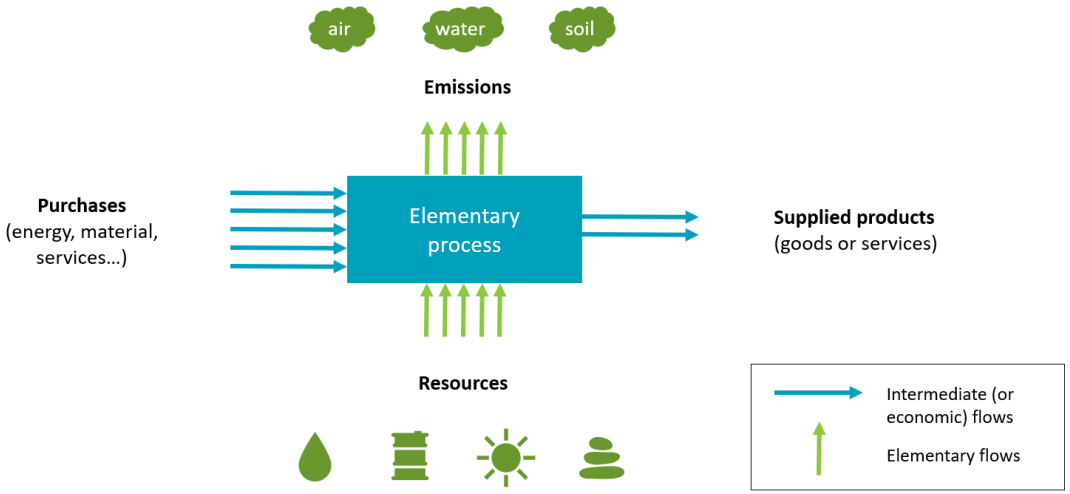


1. Goal and Scope definition of the study

A product system is made up of a series of « **elementary processes**»

→ Basic elements of a product system

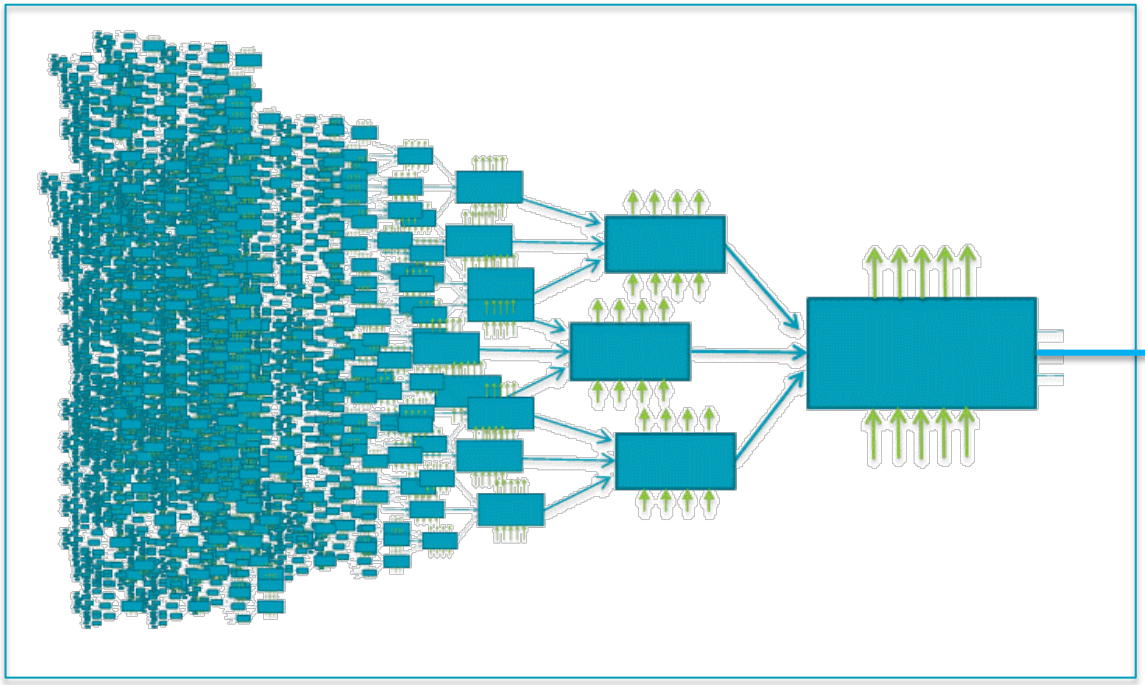
- **Intermediate flows: products and services → links with other elementary processes OR function under study**
- **Elementary flows: emissions/resources exchanged directly with the environment**



1. Goal and Scope definition of the study

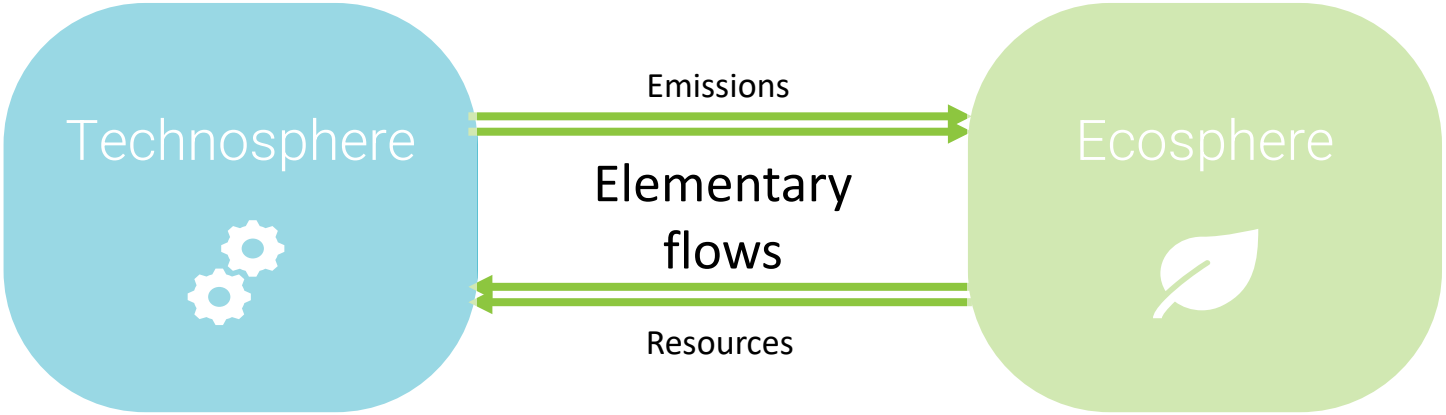
Each elementary process requires the product of other elementary processes

System boundaries

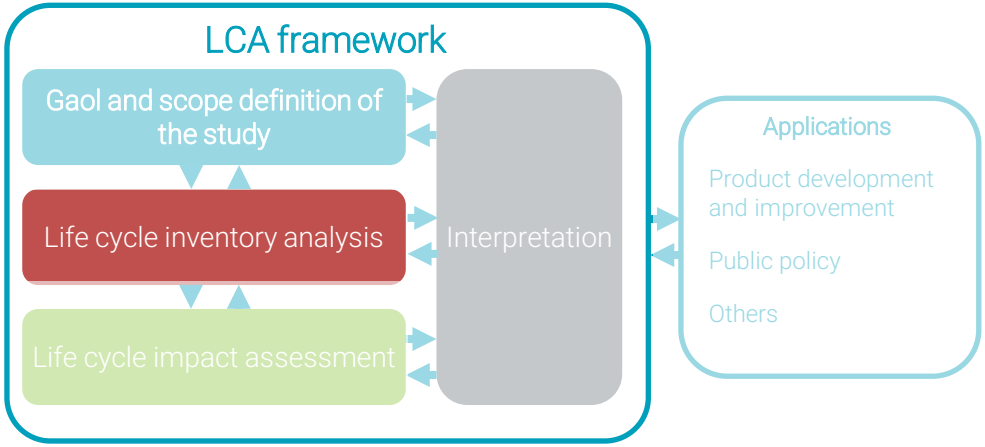


Function

2. Life Cycle Inventory (LCI)

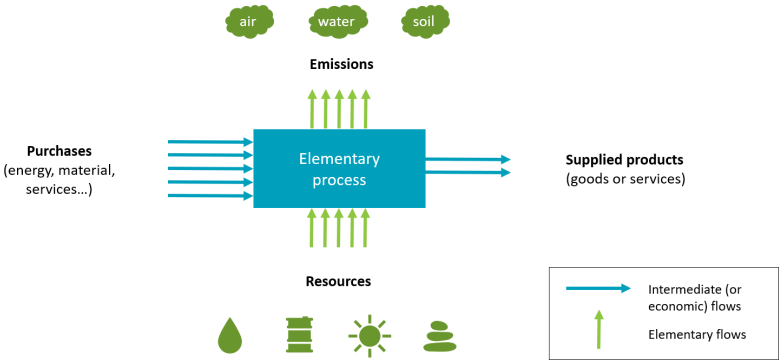


The life cycle inventory records the elementary input and output flows of the product system

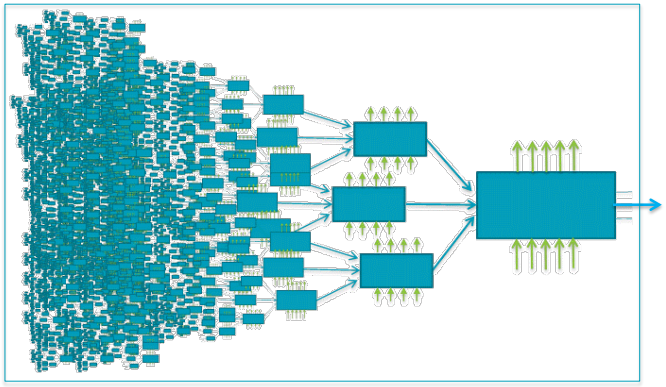


2. Life Cycle Inventory (LCI)

« Life cycle inventory phase involves the compilation and quantifications of inputs and outputs , for a given product system during its life cycle» (ISO 14044)



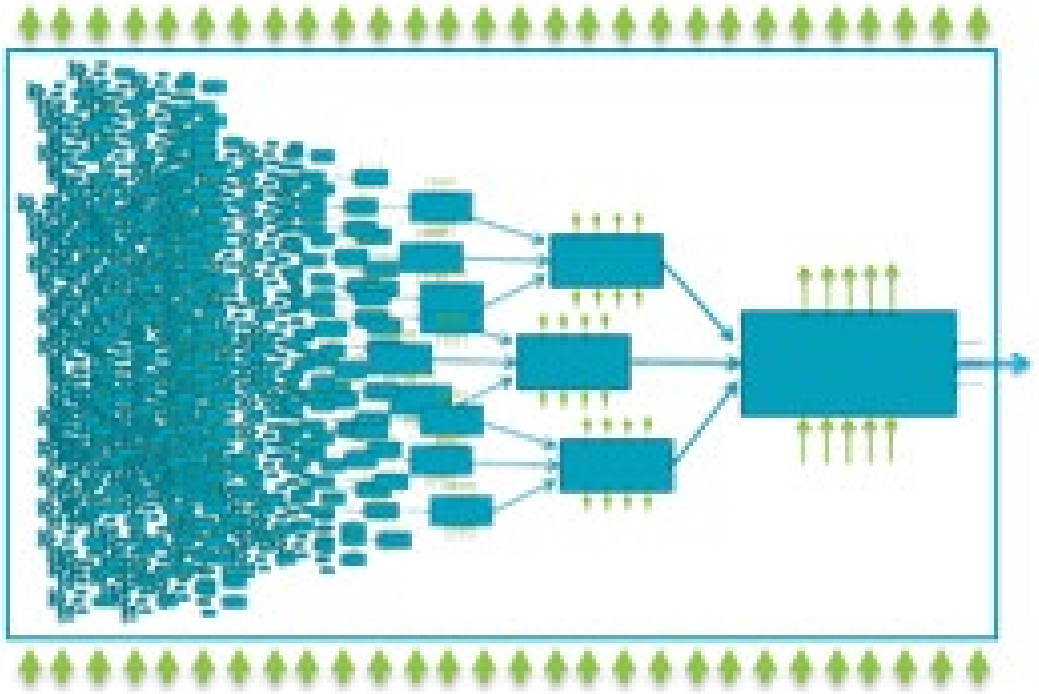
Elementary flows for an elementary process



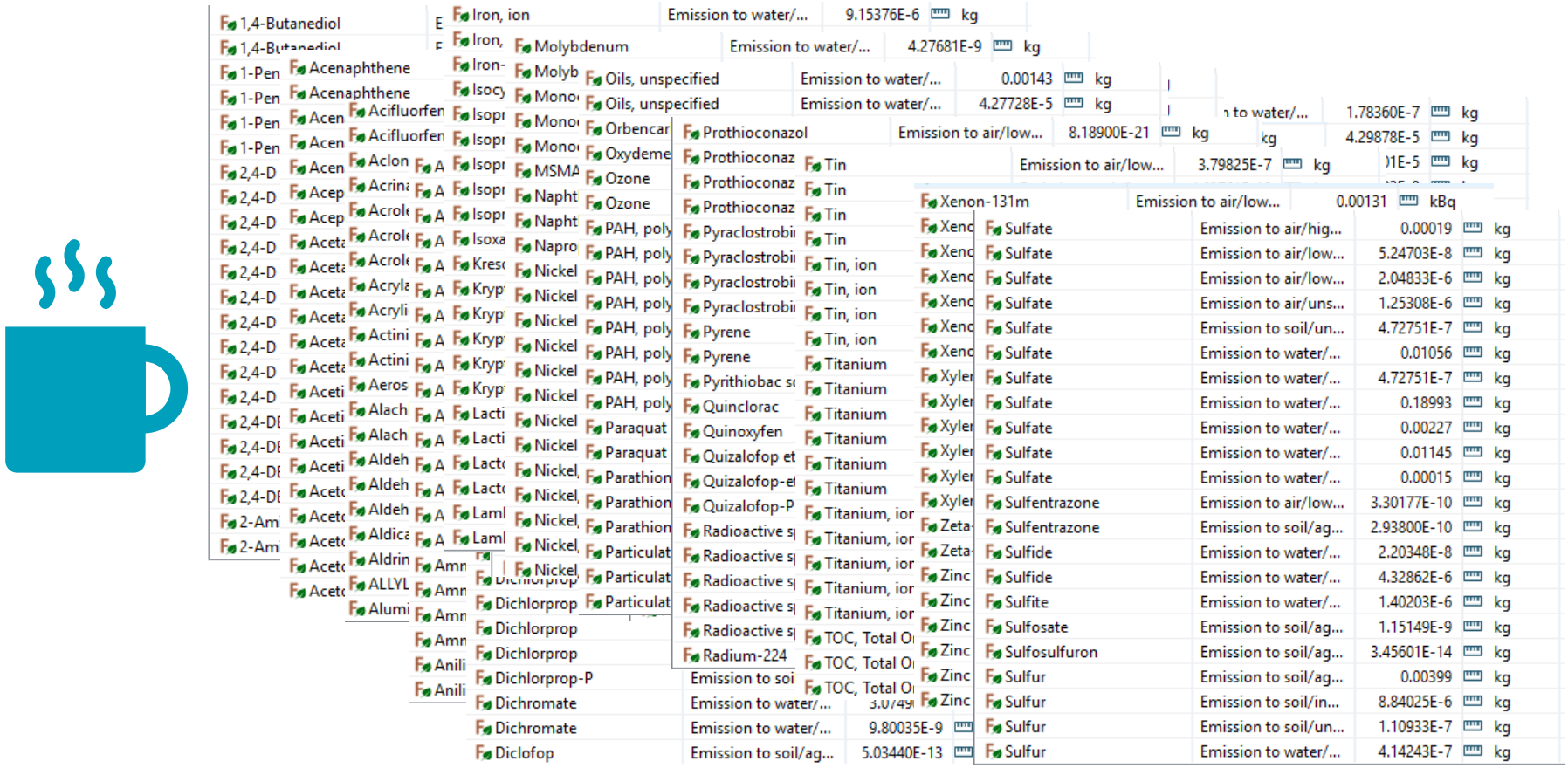
Elementary flows for each elementary process

2. Life Cycle Inventory (LCI)

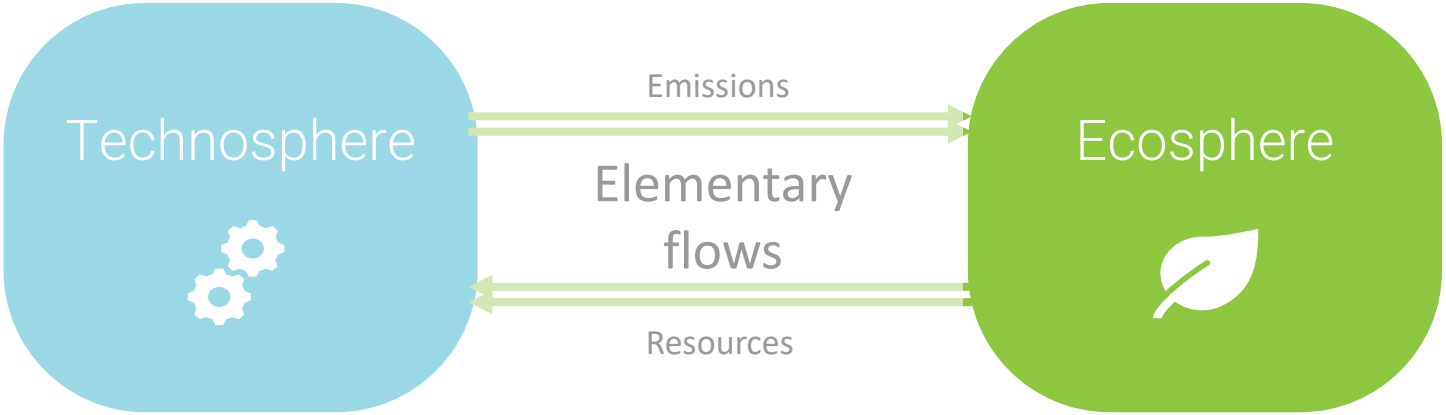
LCI = sum of elementary flows of each process



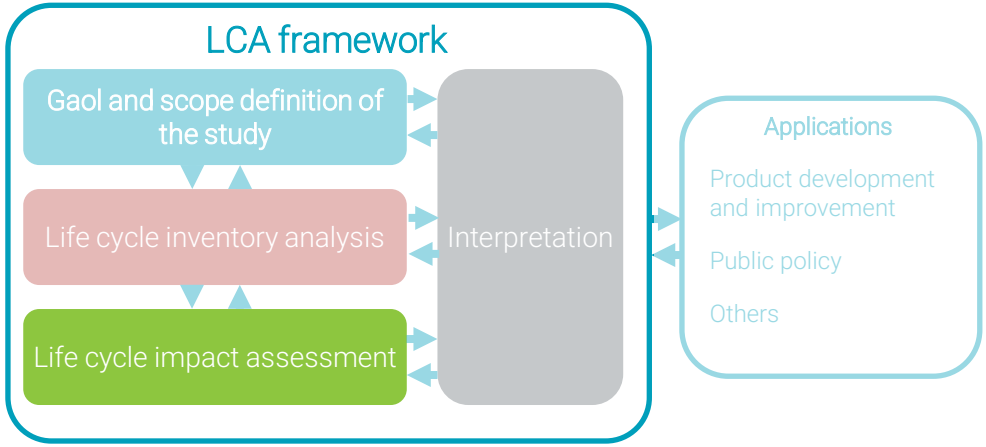
2. Life cycle inventory (LCI) –example



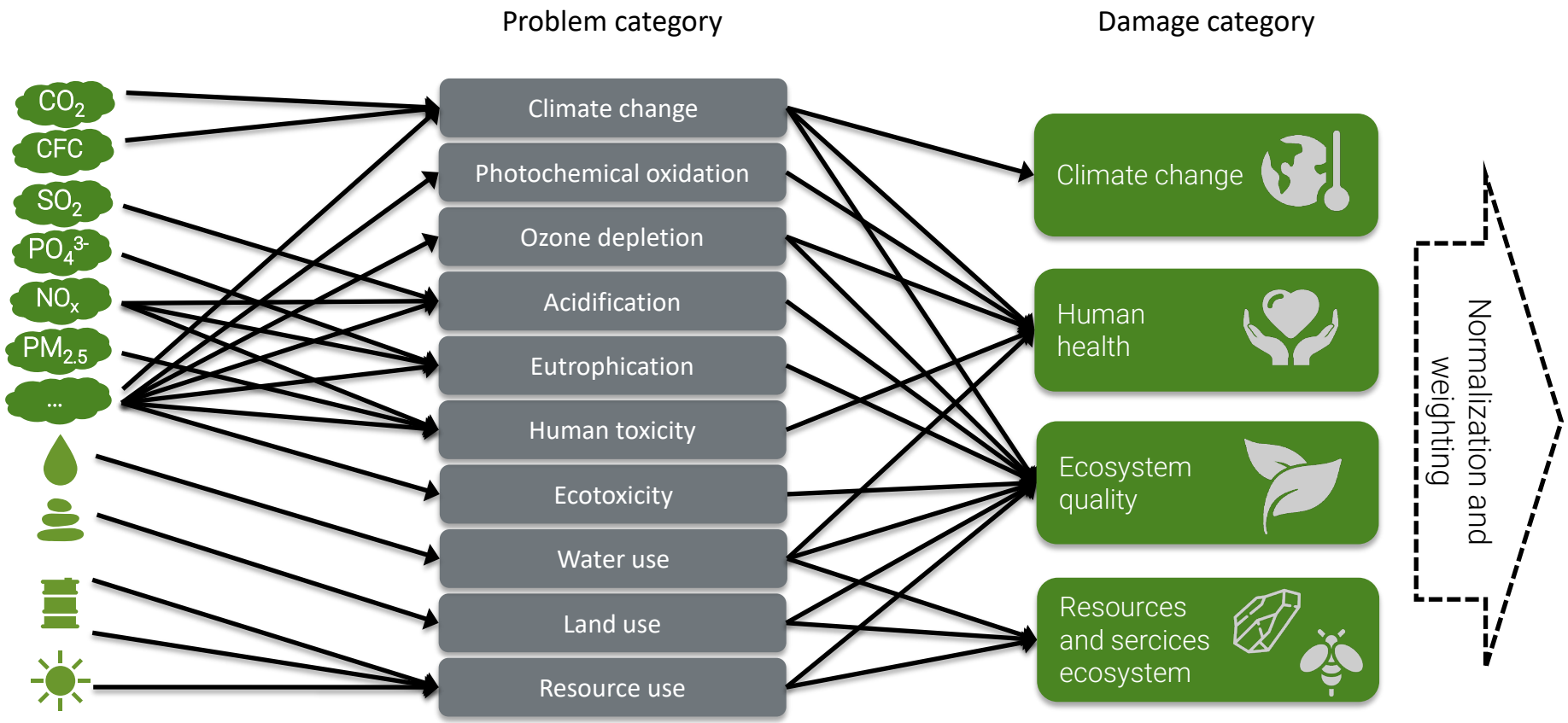
3. Life Cycle Impact Assessment (LCIA)



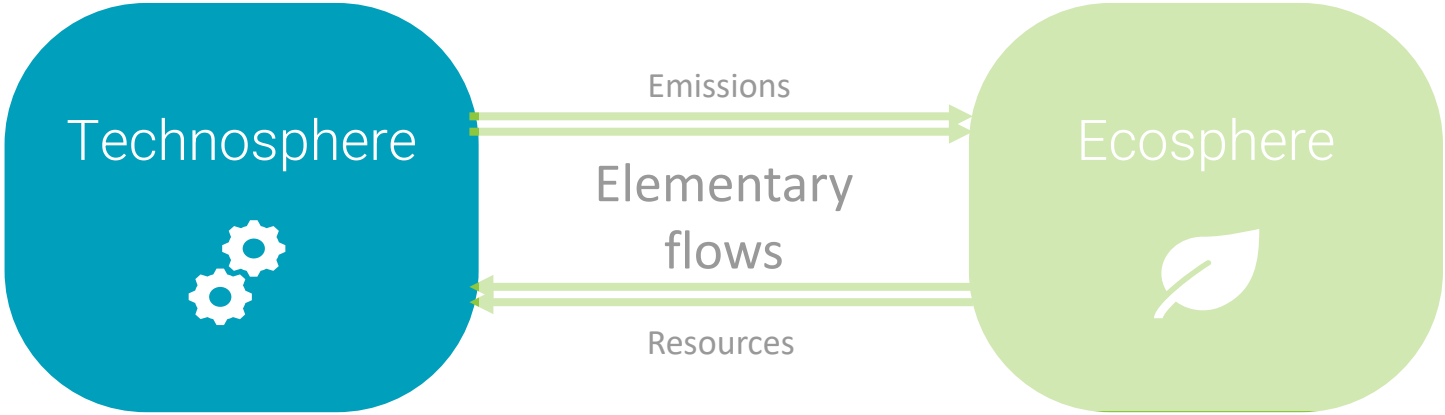
« *Life cycle impact assessment phase intends to understand and assess the magnitude and significance of the potential impacts of a product system on the environment during its life cycle*» (ISO 14044)



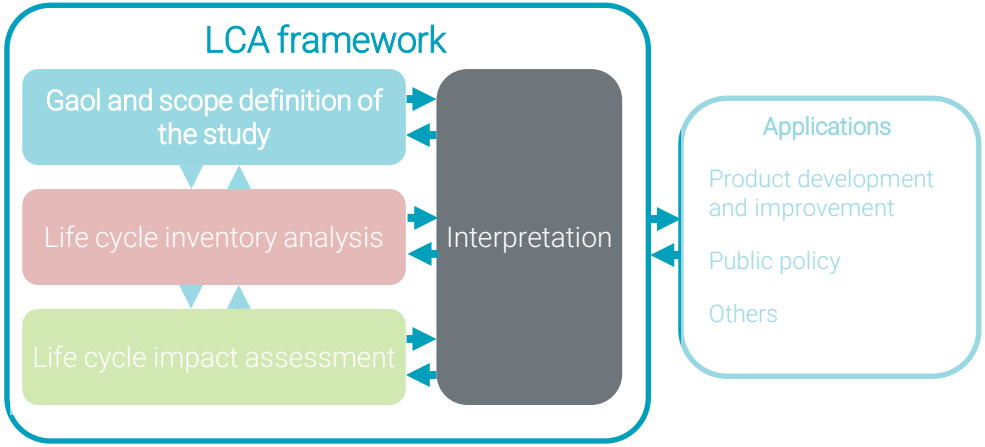
3. Life Cycle Impact Assessment (LCIA)



4. Interpretation of results



« *The results of an LCI or an LCIA are summarized and discussed to draw conclusions, recommendations, and lead to a decision-making in accordance with the goal and scope definition of the study*» (ISO 14044)



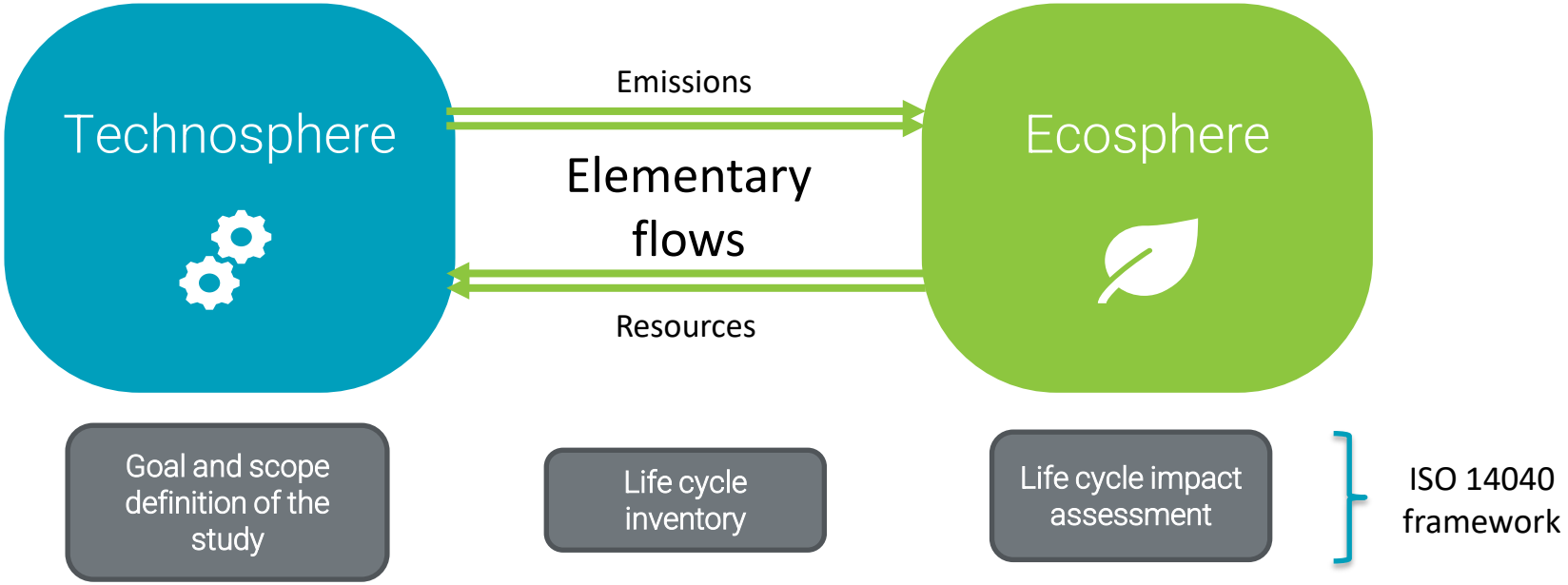
Interpretation

- To get impact scores, we make hundreds of hypotheses, and lots of calculations
- We need to put things in perspective, understand what the quantitative results really mean in the context of decision making and in relationship to the question asked by the commissioner (goal of the study).

Conceptual model and ISO 14040 analysis framework

In summary, an LCA consists of

1. **Defining the product system (activities linked to a product / service)**
2. **Calculating all the exchanges between the product system and the environment (elementary flows)**
3. **Calculating the potential environmental impacts associated with thesee elementary flows**
4. **… without forgetting to interpret the results according to the goal of the syudy (ISO 14040)**



Make sure you translate the results from a virtual model to respond to a question in the real world !!!

GROUP EXPLORATION OF LCA CONCEPT

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Group exploration of LCA concepts

Question 1: Environmental impacts of a product

- **Choose a random product**
- **What should we consider in the evaluation of the environmental impacts of that product?**

Question 2: Environmental comparison of the products

- **What product could we compare the first one to?**
- **Repeat exercise 1 for the alternative product.**
- **How could we be sure that the comparison is a valid one?**

Iterative session - exploring LCA of the selected product

On the agenda today

- Presentation of teachers and participants
- Presentation of the syllabus
- Introduction to the LCA project

BREAK 1

- Why LCA?
- IPAT equation

BREAK 2

- Conceptual model of LCA
- LCA framework according to ISO 14040
- Group exploration of LCA concepts
- Conclusion

Conclusions

- Environmental issues usually lead to
  - **Emotional reactions**
  - **Political speeches**

    A playing field for the dissemination of ideas, prejudice, power dynamics, etc.
- LCA doesn't have the answer to these questions and though it is imperfect, it is:
  - **Science-based**
  - **Holistic**
  - **Nuanced**
- LCA is a diagnostic tool which tries to see things as they are and to put them in perspective.

Conclusion

- LCA is a tool to **help decision-making**
  - **LCA does not make a decision**
  - **It gives a vision of reality to inform decision-makers**
  - **Decisions are based on:**
    - values;
    - Ethical considerations, morals, beliefs (religious or other);
    - Political ideology;
    - Economics;
    - Practical considerations

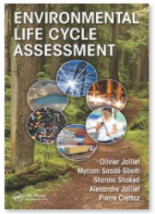
Science (or LCA) does not have all the answers: decision-makers must assume their responsibility

Conclusion

Reading suggested:

https://doi.org/10.1201/b19138

- Chapter 1
- Chapter 2



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Book

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By Olivier Jolliet, Myriam Saade-Sbeih, Shanna Shaked, Alexandre Jolliet, Pierre Crettaz

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eBook ISBN	9780429111051
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OA Funder	Knowledge Unlatched GmbH

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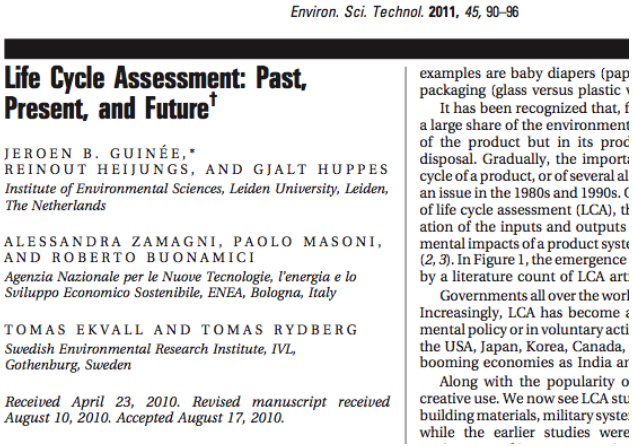

Environ. Sci. Technol. **2011,** *45,* 90–96

Life Cycle Assessment: Past, Present, and Future†

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examples are baby diapers (pap
packaging (glass versus plastic
It has been recognized that, f
a large share of the environment
of the product but in its proc
disposal. Gradually, the import
cycle of a product, or of several al
an issue in the 1980s and 1990s. (
of life cycle assessment (LCA), th
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(*2, 3*). In Figure 1, the emergence
by a literature count of LCA art
Governments all over the worl
Increasingly, LCA has become a
mental policy or in voluntary acti
the USA, Japan, Korea, Canada,
booming economies as India ar
Along with the popularity o
creative use. We now see LCA stu
building materials, military syste
while the earlier studies were