LIFE CYCLE ASSESSMENT (LCA) AND ICT: PRINCIPLES, MAIN ISSUES AND LIMITS

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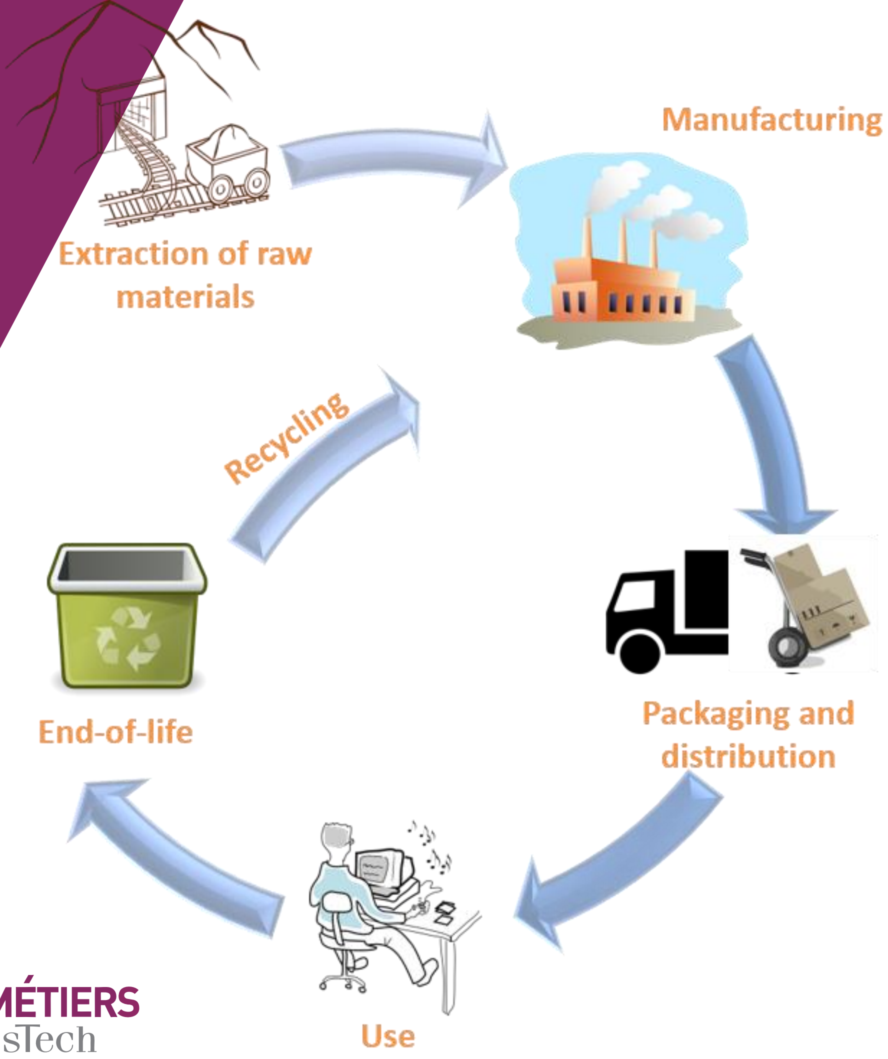
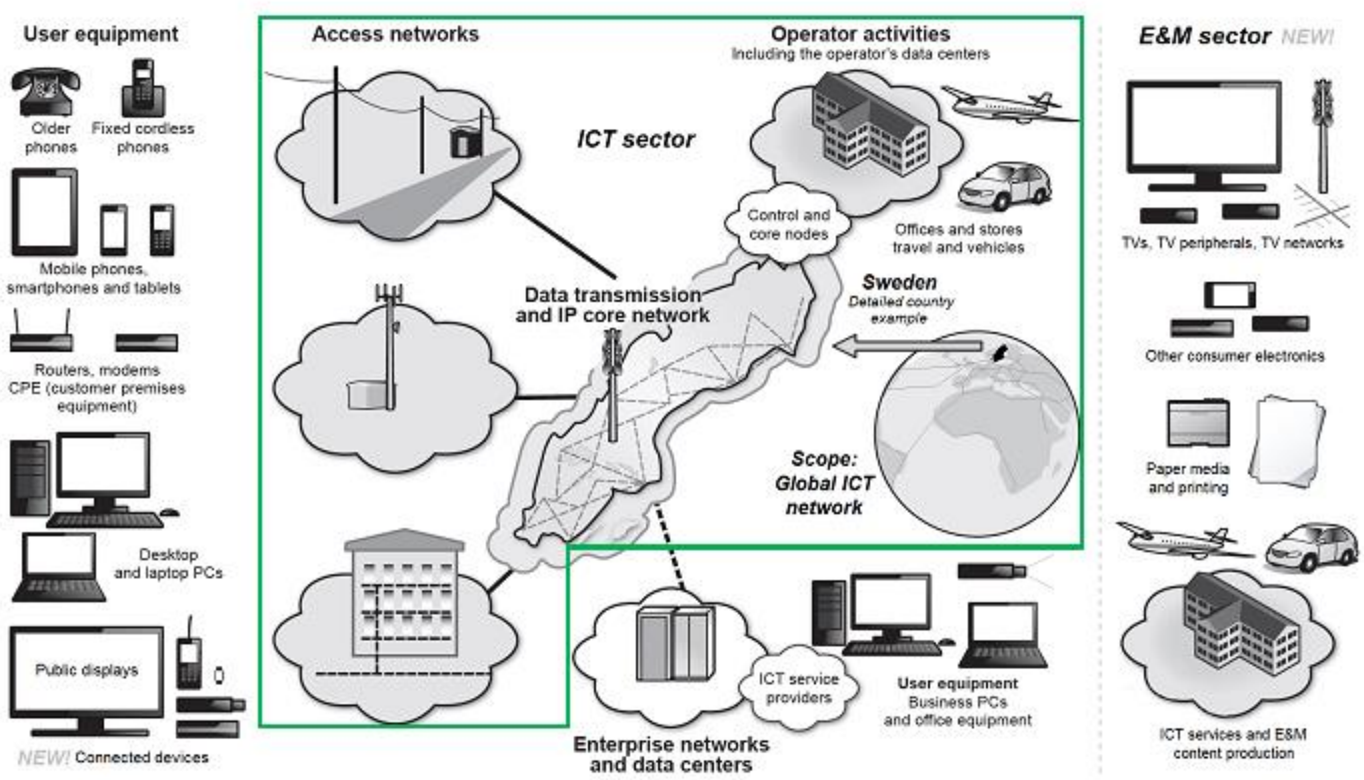


WHAT ARE ICT?

ICT are everywhere…



Malmodin J., 2014, Life Cycle Assessment of ICT, *Journal of Industrial Ecology*.

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WHAT ARE THE ENVIRONMENTAL CHALLENGES OF ICT?

- **Question 1:**

  - Led screens are less energy consuming than CRT.
  - It is better for the environment to change the old screen?

    A- Yes

    B- No

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WHAT ARE THE ENVIRONMENTAL CHALLENGES OF ICT?

- A: if you consider only the use phase
- B: if you consider the life cycle stages

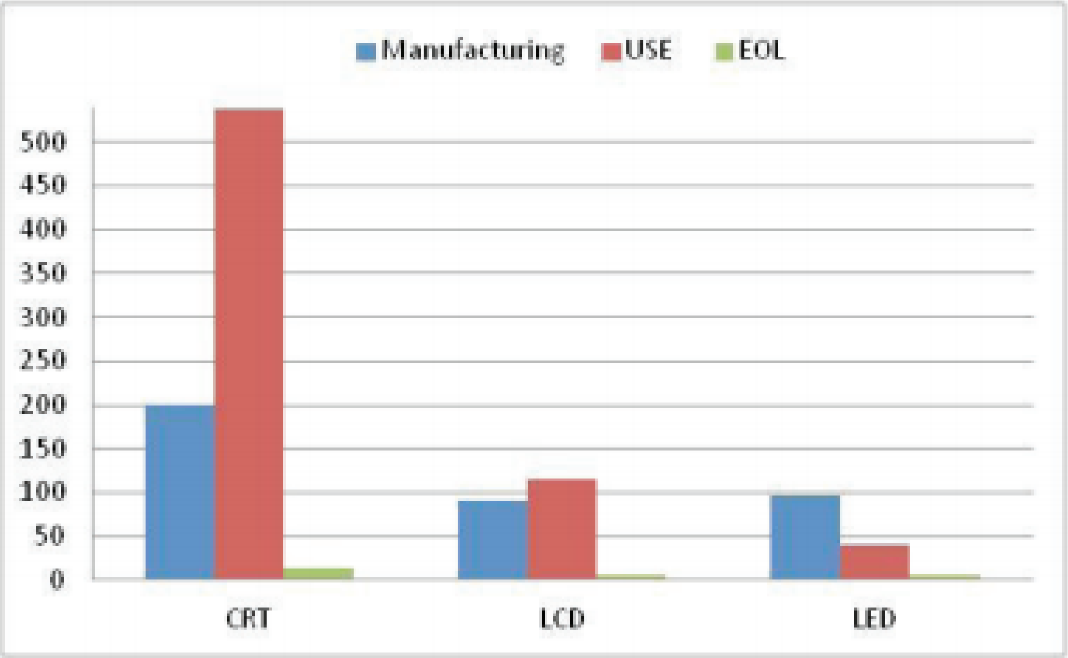

Fig. 7 Climate change potential of three monitors (Kg Co_2 Eq.)

(Bhakar 2015)

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WHAT ARE THE ENVIRONMENTAL CHALLENGES OF ICT?

- **Question 2: the localization of the manufacturing site doesn't matter?**

  A- Yes

  B- No

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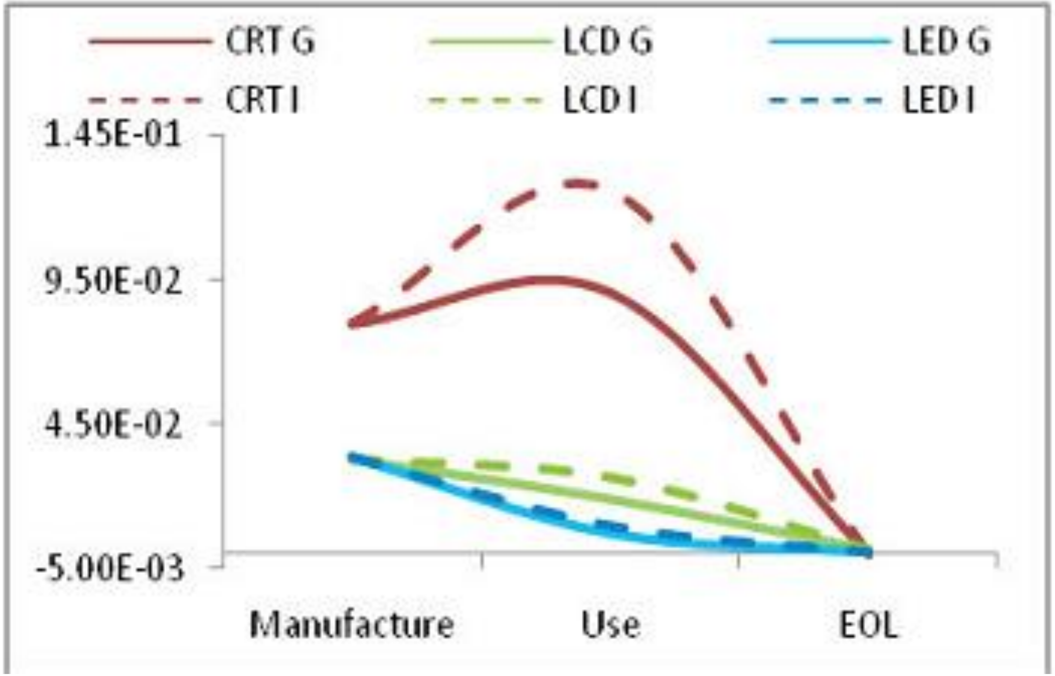
WHAT ARE THE ENVIRONMENTAL CHALLENGES OF ICT?

➢A: direct impact on environment



(Bahkar 2015)

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WHAT ARE THE ENVIRONMENTAL CHALLENGES OF ICT?

➢ **Question 3:**

– The measure of CO_2 emissions is sufficient to improve environmental performance of ICT

A: Yes

B: No

➢ **Question 4:**

- Energy is the major environmental challenge of ICT?

A: Yes

B: No

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WHAT ARE THE ENVIRONMENTAL CHALLENGES OF ICT?

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What are the environmental impacts of a connected watch?

WHAT ARE THE ENVIRONMENTAL CHALLENGES OF ICT?

What are the environmental impacts of a connected watch?

Conflict minerals

Critical metals

Oil depletion

WEEE

Very low recycling rate

Hard repair

Toxic pollutions

Low lifespan

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WHAT ARE THE ENVIRONMENTAL CHALLENGES OF ICT?

➢Potential benefits

Teleworking
E-books
Online purchase
Dematerialization

Energy and resources savings

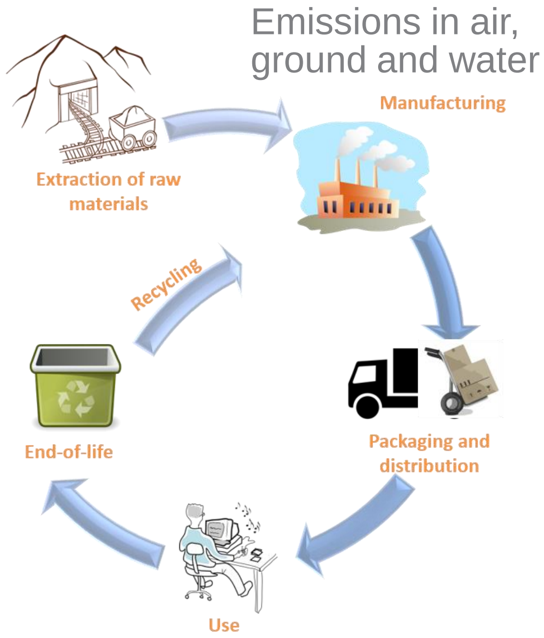
<u>But it is not always the case</u>

Necessity to develop a methodology in order to find the best compromise

LCA: A MULTI-STAGE AND MULTI-CRITERIA METHODOLOGY

The Life Cycle thinking includes all the following activities:

- – Raw materials extraction
- – Manufacturing
- – Packaging
- – Distribution
- – Use
- – Maintenance
- – Reuse and recycling
- – Landfill



All these stages need energy, non-renewables resources and generate environmental impacts .

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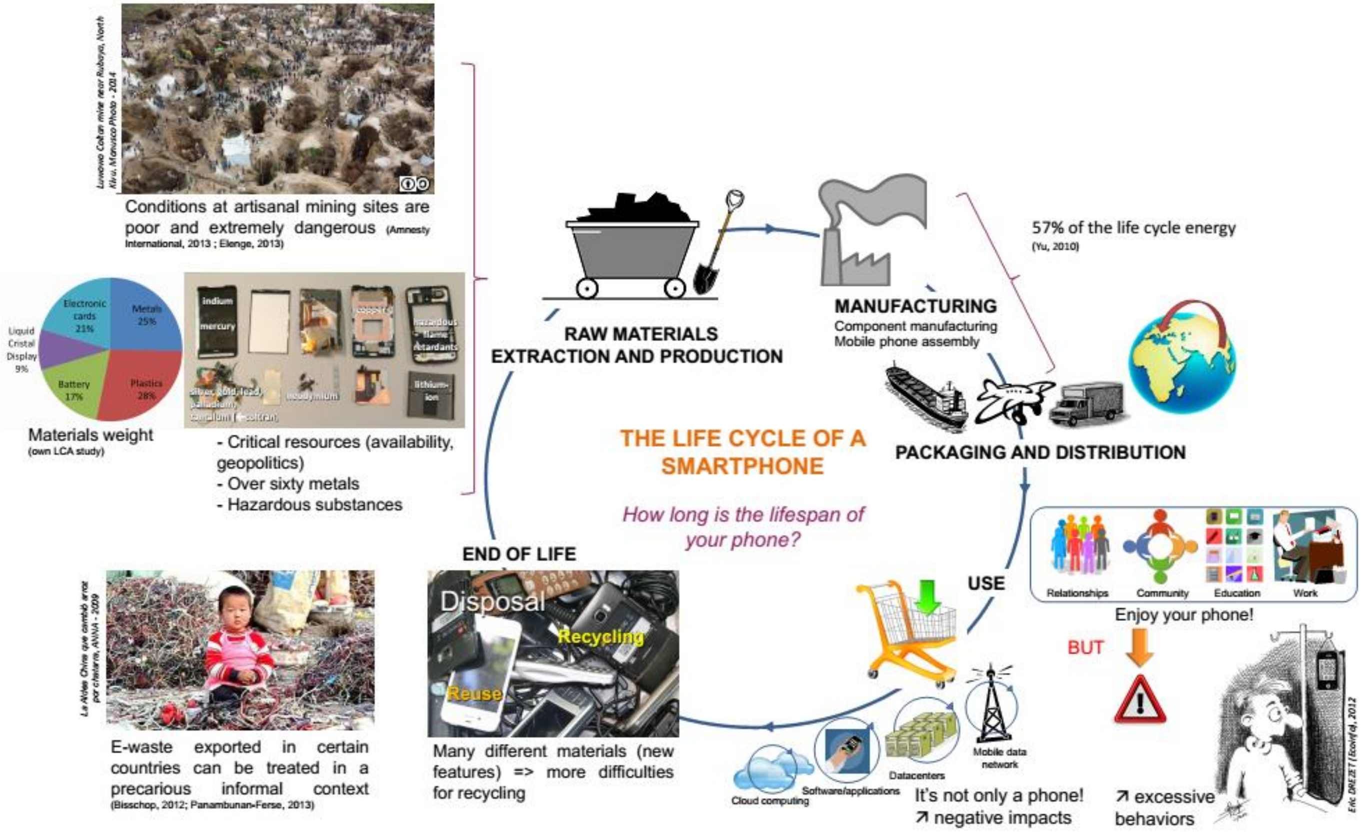
LCA: A MULTI-STAGE METHODOLOGY

Product Life Cycle: Example of a smartphone



(ICT4S conference)

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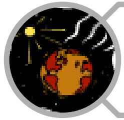
LCA: A MULTI-CRITERIA METHODOLOGY

Climate Change: Greenhouse emissions



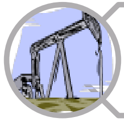
Ozone depletion: all damages to the ozone layer

Human toxicity: emissions in air, water and ground of toxic substances for humans

Aquatic ecotoxicity: emissions in air, water and ground of toxic substances for aquatic fauna and flora

Eutrophication: decrease of the aquatic fauna and flora due to algae contamination (excess of nutrients)

Water consumption



Energy consumption

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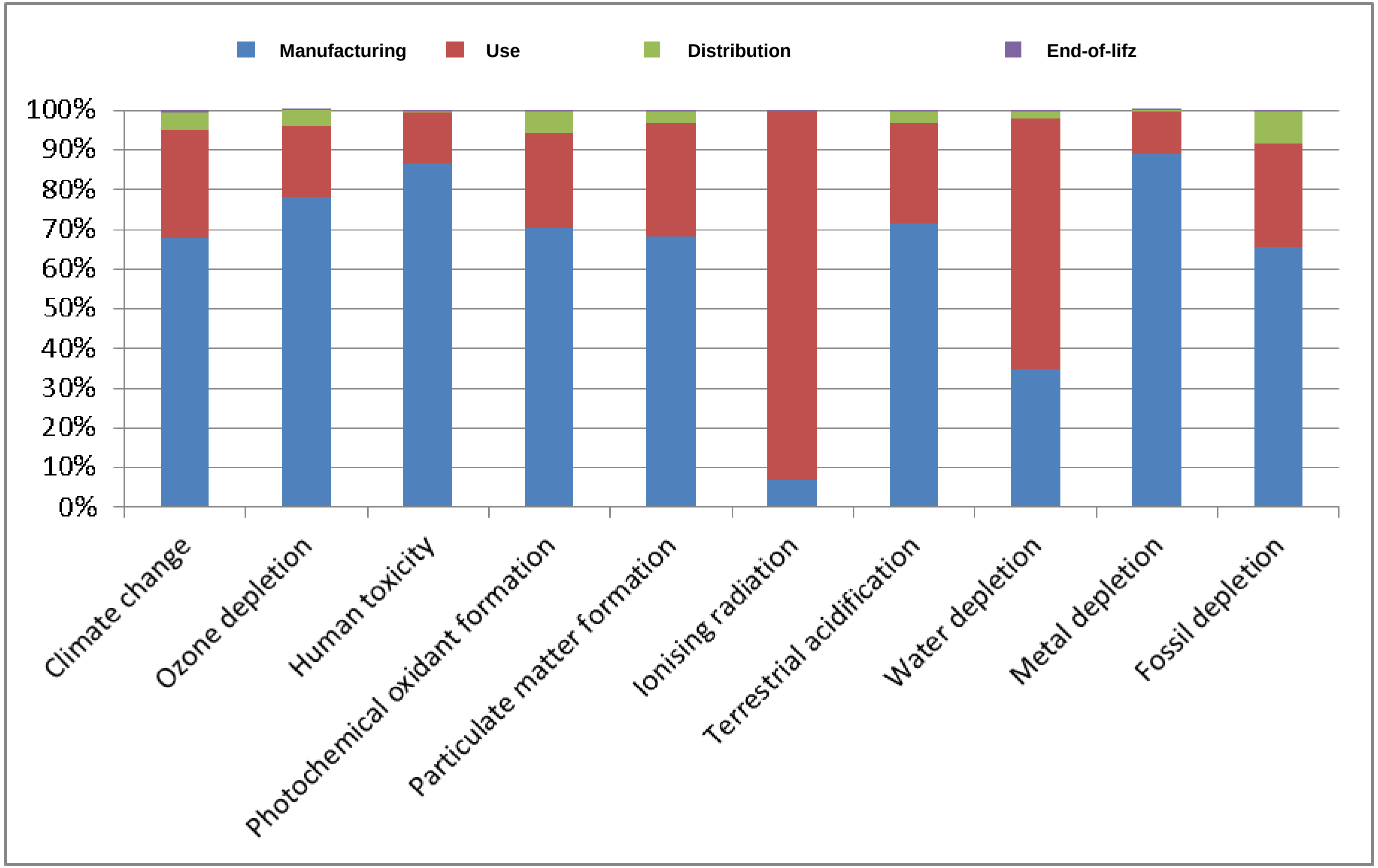
Example: Environmental impacts of a Smartphone in France

LCA: A MULTI-CRITERIA METHODOLOGY



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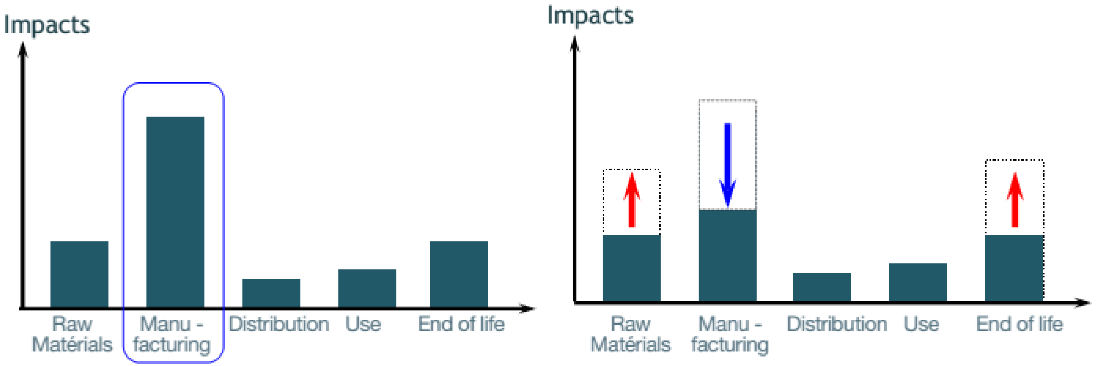
LCA: A MULTI-STAGE AND MULTI-CRITERIA METHODOLOGY

- **Avoiding transfer of environmental pollution**



- **Global view of several impacts**
  – Necessary to identify the most important environmental aspects

- **Data quality**
  - LCA results are goal and data dependent

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WHY DO LCA?

	STRATEGY	ECO-DESIGN	COMMUNICATION MARKETING
INTERNAL	• Identification of the main challenges • Objectives definition • Legislation anticipation	• Environmental impacts assessment • Product improvement • Eco-innovation • Optimization of industrial processes	• Systems comparison • Competitive positioning • Ecolabelling
EXTERNAL	• Lobbying • Standardisation actions	• Sustainable purchasing specifications	• Communication on environmental performances • Increase environmental awareness of customers

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LCA METHODOLOGY:

A BIT OF HISTORY

-'60s
- First « Resource and Environment Profile Analysis » realised by Coca-Cola (1969)

-'80s
- First LCA public databases (BUWAL, Switzerland)

-'90s
- First ISO standards
- Development of LCA software

2000
- Research on simplified LCAs

Today
- A scientific framework but improvements are needed.

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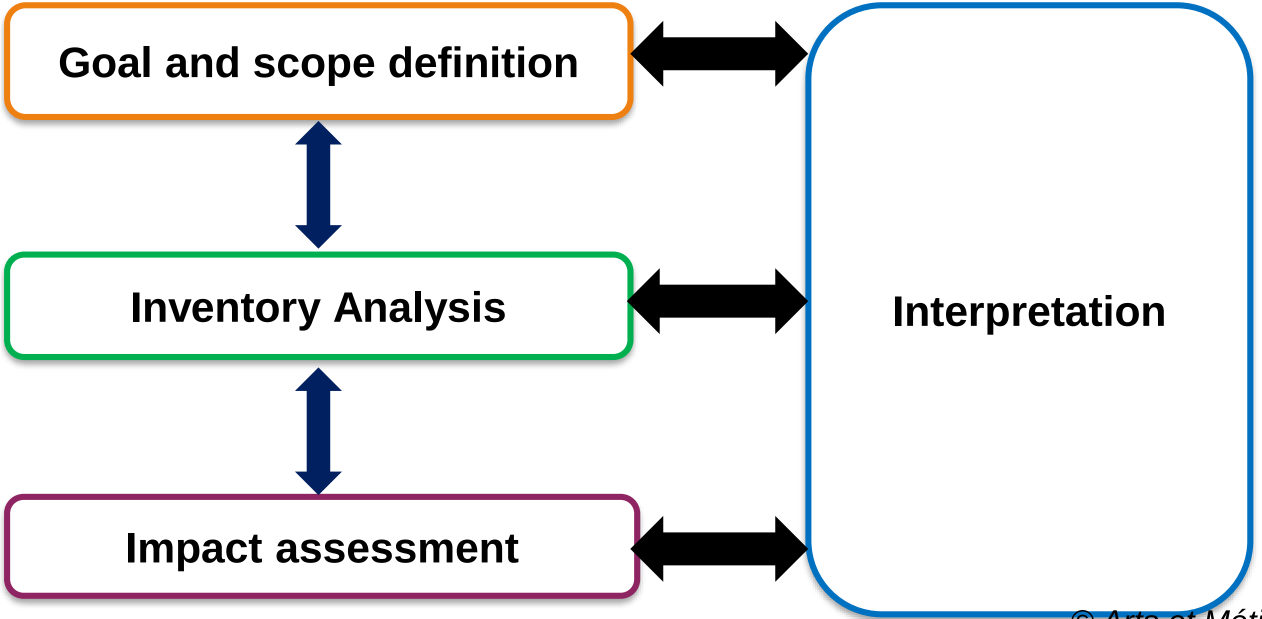
LCA: DEFINITION AND PRINCIPLES

ACV (ISO 14040)

« Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle »

ISO standard ensures that a LCA is completed in a certain way.



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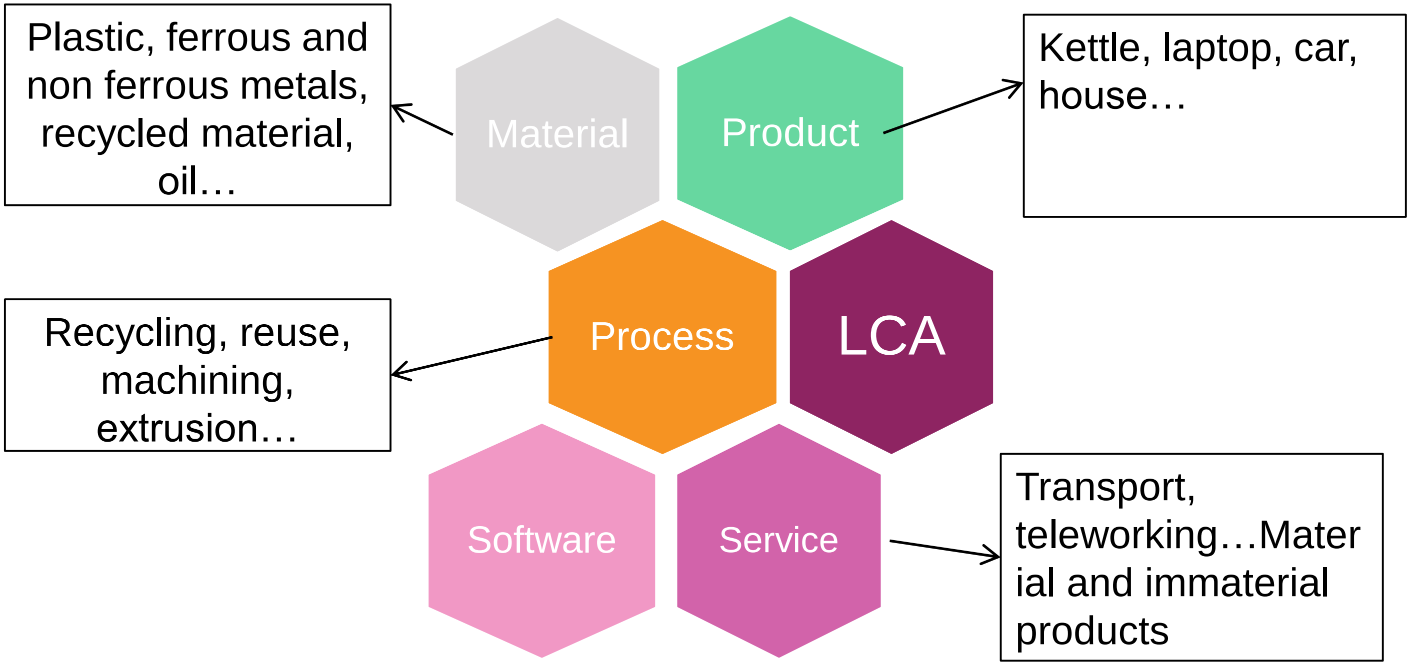
STAGE 1: THE STUDIED SYSTEM



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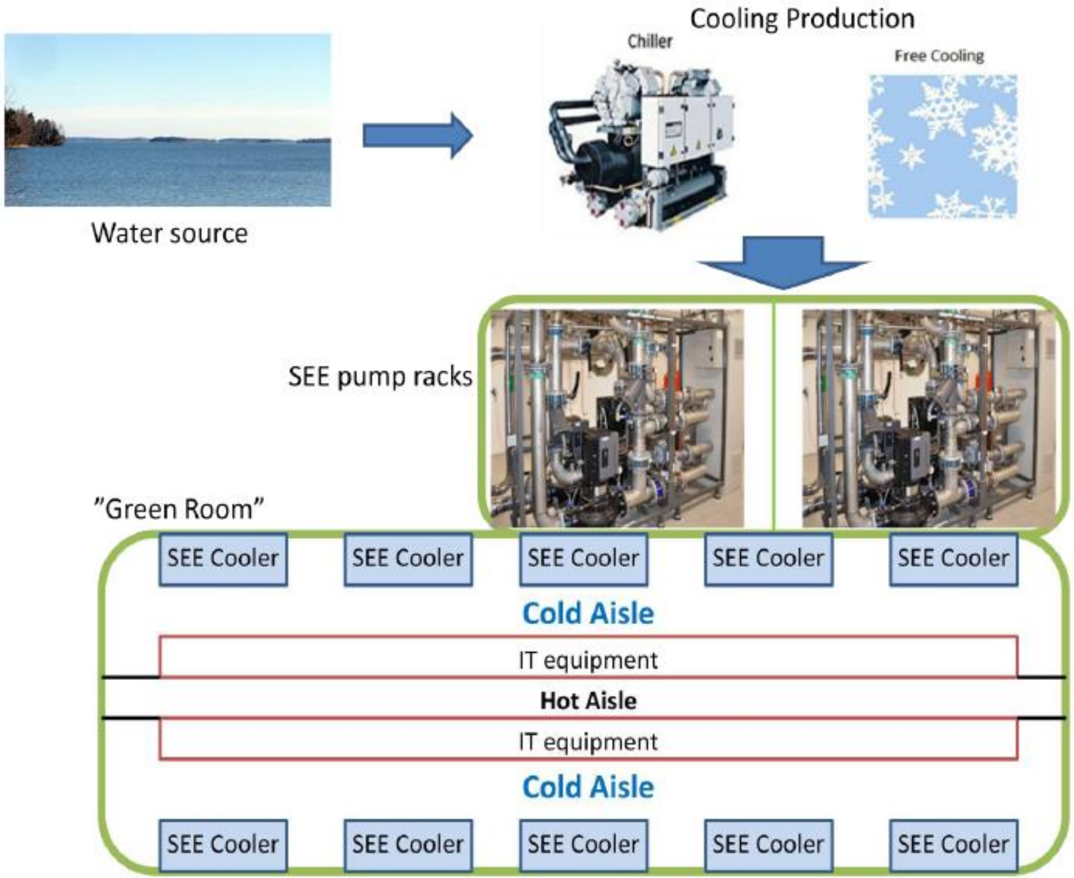
Cooling system of a datacenter in Sweden (Oliveira F., 2012)

STAGE 1: THE STUDIED SYSTEM



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STAGE 1: GOAL AND SCOPE

Application	Communication	Regulation	Eco-design
Reason	Environmental labelling	Non-compliance	Keep or increase market shares
Public	Consumers, Competitors	Producer	Internal design offices
Result	LCA report	LCA report (non comparative)	No report

STAGE 1: GOAL AND SCOPE

The Functional Unit

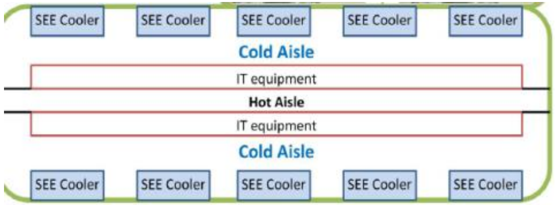
- Quantification of the product function
- Reference to calculate the inputs and outputs
- Necessary to compare products

Action verb+ performance level + operating conditions+lifespan

STAGE 1: GOAL AND SCOPE

The Functional Unit

Use a standard monitor with a diagonal viewing area of 15 inches, working 240 days a year for 6 year in which five hour normal operation, two hour sleep mode and one hour standby mode



(Oliveira F., 2012)

Dissipate a heat load of 5 kW/m2 maintaining a temperature no higher than 22°C to the inlet of electronics device during 20 years»

USB key? e-book? Online purchase…

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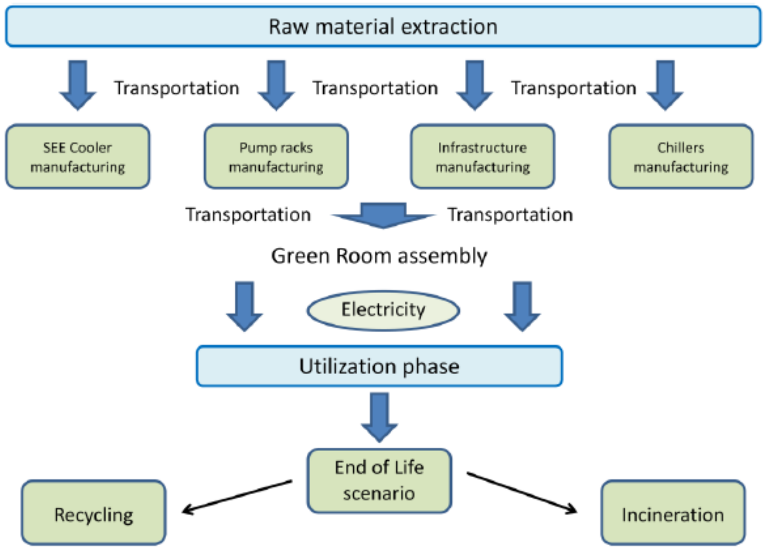
STAGE 1: GOAL AND SCOPE

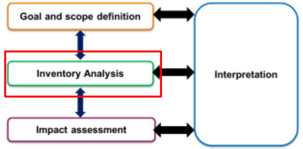
System boundaries

- Definition of the elementary processes taken into account in the LCA
- Life cycle stages+processes+flow



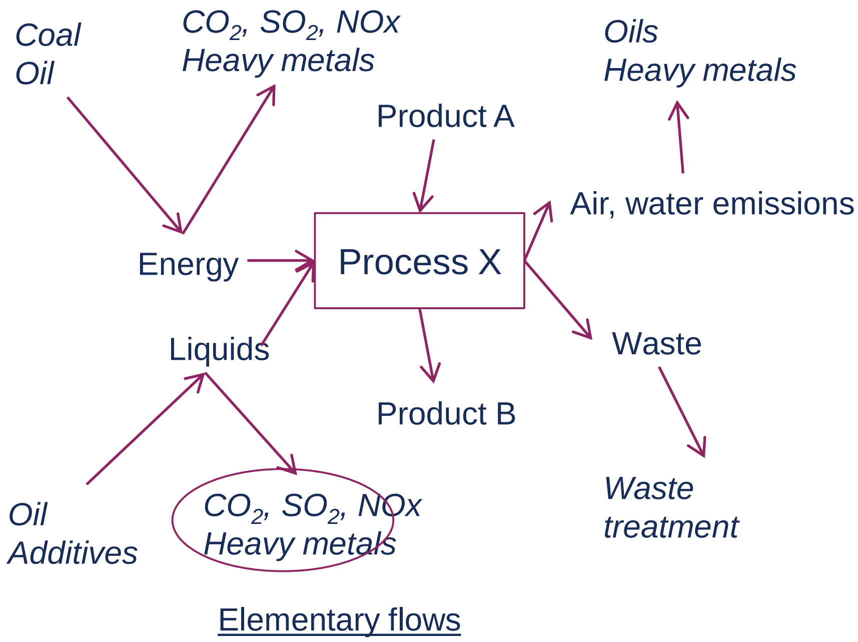
(Oliveira F., 2012)

STAGE 2: LIFE CYCLE INVENTORY



Life Cycle Inventory

- **Quantification of the input and output flows**

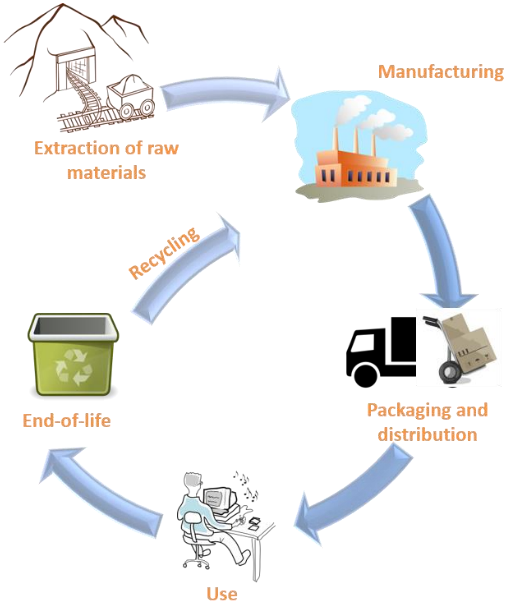


STAGE 2: LIFE CYCLE INVENTORY

Inputs

Resources

- Material
- Chemical product
- Water
- Energy mix



Outputs

Generated materials

- Products
- Waste
- Substances in air, ground and water

Others

- Radiations
- Heat
- Noise

Inputs and outputs are calculated for one functional unit.

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STAGE 2: LIFE CYCLE INVENTORY

The data

➢Primary data versus secondary data

Primary data= **industrial data**

- Specific for a product or a process
- From a survey (supplier, producer…)

Secondary data= **generic data**

- Average value for a product or process
- From databases or LCA reports

Reference:

- Data source
- Collection date
- Collection process

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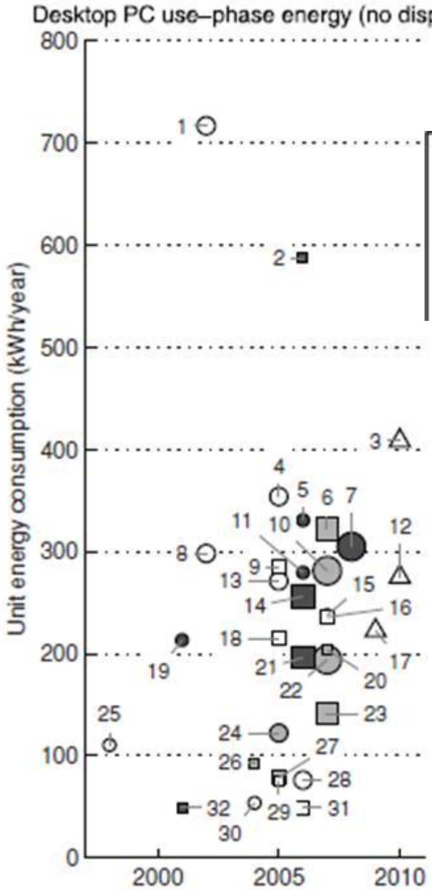
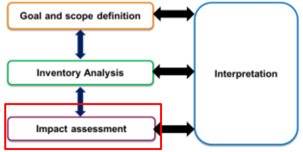
Importance of the data choice: desktop computer case study

STAGE 2: LIFE CYCLE INVENTORY



1	Roth et al. (2002) (high-power PC): Secondary data
2	Braune and Held (2006) [EPIC-ICT] (gamer PC): Dell data
3	US EPA (2010) [Energy Star, baseline]: Secondary data
12	US EPA (2010) [Energy Star, certified]: Secondary data
13	US EPA (2005) [Energy Star, certified]: Secondary data
14	Porter et al. (2006): California plug-load measurements
15	Hischier et al. (2007) [ecoinvent]: Secondary data
16	Roth and McKenney (2007): Phone survey, secondary data
17	Duan et al. (2009): ecoinvent; China statistics
18	US EPA (2005) [Energy Star, certified]: Secondary data
19	Kawamoto et al. (2001): Small-scale measurements
20	Hischier et al. (2007) [ecoinvent]: Secondary data
21	MTP (2006): Measurements and secondary data
22	IVF (2007): Meta-analysis of prior studies
23	IVF (2007): Meta-analysis of prior studies
24	Schlomann et al. (2005): Measurements and secondary data
25	Atlantic Consulting (1998): Secondary data
26	Nordman and Meier (2004): Estimates based on prior studies
27	Schlomann et al. (2005): Measurements and secondary data
28	Choi et al. (2006): Korea statistics
29	Hikwama (2005): Secondary data
30	Williams (2004): Secondary data
31	Choi et al. (2006): Korea statistics
32	Kawamoto et al. (2001): Small-scale measurements

(Teehan, 2012)



STAGE 3: IMPACT ASSESSMENT

Compulsory	Impact categories choice	→	The most relevant for the study
Compulsory	Classification	→	Flows distribution between the categories
Compulsory	Characterization	→	Quantification of flows contribution for each impact category
Optional	Standardization	→	Quantification according to a reference (European impacts)
Optional	Weighting	→	Impacts ranking

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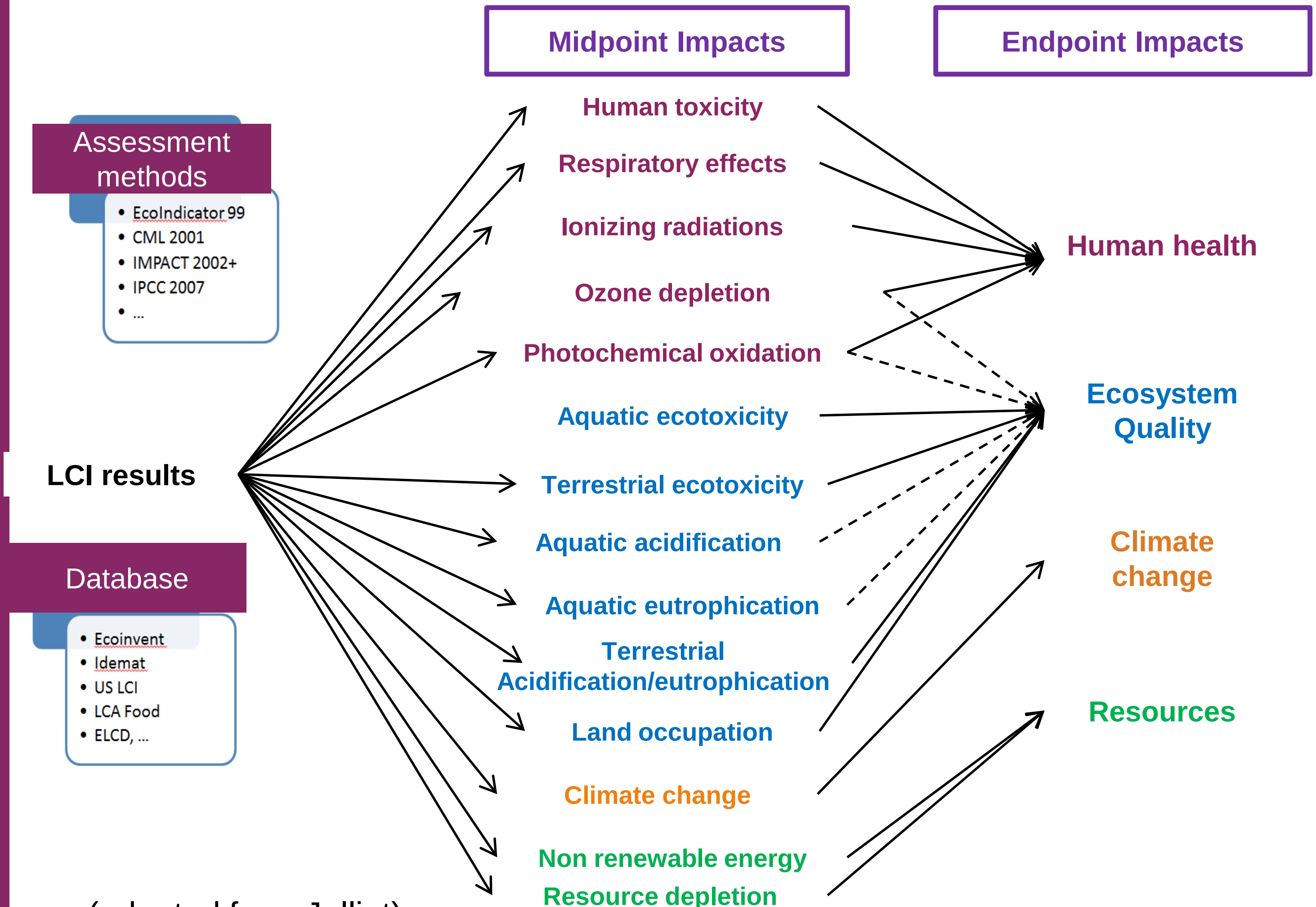
STAGE 3: IMPACT ASSESSMENT

CLASSIFICATION



(adapted from Jolliet)

STAGE 3:
IMPACT
ASSESSMENT

CHARACTERIZATION

Impact calculation model

- A characterization factor
- A characterization model
- A list of contributive substances

$$IE_i = \sum_s FI_{s,i} \times m_s$$

Characterization Factor

$$FI_{s,i_i} = \frac{\text{Substance s contribution to the impact category I during a time t}}{\text{Contribution of the standard substance to the impact category I during a time t}}$$

Characterization model

STAGE 3: IMPACT ASSESSMENT

CHARACTERIZATION

Example: the climate change factor (greenhouse emissions)

$$\text{CC} = \sum_i GWP_{a,i} \times m_i$$

-a= number of years (often 100 years)
-i= the studied substance
-m_i=quantity ot substance i emitted (kg)

- **GWP= Global Warming Potential (GIEC)**
  – Effect of the gases on infrared radiation absorption and their lifetime in the atmosphere

$$GWP_i = \frac{\int_0^T a_i c_i(t)\,dt}{\int_0^T a_{CO_2} c_{CO_2}(t)\,dt}$$

- a_i= radiation absorption due to a gas increasing
- $c_i(t)$=gas concentration remaining in the atmosphere
- T= number of years

STAGE 3: IMPACT ASSESSMENT

CHARACTERIZATION

GWP

Gas	GWP 100y (eq CO_2)	% of emissions
CO_2	1 (standard gas)	70%
N_2O	298	16%
CH_4	25	13%
HFC	Entre 1300 et 11700	2%
PFC	Entre 6500 et 9200	
SF_6	23900	

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STAGE 3: IMPACT ASSESSMENT

CHARACTERIZATION

LIMITS

- ✓ Many uncertainties (calculus, characterization models)
- ✓ A different laboratory for each stage and each impact category
- ✓ All substances are not taken into account because their characterization factor doesn't exist in the databases.

But : this is not synonymous of no impact of the substance

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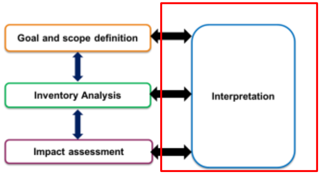
STAGE 4: INTERPRETATION



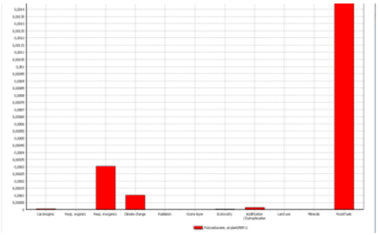
Objectives :

- Results analysis,
- Validate the assumptions of the stage 1
- Quality data assessment
- Define recommendations to improve the product

Contributors identification (materials, process, life cycle stages…)

Assumptions and data quality

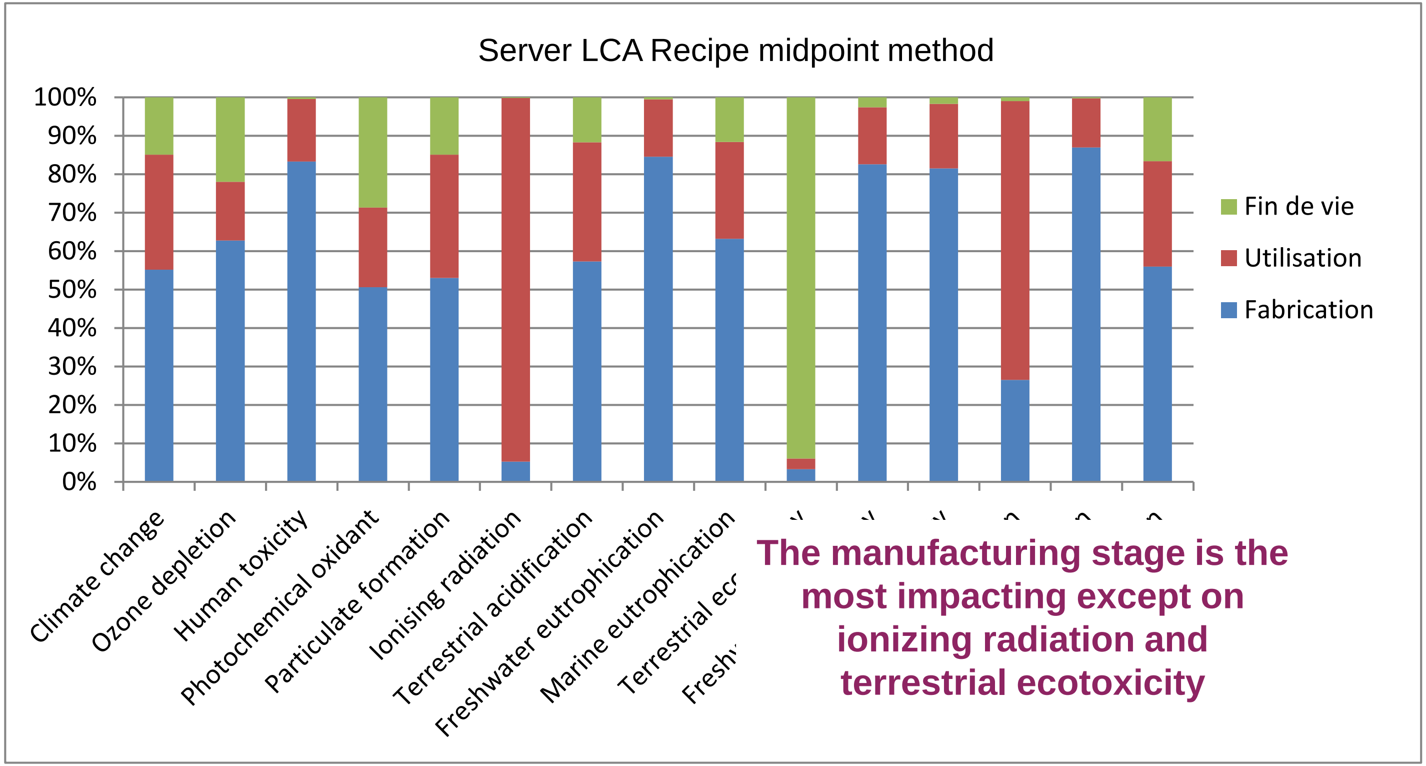
Conclusions et recommendations



STAGE 4: INTERPRETATION

LCA OF A SERVER

For the entire Life cycle

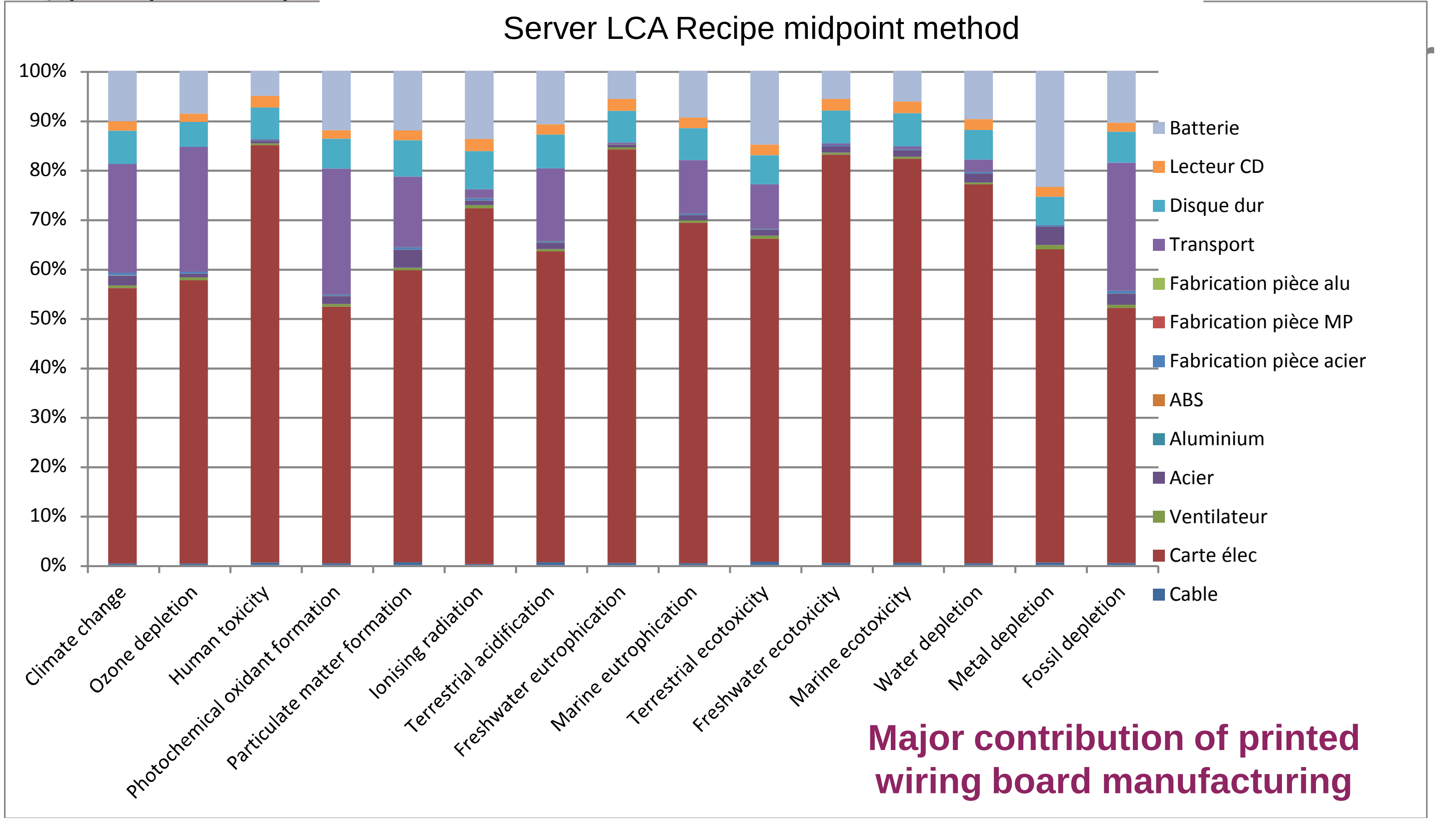


The manufacturing stage is the most impacting except on ionizing radiation and terrestrial ecotoxicity

STAGE 4: INTERPRETATION

LCA OF A SERVER

For a phase, the main contributors (components)



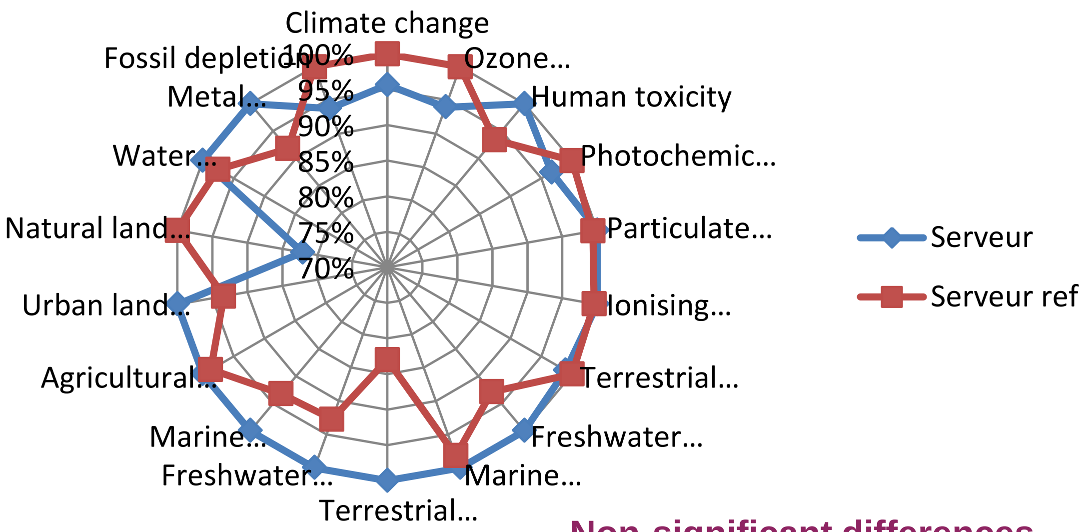
Major contribution of printed wiring board manufacturing

STAGE 4: INTERPRETATION

SENSITIVITY ANALYSIS

Results reliability (sensitivity analysis, uncertainties…)

Variation of the parameters with poor data quality
Comparative LCA with a more recent server



Non-significant differences

STAGE 4: INTERPRETATION

5- Conclusions and Recommendations

- ✓ Summary of the major contributions for each impact category
- ✓ Proposal of scenarios in order to reduce the impact sources
- ✓ Examples of recommendations:
  - – Change the localization of the manufacturing site (energy mix impact)
  - – Choice of low impact materials
  - – Production optimization
  - – End-of-life improvement

  …

Server: Increase the components lifespan

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LCA LIMITS

Methodological Limits

- Only the environmental criteria are assessed.
- Risk related to a lack of impartiality- Need to do a critical review.
- FU variability : lifetime, system boundaries .
- Data heterogeneity

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LCA LIMITS

Scientific limits

- Which impact categories?
- Diversity of the assessment methods
- Discussion about the scientific validity
- Methods must be updated regularly.

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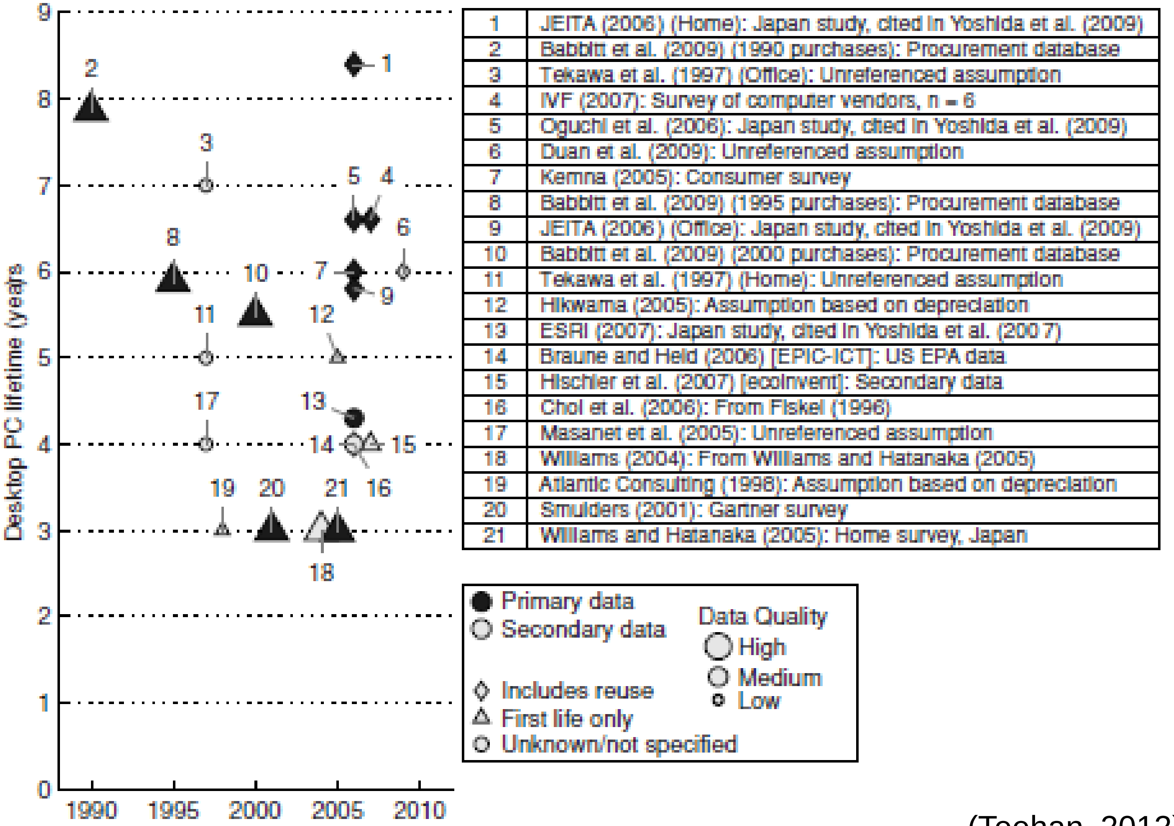
Sources of variability

➢Their lifespan

LCA AND ICT

MAIN ISSUES



1	JEITA (2006) (Home): Japan study, cited in Yoshida et al. (2009)
2	Babbitt et al. (2009) (1990 purchases): Procurement database
3	Tekawa et al. (1997) (Office): Unreferenced assumption
4	IVF (2007): Survey of computer vendors, n = 6
5	Oguchi et al. (2006): Japan study, cited in Yoshida et al. (2009)
6	Duan et al. (2009): Unreferenced assumption
7	Kemna (2005): Consumer survey
8	Babbitt et al. (2009) (1995 purchases): Procurement database
9	JEITA (2006) (Office): Japan study, cited in Yoshida et al. (2009)
10	Babbitt et al. (2009) (2000 purchases): Procurement database
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15	Hischier et al. (2007) [ecoinvent]: Secondary data
16	Choi et al. (2006): From Fiskel (1996)
17	Masanet et al. (2005): Unreferenced assumption
18	Williams (2004): From Williams and Hatanaka (2005)
19	Atlantic Consulting (1998): Assumption based on depreciation
20	Smulders (2001): Gartner survey
21	Williams and Hatanaka (2005): Home survey, Japan

(Teehan, 2012)

Other sources of variability

- **Systems boundaries: localization of the suppliers**
  – French energy mix more favorable for the use phase than the Chinese one (be careful about the others impacts of nuclear energy)

- **The choice of the end-of-life scenario**: often not considered.

- **The technological evolution**

- **Planned obsolescence, rebound effect**

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CONCLUSION

ICT systems: major environmental challenges

A global vision

Recycled Material

Waste designed for recycling

Product Eco-design
Process Eco-design

Recycling networks

LCA

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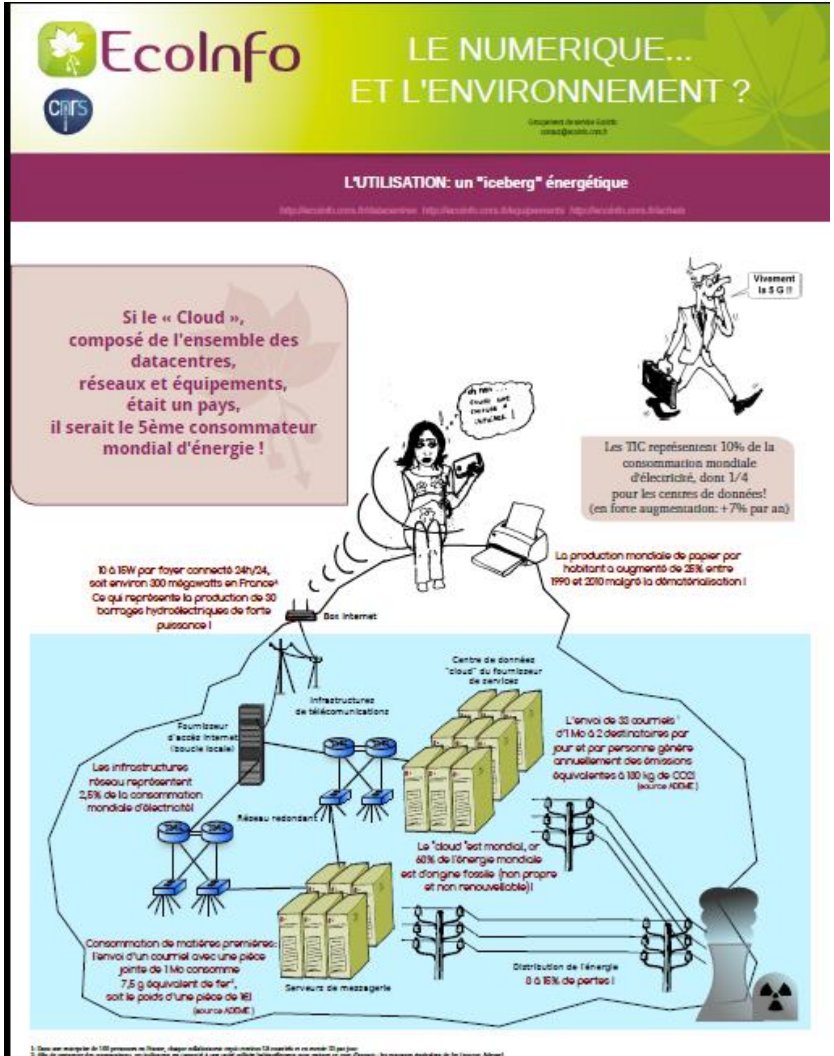
LE GDS ECOINFO



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THANK YOU FOR YOUR ATTENTION!

October 2th 2018

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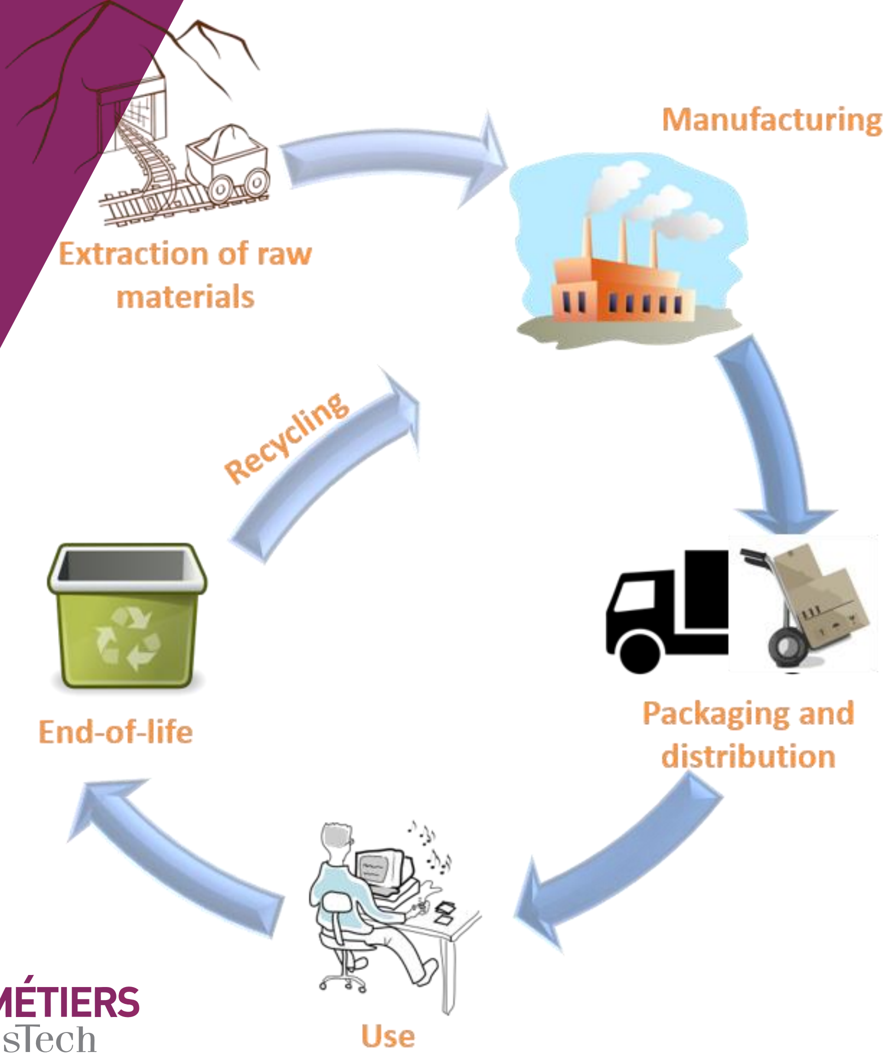

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