Lumière & Matière

UMR 5213

Understand the circular economy approach to lighting sector

The principles of Life Cycle Assessment

R2P2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857061.

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Circular Economy - Definition

- ✓ Circular economy aims to redefine growth, focusing on positive society-wide benefits.
- ✓ Looking beyond the linear model "Extract-Produce-Consume-Waste" current industrial model.
- ✓ It entails gradually decoupling economic activity from the consumption of finite resources, and designing waste out of the system.
- ✓ It is built on three principles, driven by design:
  - Eliminate waste and pollution
  - Circulate products and materials (at their highest value)
  - Regenerate nature

Linear economy model

Circular economy model

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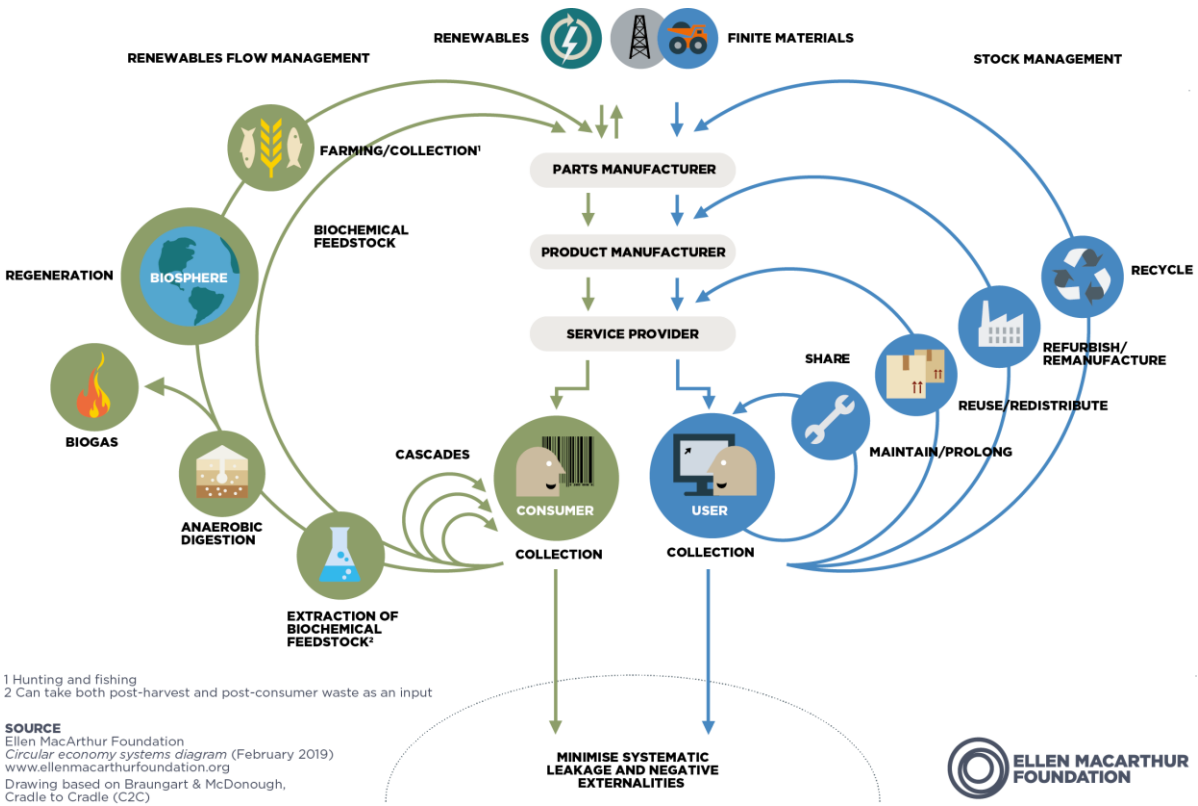
The butterfly diagram



The circular economy system diagram, known as the butterfly diagram, illustrates the continuous flow of materials in a circular economy.

There are two main cycles – the technical cycle and the biological cycle.

- In the technical cycle, products and materials are kept in circulation through processes such as reuse, repair, remanufacture and recycling.
- In the biological cycle, the nutrients from biodegradable materials are returned to the Earth to regenerate nature.

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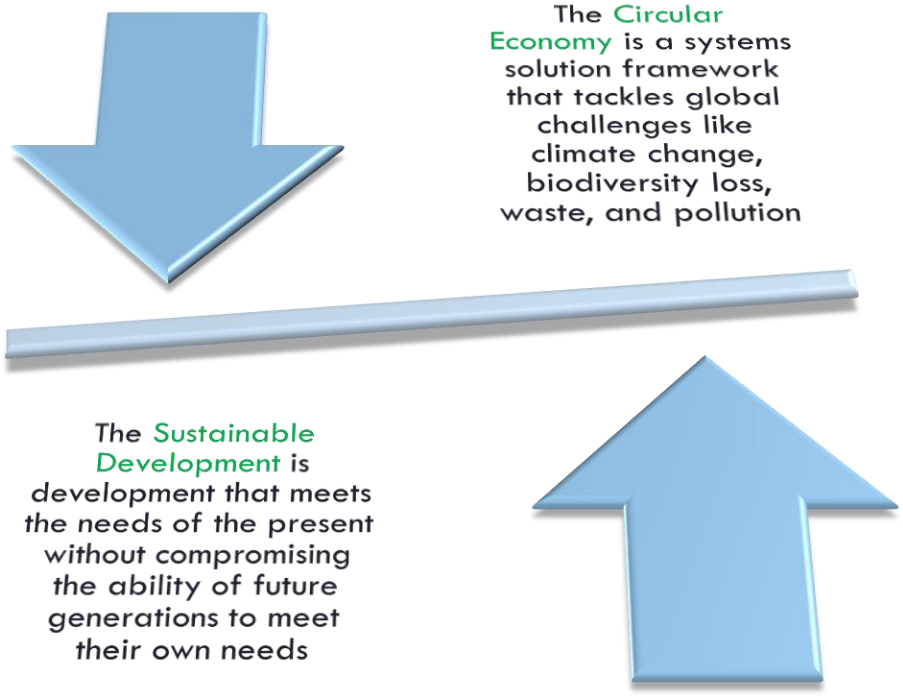
Circular economy vs Sustainability



- Sustainable Development implies a wider approach than simply economic growth, as it includes as well other indicators as social and environmental ones
- Circular economy implies to get into a system able to regenerate by itself by reducing the use of resources and energy, wastes and emission. Thanks to that, economic systems become more sustainable.
- Circular economy not necessarily imply sustainability, although circular economy is needed in order to promote goals of sustainable development.

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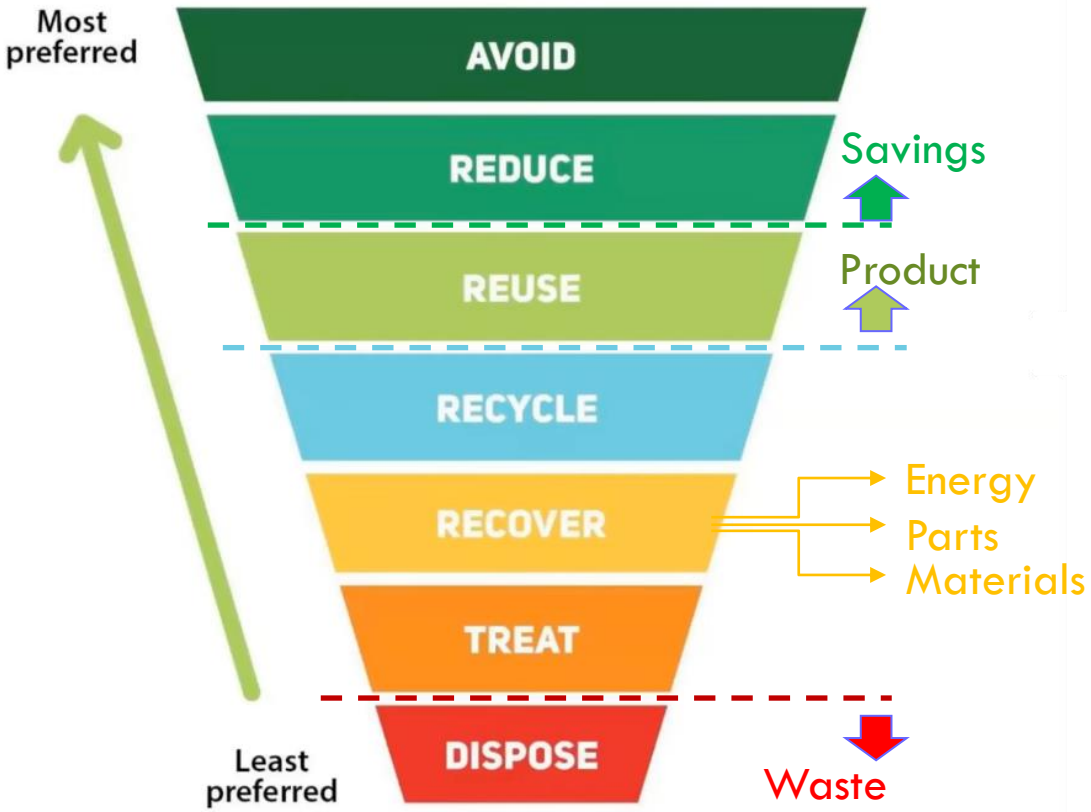
The waste management hierarchy...



- The Waste Management Hierarchy is a tool used in the evaluation of processes that protect the environment alongside resource and energy consumption from most favourable to least favourable actions.
- The more the waste management hierarchy is respected the greater the potential of reducing emissions & impacts.

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Recycling vs Reusing

Recycling:

- ✓ Enables to reduce demand in raw materials
- ✓ Demands less energy than production of primary materials.

Savings in energy use and greenhouse gas emissions by recycling will be between 40-80% for most recycled materials compared to the energy needed to produce primary materials.

EU recycling targets:

- All packaging: 70% by 2030
- Municipal waste: 65% by 2035

Reusing:

- ✓ Reducing demand for primary raw materials by:
  - making products more durable or easier to repair from the design stage
  - or remanufacturing processes where a product or component is returned to a new like condition.

Examples/Initiatives:

- Predictive maintenance solutions.
- Second hand markets, community initiatives…

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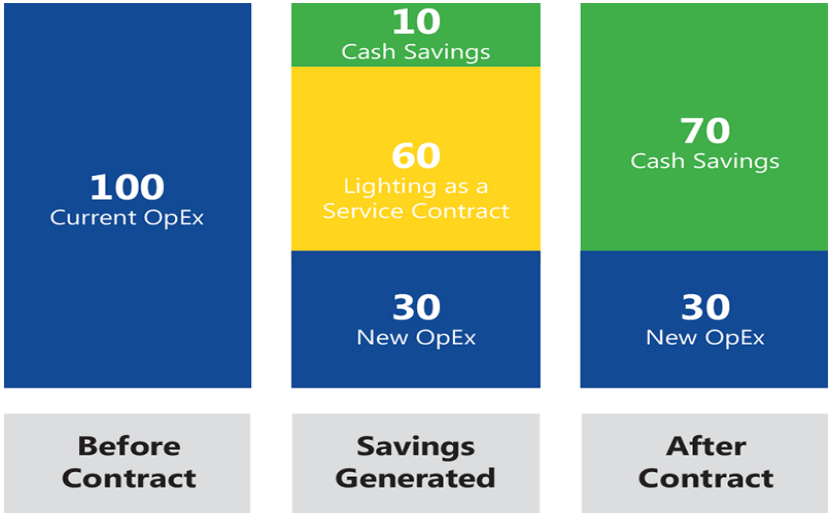
Reduce

- ✓ Reduce the demand of a product
  - Rethinking the concept of ownership (“lease than own”)

Light as a Service (LaaS concept)

- Pay for electricity rather than lightbulbs
- Switch from lighting replacement products to financing and leasing lighting as a service



“…This will reap not only the direct economic benefits of lighting but also the benefits beyond lighting fully in line with the transition from a linear to a circular economy…” (Signify)

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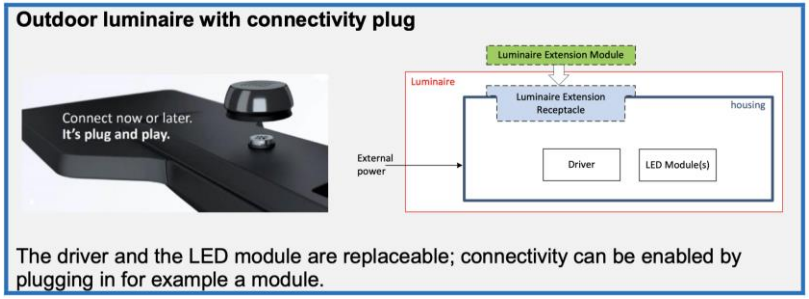
- ✓ Making the full process more energy efficient
  - Turning one industry's by-product into another industry's raw material or/and energy.
  - Increase reparability and facilitate maintenance
  - Increase modularity and "intelligence" of the product
  - Standardise the product

Improving the serviceability of lighting products (luminaires)

- Luminaires can be repaired and have a longer technical lifetime thereby improving the material efficiency of the sector and reducing wastes.
- Serviceable luminaires enable new business models and create new jobs (new opportunities arise for professionals offering monitoring, maintenance, data analytics etc.)



Source: White Paper, LightingEurope

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How evaluate the impact of a product?

Challenges in lighting

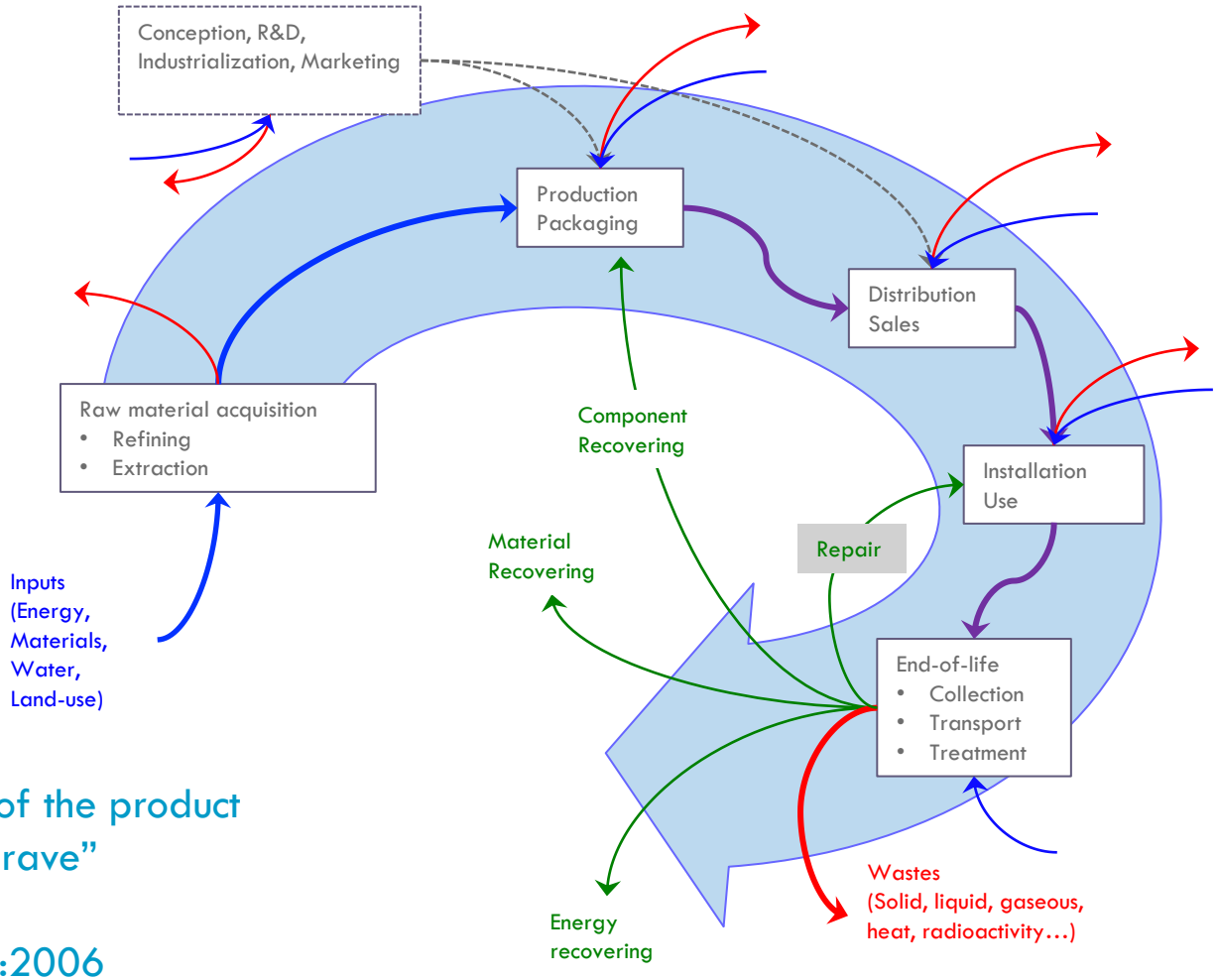
- Reduced impacts related to energy consumption
- Avoid/limit the extraction of critical raw materials
- Avoid/limit use of toxic materials
- Avoid/limit impacts on human health & wellbeing
- Avoid/limit ecosystem disturbances

NOTE

To perform that evaluation the full life cycle from cradle-to-grave of a product needs to be taken into account

Life Cycle Assessment fundamentals

- ✓ Life Cycle Assessment (LCA) is primarily a method to measure the environmental impacts of various economic activities and, throughout the life cycle of the product or process.
- ✓ LCA can identify the points on which a product can be improved and designed to prevent impacts from human activities.
- ✓ LCA does not include economic aspects.



Take into account the full life of the product
"From cradle to the grave"

ISO 14040 & 14044:2006

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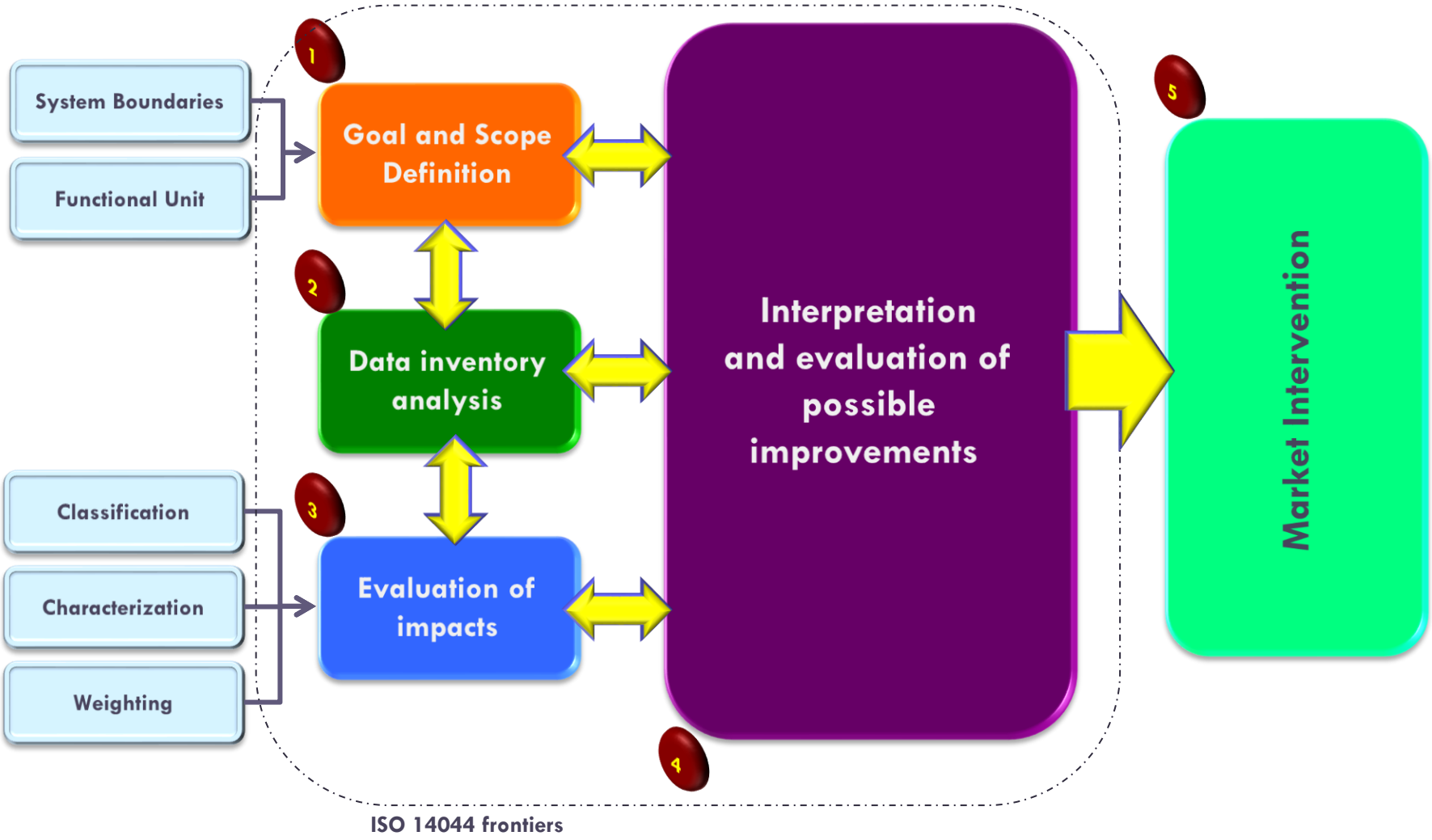
LCA steps



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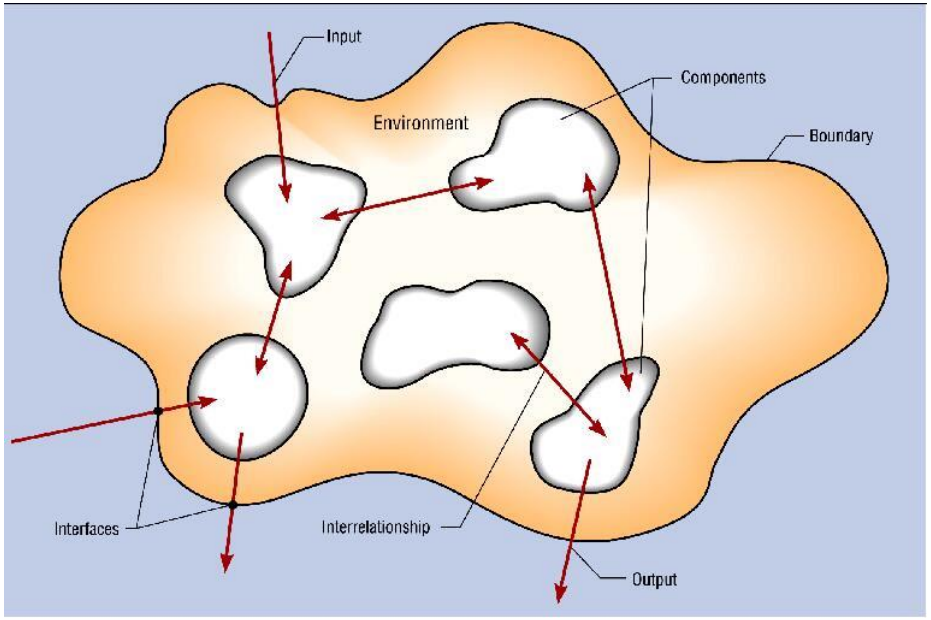
System boundaries (SB)

- ✓ System boundaries in LCA must be specified in several dimensions:
  - boundaries between the technological system and nature, delimitations of the geographical area and time horizon considered
  - boundaries between production of capital goods and provision of services
  - boundaries between the life cycle of the product studied and related life cycles of other products.
- ✓ System boundaries must be relevant in relation to the purpose of the LCA.
  - Including processes outside the process tree in many cases has more influence on the result than details within the process tree.

STEP 1A



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Functional Unit (FU)

STEP 1B

- ✓ A FU refers to the product, service, or system whose impacts are calculated by a LCA
  - The FU is an arbitrary parameter of standardization used to describe the final outcome
  - The FU is a measure of the performance of the product.
- ✓ The definition of a FU is essential for building and modelling a product system in LCA.
  - A FU should as far as possible relate to the functions of the product rather than to the physical product.

EXAMPLE

For example, use rather "annual light quantity needed for illuminating a work area of 10 m^2 with 300 lx", than "number of bulbs providing 30 000 lm for one year".

In a comparative study, the functional unit has to be the same for all the compared product or systems.

Remind: you can't compare apples and pears…

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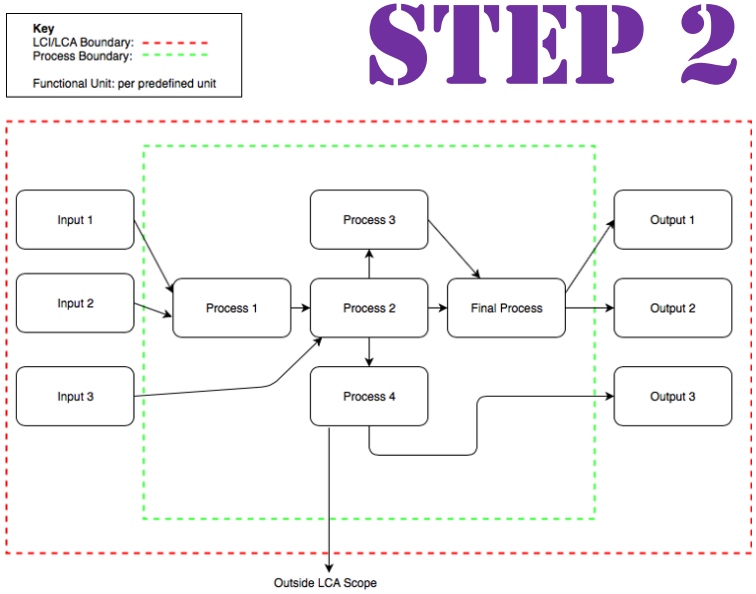
Life Cycle Inventory (LCI)

- ✓ The inventory relates to the compilation of various environmental inputs and outputs involved in the life cycle of a product.
- ✓ Compiling and preparing life cycle inventory data is a critical step in conducting an LCA.
- ✓ Inventory analysis translates in practice to data collection and analysis.
- ✓ Data collection involves the recording of the relevant inputs and outputs of the life cycle of a product or process.
  - ✓ Establish the life cycle flow map, detailing which processes are included within the boundaries of your LCA.
  - ✓ Decide if enough data for each process, or for the overall system are collected.
  - ✓ Compile relevant data such as electricity consumption, natural gas, materials, etc.
  - ✓ Ensure listing appropriate units and all relevant details and/or calculations for easier understanding

STEP 2



Remind: If the data set is not representative of the process, the LCA results will be skewed and irrelevant.

Examples of existing LCI databases

ecoinvent

FEDERAL LCA COMMONS

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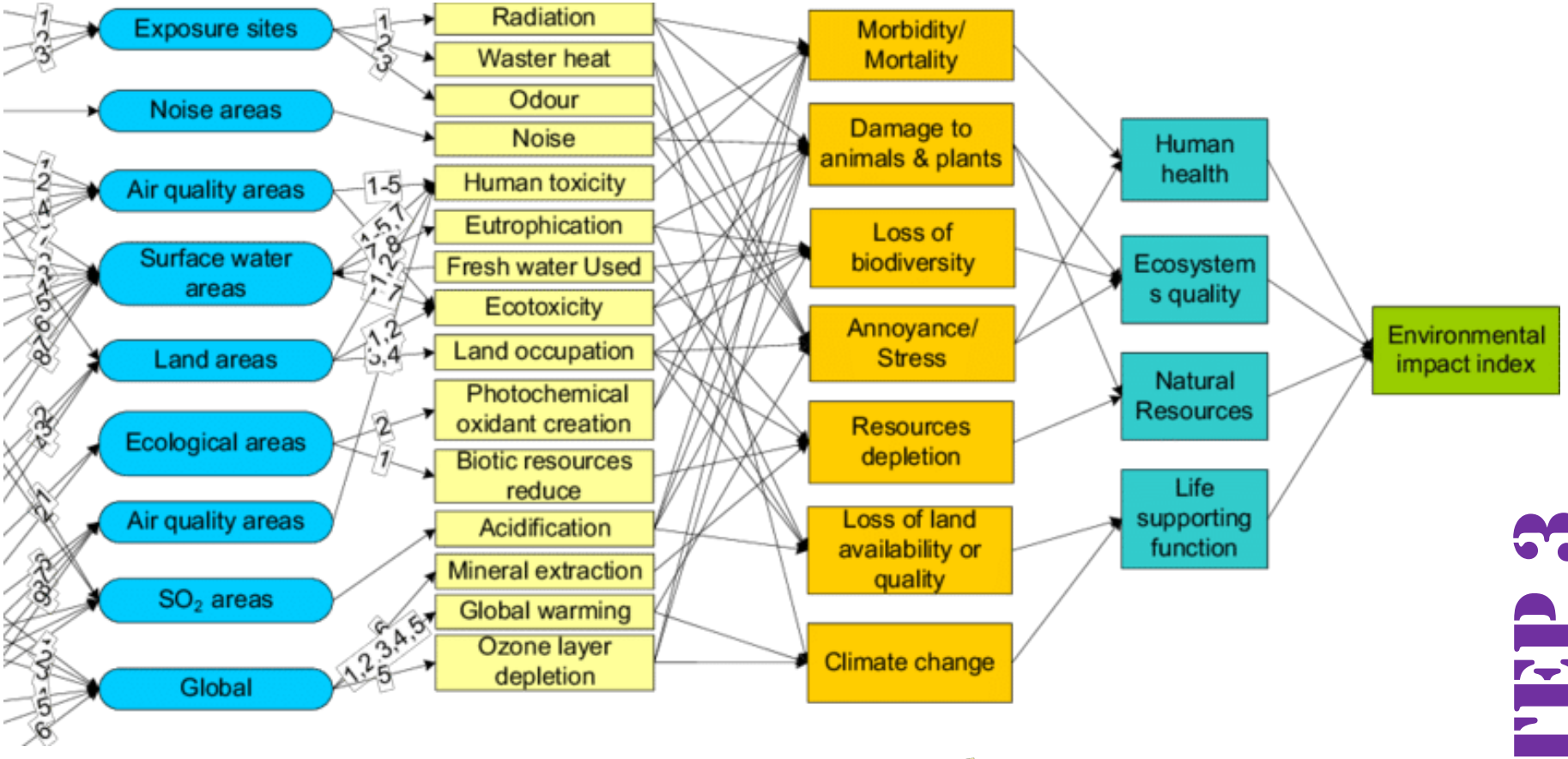
Weighting – the CML method



STEP 3

CML:2001 is an impact assessment method which restricts quantitative modelling to early stages in the cause-effect chain to limit uncertainties.

NOTE

Other weighting methods exists…

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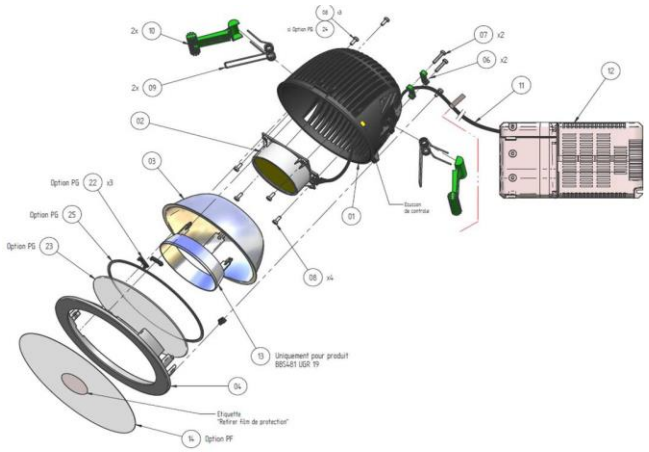
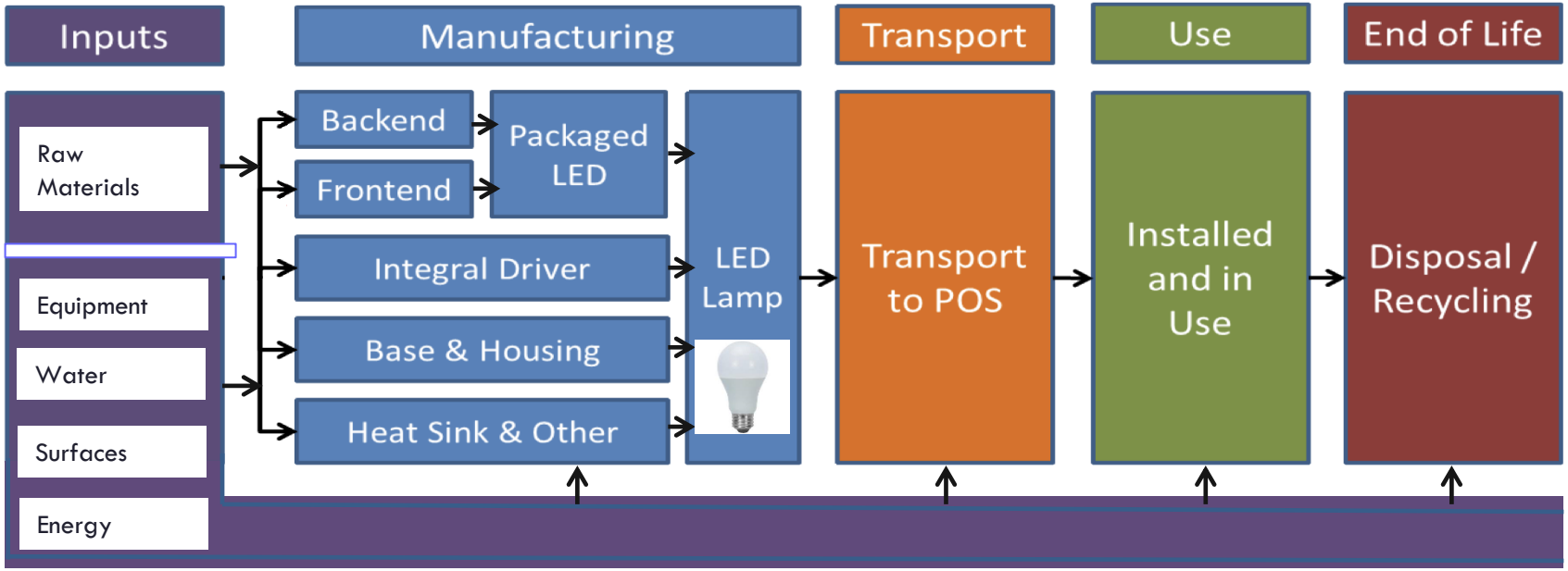


EXAMPLE: APPLICATION TO DOMESTIC LIGHTING SYSTEMS

The scope & system boundaries

The case of LED lamps



The scope of this LCA is to study the environmental impacts of an LED lamps for domestic use and to determine the life cycle stages and material and energy inputs that cause the greatest impacts.

The system's boundaries include the manufacturing, transport, installation, use and end-of-life (EoL) stages.

- Row material transformation: ~4%
- Manufacturing: ~5-8%
- Transport: ~3%
- End-of-Life: ~4%.

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The choice of Functional Unit

- ✓ A lamp absorbs electrical power in watts and produces a luminous flux expressed in lumens
- ✓ A lamp has a lifespan expressed in thousands of hours
  - For Incandescent and CFLs the economic or median lifespan is used.
  - For LEDs the median lifespan is considered

Incandescent Lamp	Compact Fluorescent Lamp	LED Lamp
75 W	13 W	9 W
900 lm	845 lm	855 lm
1 500 h	8 000 h	25 000 h
		
~15 lamps (GLS)	~3 lamps (CFL)	~1 lamp (LED)

~20 million lumen-hours (Mlm.h)

To compare different technologies, the usual choice of functional unit is the radiated luminous energy generated during its lifespan, expressed in million lumen-hours (Mlm.h)

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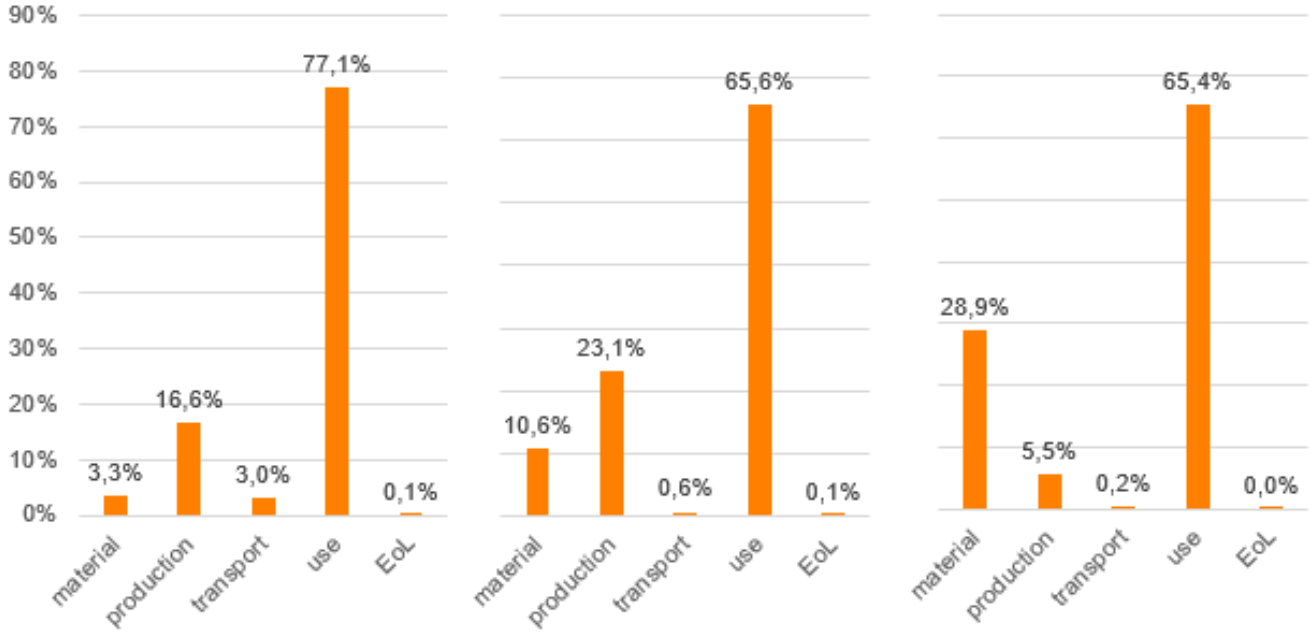
Comparison between technologies

INCANDESCENCE	FLUOCOMPACTE (CFL)	LED
 x 15 LAMPS	=  x 3 LAMPS	=  x 1 LAMP

= 20 Mlm.h

Breakdown of the environmental impact of a system by phase of the life cycle



- Predominance of use phase
- Transport & EoL phases are negligible
- The environmental impacts are almost independent from the EoL scenario.

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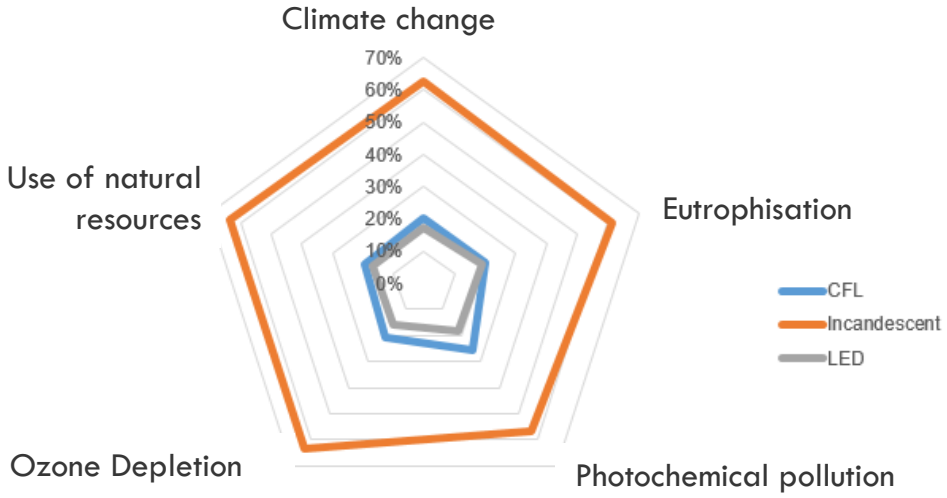
Impact quantification

INCANDESCENCE	CFL	LED	
 x 15 LAMPS	=  x 3 LAMPS	=  x 1 LAMP	= 20 Mlm.h
585 points	201 points	194 points	

Global Impact Quantification
(Eco-indicator CML method)

Impact per indicator (CML method)



LED LAMP MADE IN CHINA (2016 model)

LED LAMP USED IN **FRANCE**

- Incandescence has the worse results
- LED and CFL are still comparable in 2016
- This will not be the case with more efficient LEDs

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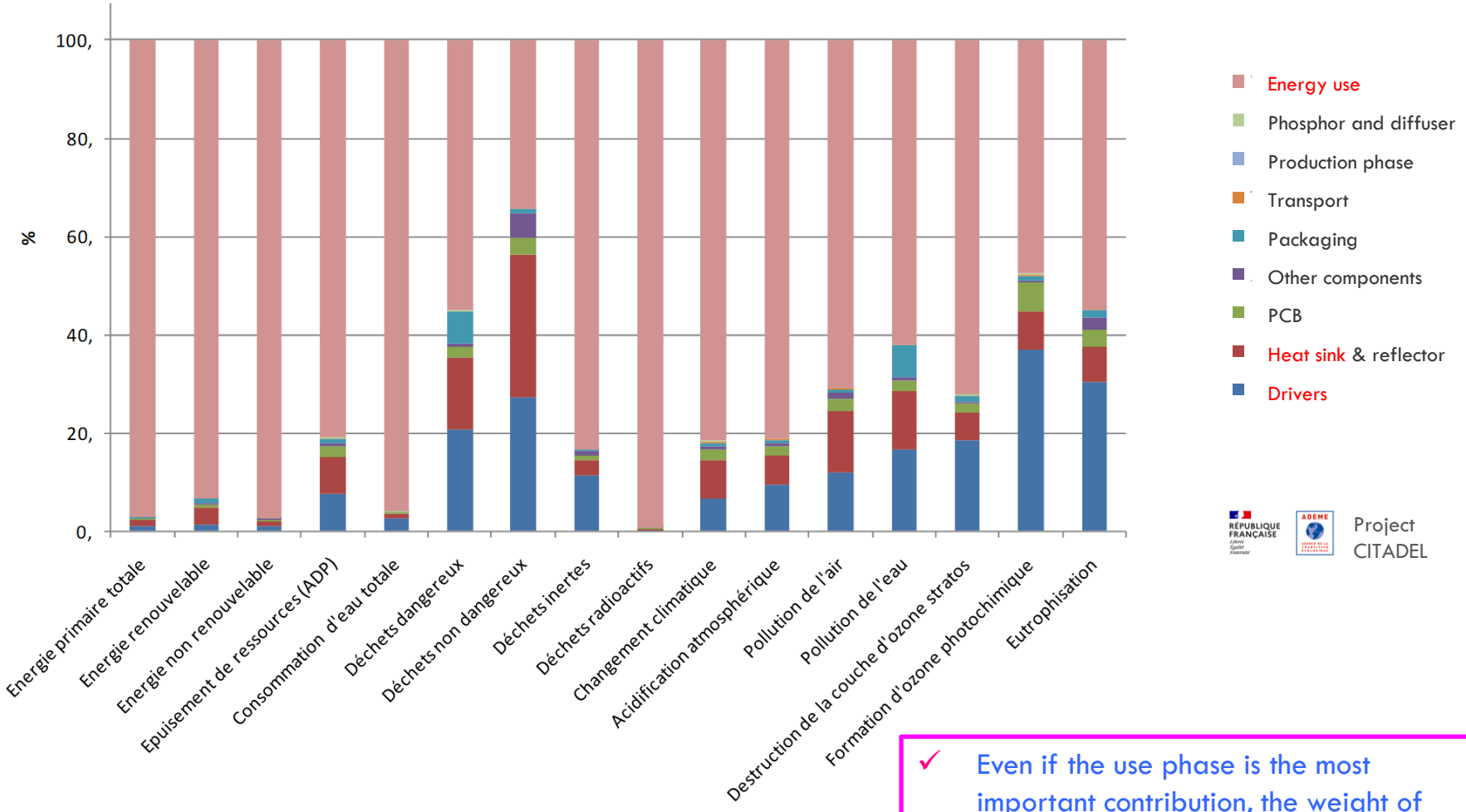
Global LCA



Project CITADEL

- ✓ Even if the use phase is the most important contribution, the weight of driver and heat sink are not always negligible

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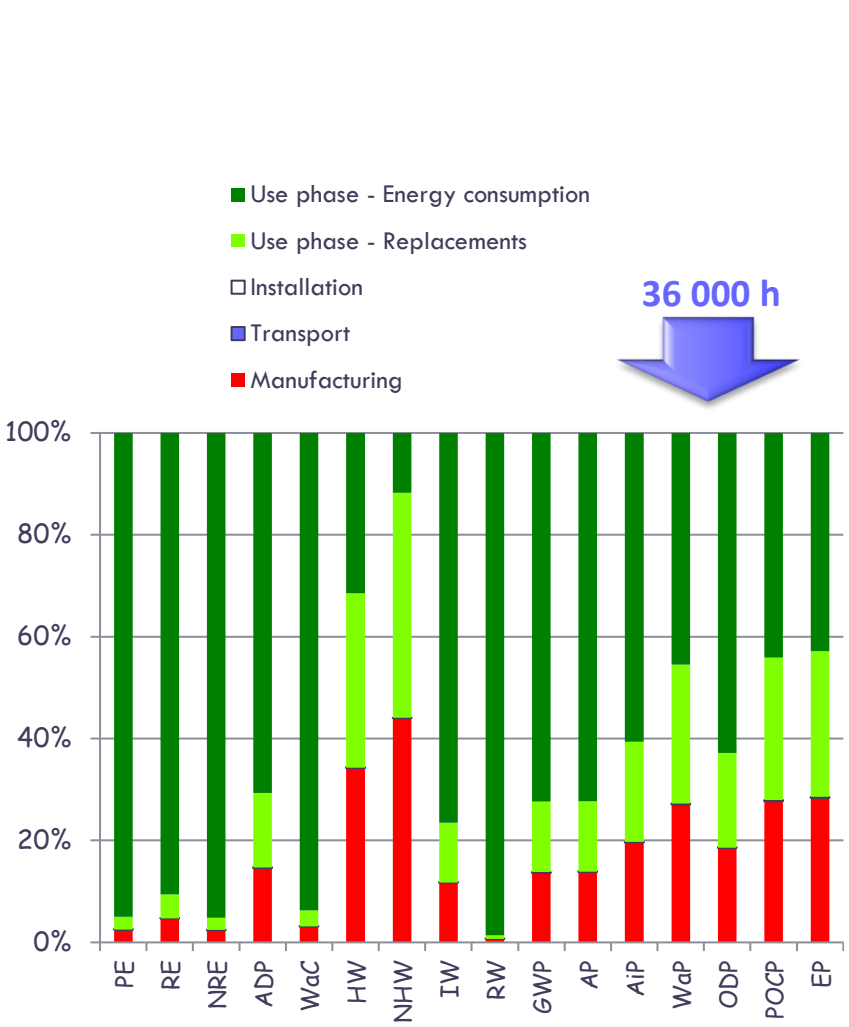
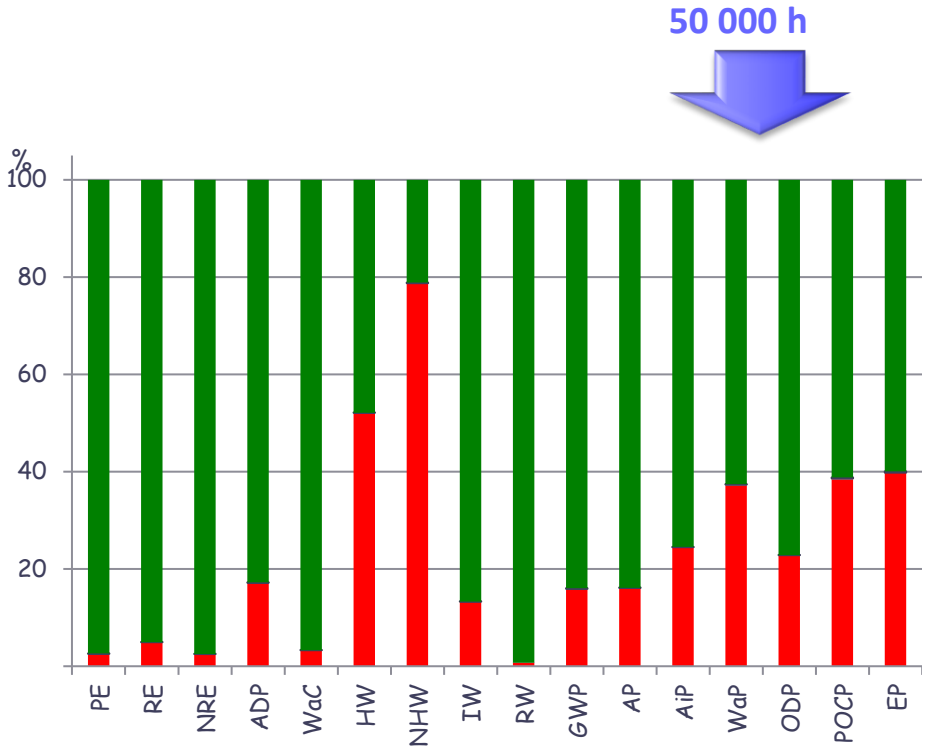
Lifespan influence





- ✓ Due to the lower manufacturing efforts, the environmental impacts of the 50 000h were 44 % lower than the ones of the case of 36 000 h.
- ✓ Re-lamping impact goes to zero

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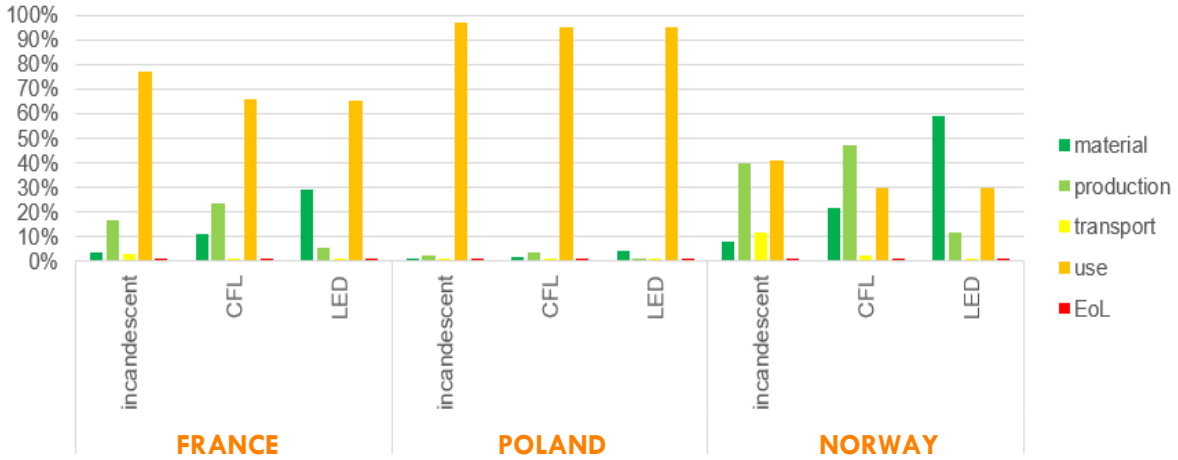
Where the lamps are used?

INCANDESCENCE	CFL	LED	
 x 15 LAMPS	=  x 3 LAMPS	=  x 1 LAMP	= 20 Mlm.h
585 points	201 points	194 points	
2001 points	581 points	520 points	
299 points	115 points	126 points	

Manufactured in	Used in
CHINA	FRANCE
CHINA	POLAND
CHINA	NORWAY



- Use Phase is predominant for Poland
- Manufacturing phase is not negligible for Norway

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LCA of Lighting Systems
Interpretations and Limits

- ✓ Incandescent lamp is the most impacting lamps regardless of any other compared technology.
- ✓ LEDs will be the champion.
- ✓ Electricity production plays a major role in LCA : the higher the proportion of renewables in the electricity mix, lower is the impact of use phase for each lamp.

- ✓ It's difficult to conclude for other lamp-types on a generic use case.
- ✓ LED global performance depends on lifetime/efficacy couple, therefore it relies on quality of manufacturing and materials, but also on social aspects like how people use LED lamps (rated lifetime vs real time of use). LCA doesn't include social aspects.
- ✓ There is a lack of information on EoL, disposal or recycling process and facilities.
- ✓ Quality of lighting and impact on human health during use phase are not considered.

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Thank you for your attention!

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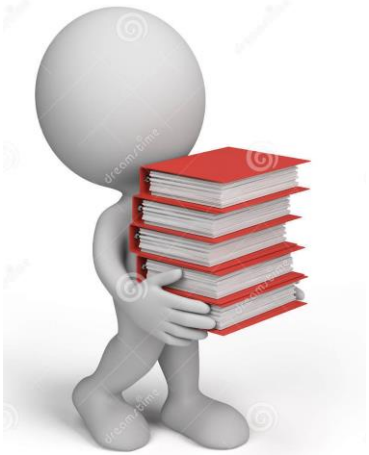
Existing Guidelines and Standards

- ✓ For further information on circular economy look at:
  - Waste Electrical and Electronic Equipment (WEEE) directive
  - EcoDesign for Energy Related products
  - EU legislation via the EcoDesign (section 4) route comes into force on 1st September 2021
  - EU Single Lighting Regulation - (EU)2019/2020 laying down the EcoDesign requirements for light sources and separate control gears
  - European Commission - Integrated Product Policy (IPP)
  - Extended Producer Responsibility (EPR)
  - Environment (Principles & Governance) Bill 2018, presented by the Department of Environment, Food and Rural Affairs (DEFRA).
  - BS8887-220:2010 covers the 'Design for manufacture, assembly, disassembly and end-of-life processing (MADE). The process of remanufacture. Specification'



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