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Energy Life Cycle Performance of Buildings

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Introduction

MORE PEOPLE

The global population reached 7 billion during 2011 and the United Nations projections indicate that it will reach between 8 and 11 billion by 2050.

MORE CONSUMPTION

The richest parts of the world per capita material consumption is far above the level that can be sustained for everyone in a population of 7 billion or more. This is in stark contrast to the world's 1.3 billion poorest people, who need to consume more in order to be raised out of extreme poverty.

STILL ONE PLANET!

The combination of increasing global population and increasing overall material consumption has implications for a finite planet. As both continue to rise, signs of unwanted impacts and of irreversible changes are growing alarmingly.

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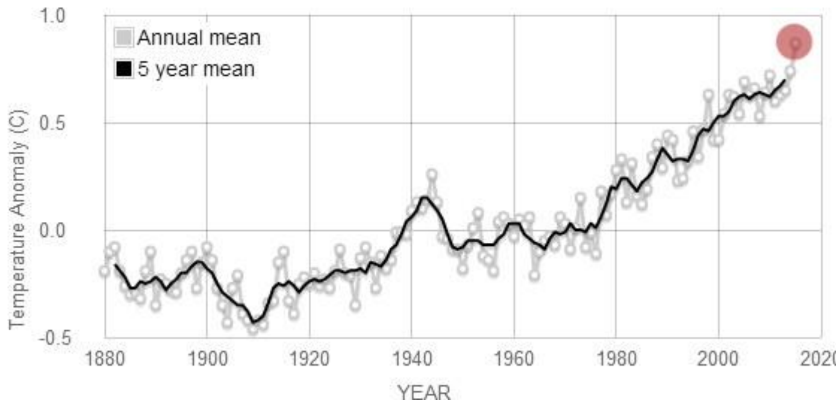
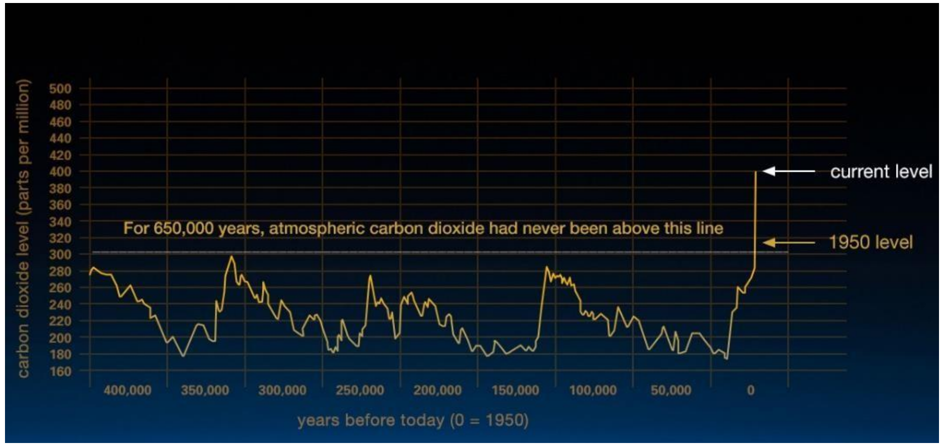
Introduction

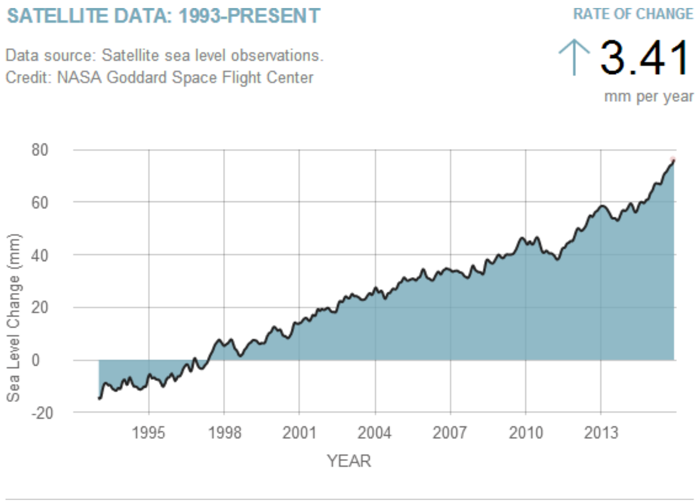
Temperature (source: NASA)



Greenhouse gas emissions (source: NASA)



Sea level change (source: NASA)



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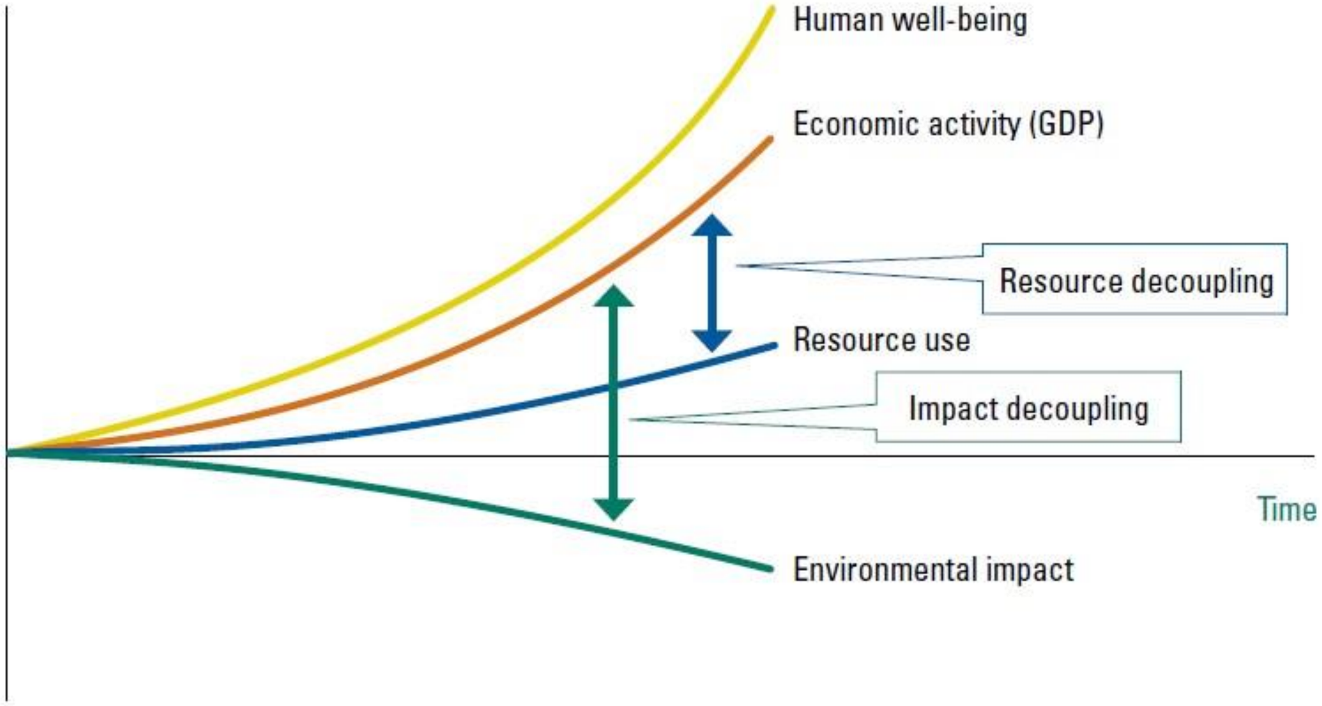
WOOD IN CIRCLE

Introduction

What can be done to "bend the trend"

Decoupling economic growth from natural resource use and environmental impacts: using less resources per unit of economic output and reducing the environmental impact of any resources that are used or economic activities that are undertaken



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Signs of a change

Sustainable mobility

Renewable energy technologies

Energy efficiency

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The way we consume has both direct and indirect impacts on the environment

The use of energy and materials in our homes and our dependence on cars are causing air pollution and increased emissions of greenhouse gases that lead to climate change. Also, we are creating more and more waste from household activities.

But in addition to those and other direct effects, consumption also indirectly leads to environmental impacts from the production, processing and transportation of the goods we consume.

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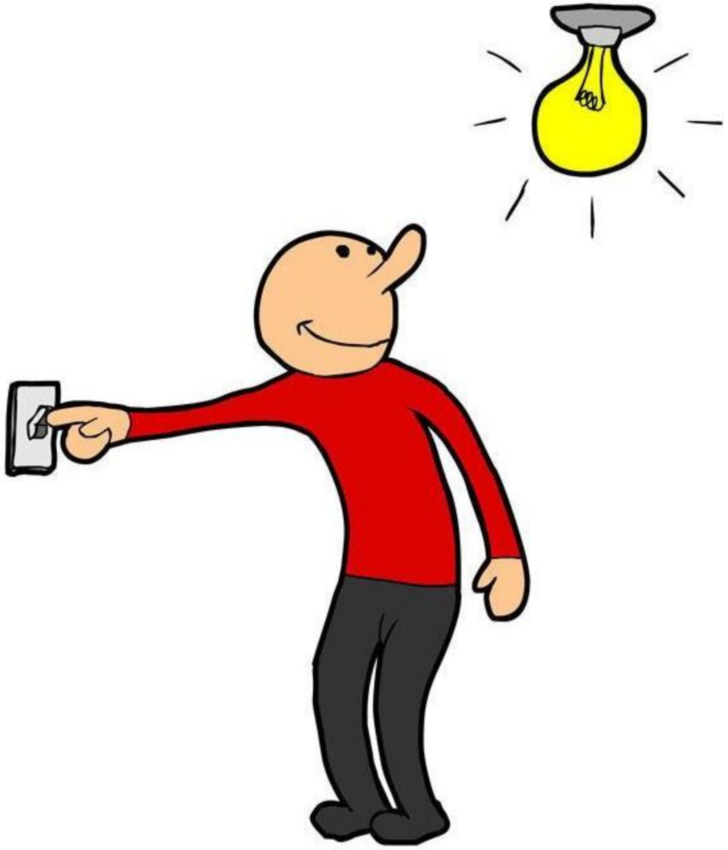
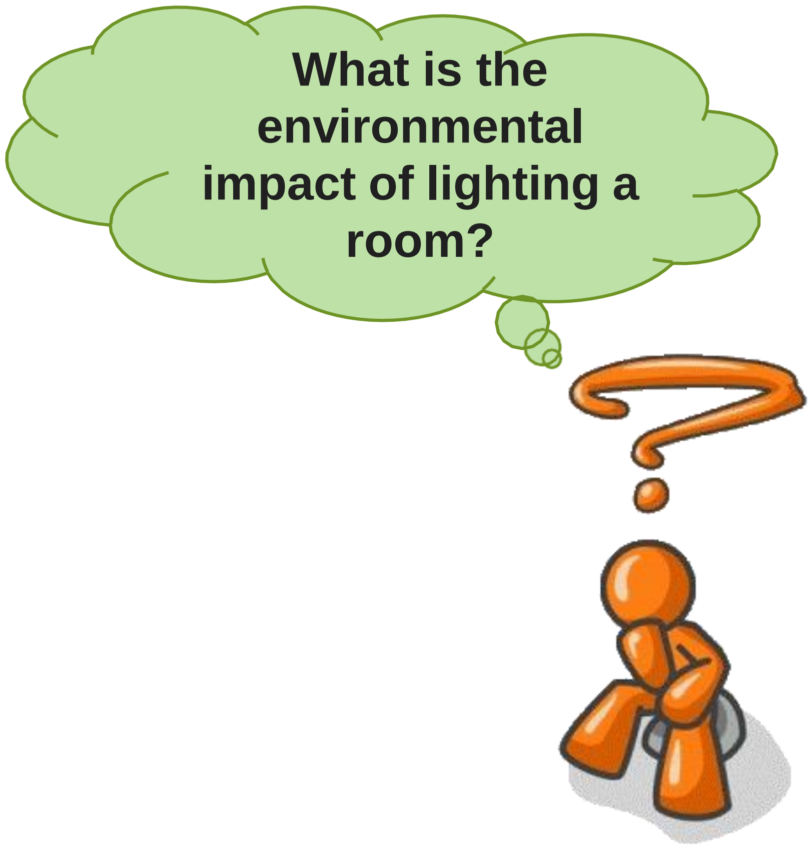
Direct and indirect environmental impacts





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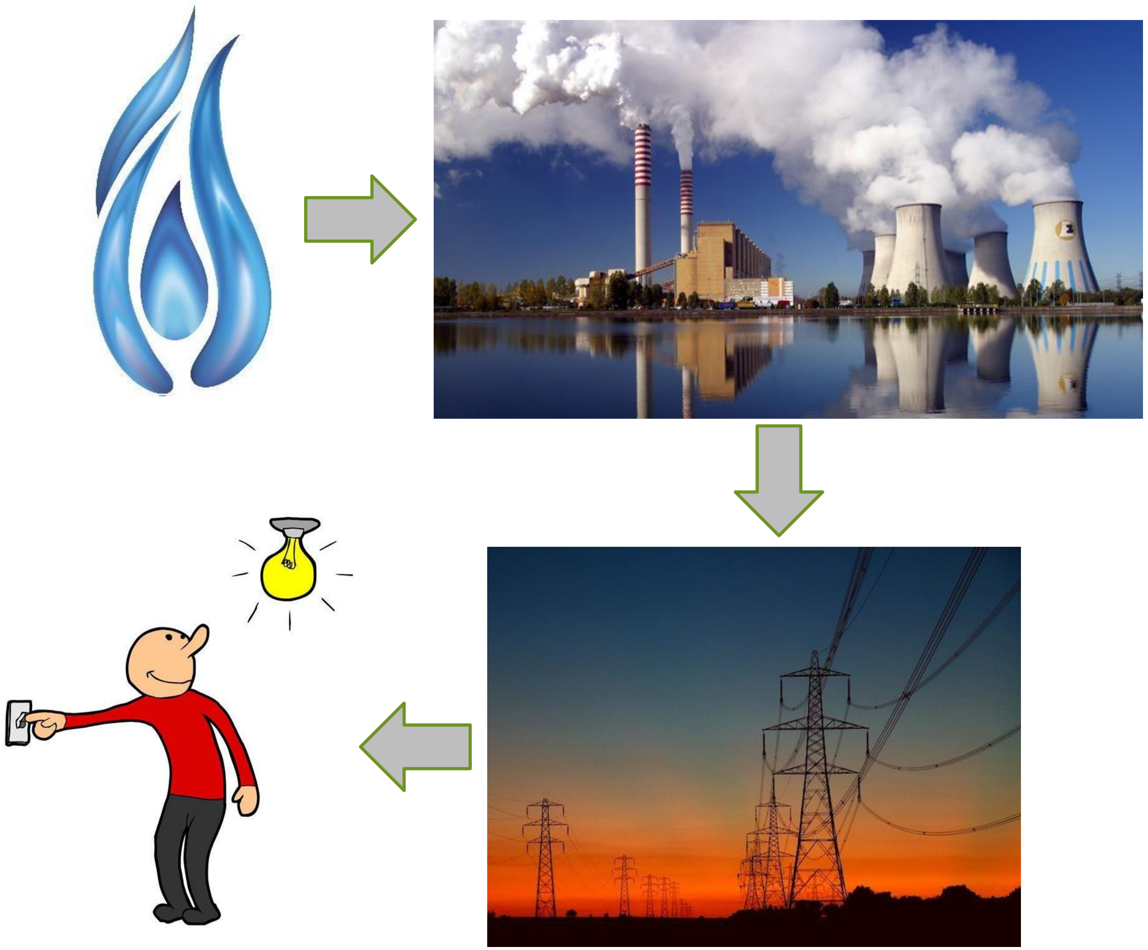
Direct and indirect environmental impacts



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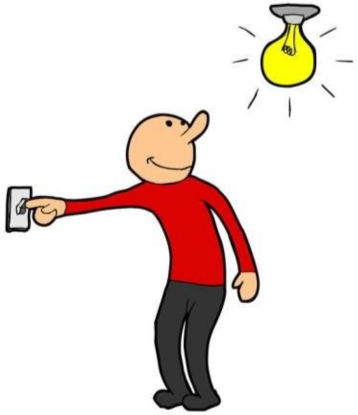
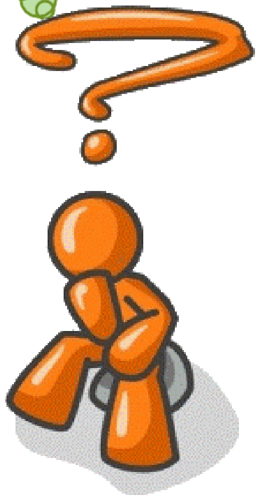
Direct and indirect environmental impacts



But … that's it?



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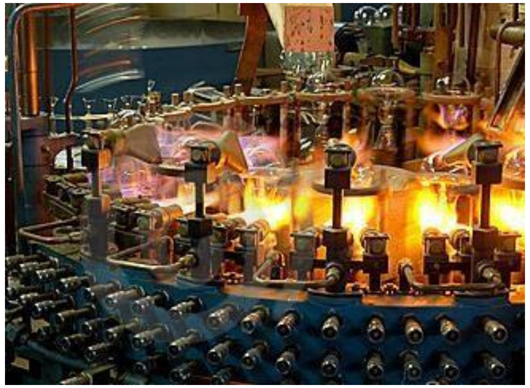
Direct and indirect environmental impacts



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WOOD IN CIRCLE

Direct and indirect environmental impacts

From a Linear Economy…

Lost value of materials and products

Scarcity of resources

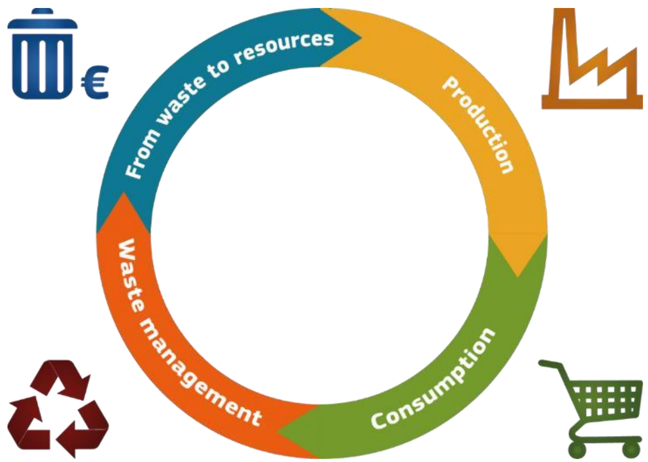
Volatile prices of resources

Waste generated

Unstable supply of raw materials

Environmental degradation & climate change

… to a Circular Economy



The circular economy is an economy where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized.

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The Life Cycle Assessment (LCA)

The Life Cycle Thinking

The LCA is a way of thinking, an approach to get an overview of the energy and environmental performances of products and services.

We talk about the LIFE CYCLE THINKING approach.

Life Cycle Thinking (LCT) goes beyond the traditional productive goals and includes environmental, social and economic impacts of a product over its entire life cycle.

The main goals of LCT are to reduce a products resource use and emissions to the environment as well as improve its socio-economic performance through its life cycle.

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The Life Cycle Assessment (LCA)

The Life Cycle Thinking

Environment
- Life Cycle Assessment (LCA)

Society
- Social LCA (S-LCA)

Economy
- Life Cycle Costing (LCC)

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The Life Cycle Assessment

The Life Cycle Assessment (LCA) is a *"compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (*Source: ISO 14040)

The LCA is an "objective procedure for assessing the energy and environmental loads related to a process or activity, carried out by identifying the energy and materials used and the waste released into the environment" (Source: SETAC)

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WOOD IN CIRCLE

The Life Cycle Assessment

Why the Life Cycle Assessment?

- **It prevents to move the problems from one life-cycle step to another;**

- **It prevents to move the problems from an impact category to another;**

- **It captures the complexity hidden behind a product;**

- **It is a useful tool to compare products and services on a scientific basis.**

LCA allows to have a global overview of the product throughout its life cycle, also including some impacts normally ignored or neglected (such as those related to the final disposal).

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The Life Cycle Assessment

Why the Life Cycle Assessment?

The LCA can assist in:

- identifying opportunities to improve the environmental performance of products at various points in their life cycle;

- informing decision-makers in industry, government or non-government organizations (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign);

- the selection of relevant indicators of environmental performance, including measurement techniques;

- marketing (e.g. implementing an ecolabelling scheme, making an environmental claim, or producing an environmental product declaration).

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The Life Cycle Assessment

One of the first studies (1969) was carried out by Coca Cola Company to establish the environmental consequences due to the production of different types of beverage containers in order to identify which material (plastic, glass or aluminum) and which strategy for use at the end of life of the container (disposable or returnable) was better from the environmental point of view.

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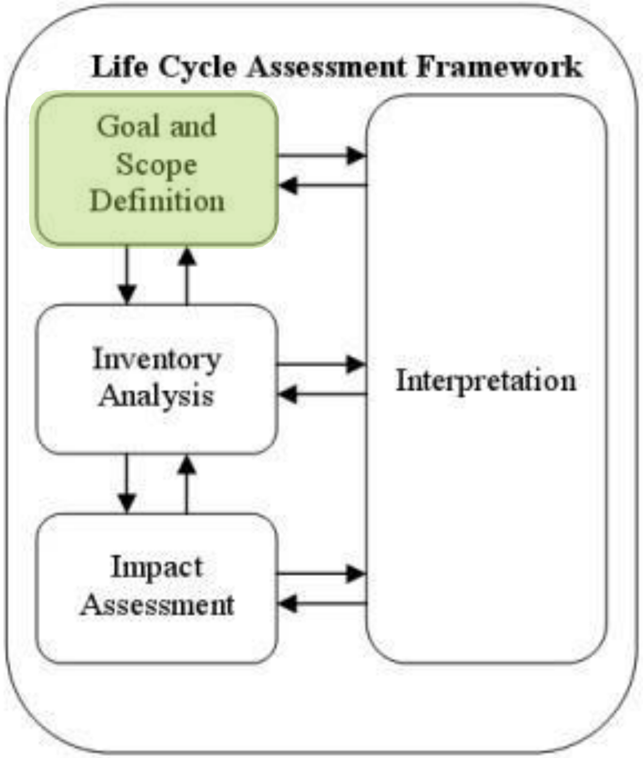
The Life Cycle Assessment

The Life Cycle Assessment Framework

There are four phases in a LCA study.

The scope, including the system boundary and level of detail, of an LCA depends on the subject and the intended use of the study. The depth and the breadth of LCA can differ considerably depending on the goal of a particular LCA.



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Goal and scope definition

The reasons for carrying out the study

- Which environmental problems can be attributed to a certain product/service?
- What are the processes and life-cycle steps that cause the higher environmental impacts of a product/service?
- What changes in environmental problems occur if option B is replaced by option A (i.e. use of different materials)?
- What are the environmental problems of choosing the product A rather than the product B for fulfilling a certain function?

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The Life Cycle Assessment

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The Life Cycle Assessment

The Life Cycle Assessment Framework

The scope includes the following items:

The function, the functional unit and the reference flow

A system may have a number of possible functions that have to be defined.

The functional unit is the "quantified performance of a product system for use as a reference unit".
It defines the quantification of the identified functions of the product.
The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results.

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The Life Cycle Assessment

Example: function, functional unit and reference flow

Products to be compared:

Air - dryer system

Paper towel

Function: drying hands.

Functional unit: number of pairs of hands dried, e.g. one pair of hand – dry (e.g. N.1 pair of hands).

Reference flow for the air – dryer system: volume of hot air required for one pair of hand-dry.

Reference flow for the paper towel: mass of paper required for one pair of hand-dry.

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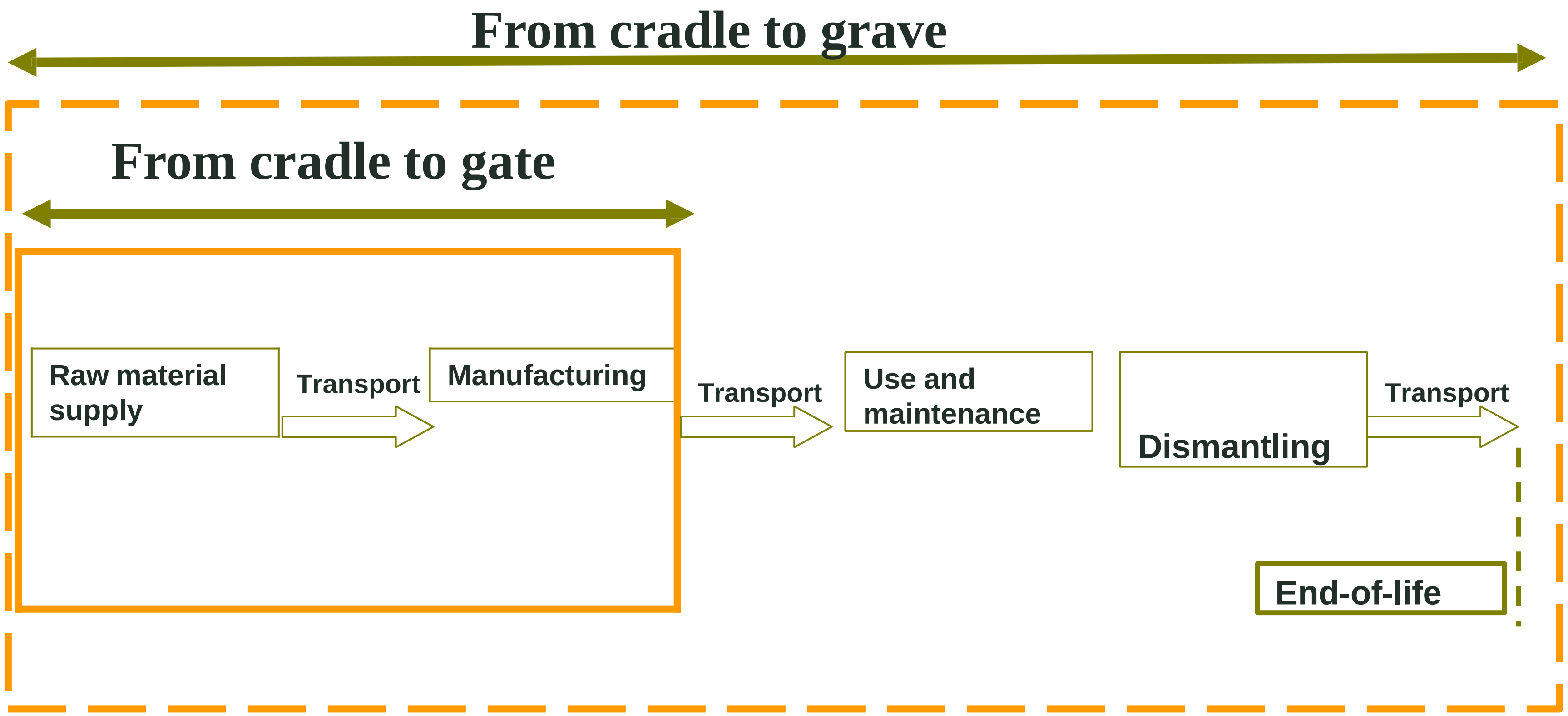
The Life Cycle Assessment

System boundaries



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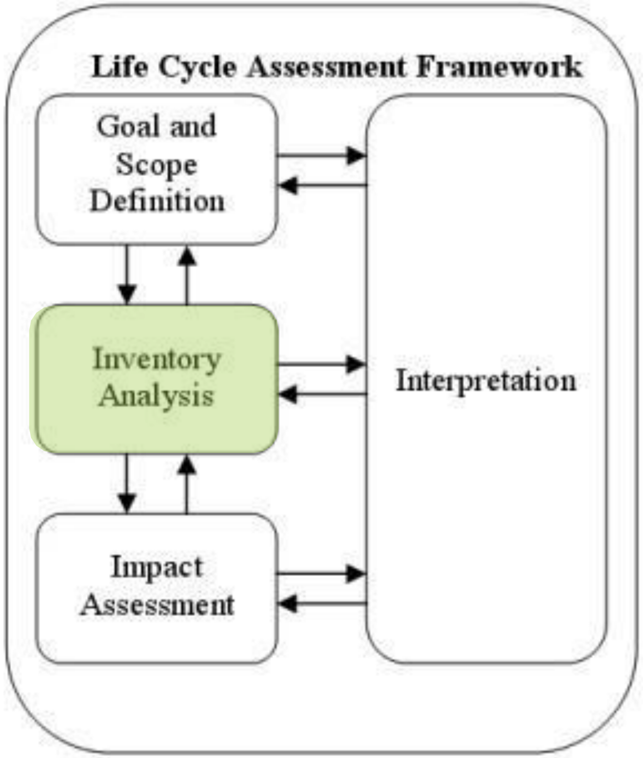
The Life Cycle Assessment

The Life Cycle Assessment Framework

There are four phases in a LCA study.

The life cycle inventory analysis phase (LCI phase) is the second phase of LCA. It is an inventory of input/output data with regard to the system being studied. It involves collection of the data necessary to meet the goals of the defined study.



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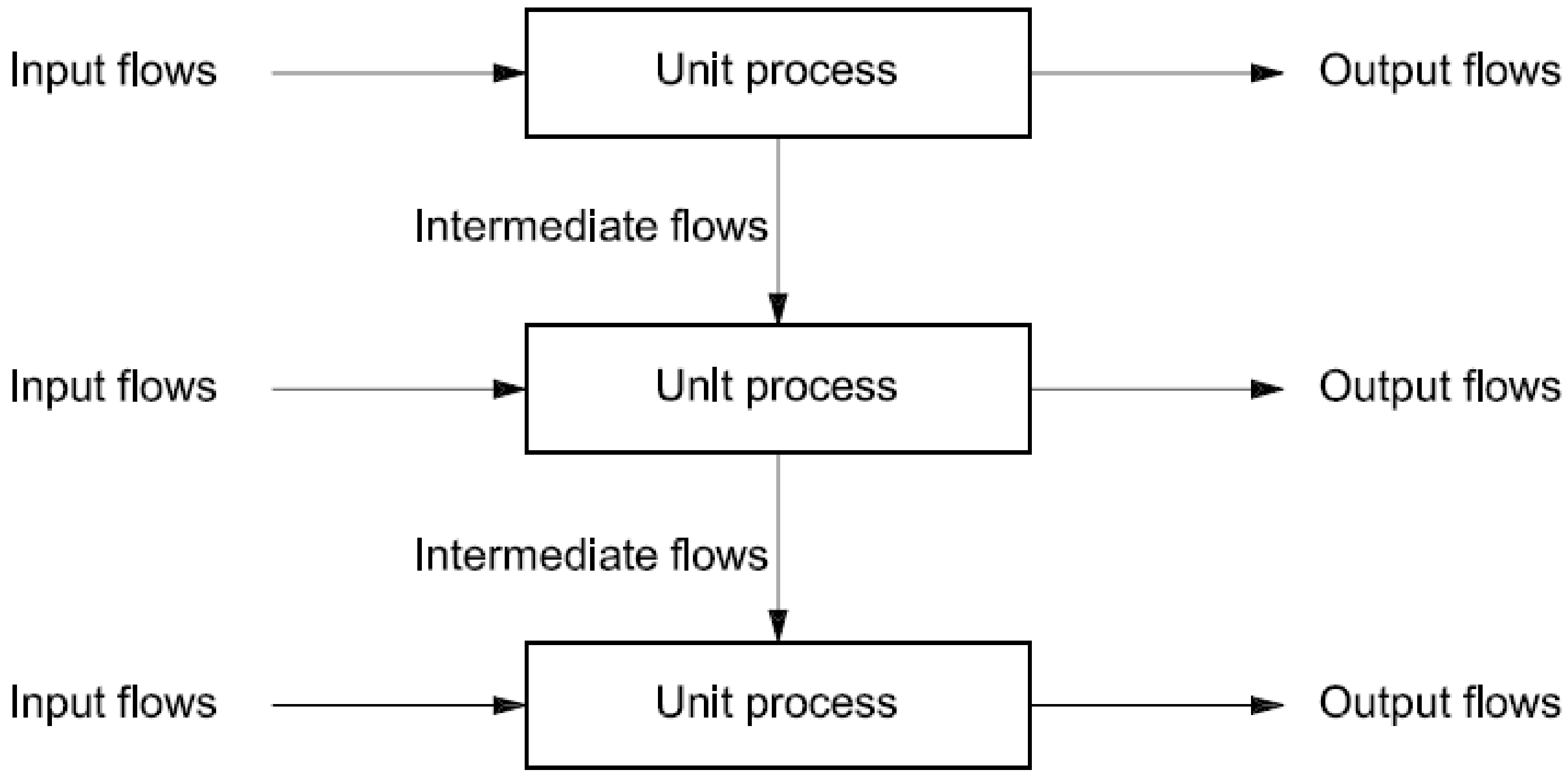

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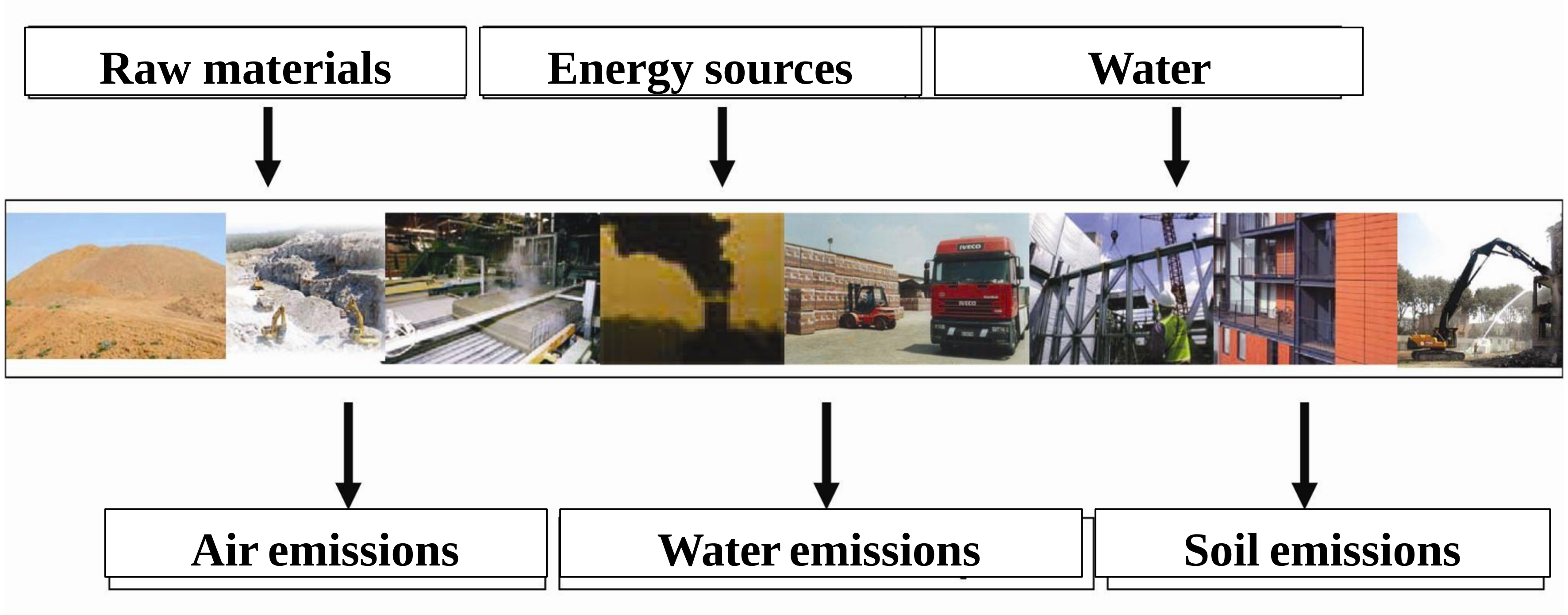
The Life Cycle Assessment

Input: raw materials (including water), energy sources

Output: waste, air emissions, water emissions, soil emissions



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The Life Cycle Assessment

Resources

- Electricity (location)
- Water (location & type)
- Fuel (in ground)
- Minerals (in ground)
- Biomass (harvested)
- Land use (area & location)

Wastes

- Solid waste
- Radioactive Waste (high, low, medium)
- Hazardous Waste

Air

- CO_2
- CO
- PM (10, 2.5)
- CH_4
- SO_X
- NO_X
- NH_3
- Hg
- Pb
- VOC (NM)
- Dioxin
- PAH's

Water

- COD
- TDS
- TSS
- BOD (5,7,10)
- Flow

ΔTemperature

- NH3 (as N)
- TKN (as N)
- NO3, NO2 (as N)
- PAH's
- Phosphates (as P)
- Cu
- Ni
- As
- Cd
- Cr
- Pb
- Hg

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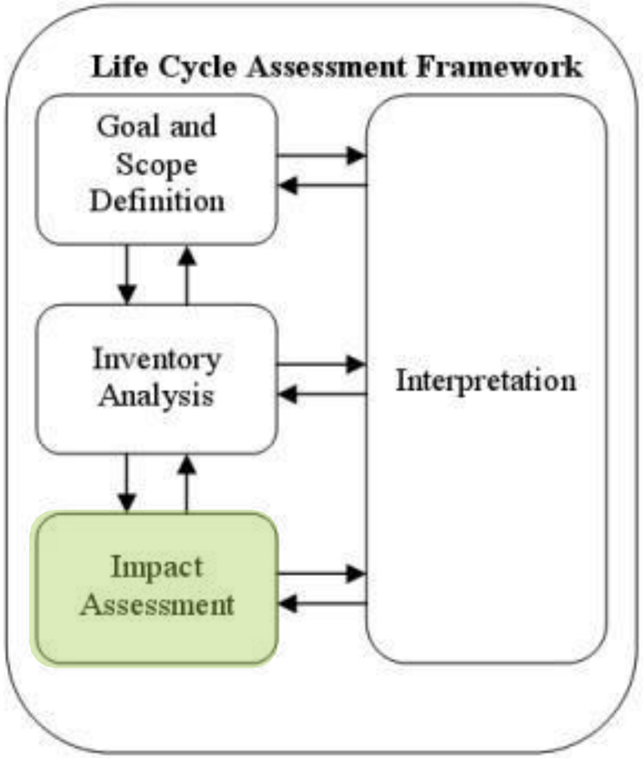
The Life Cycle Assessment

The Life Cycle Assessment Framework

There are four phases in a LCA study.

The life cycle impact assessment phase (LCIA) is the third phase of the LCA. The purpose of LCIA is to provide additional information to help assess a product system's LCI results so as to better understand their environmental significance.



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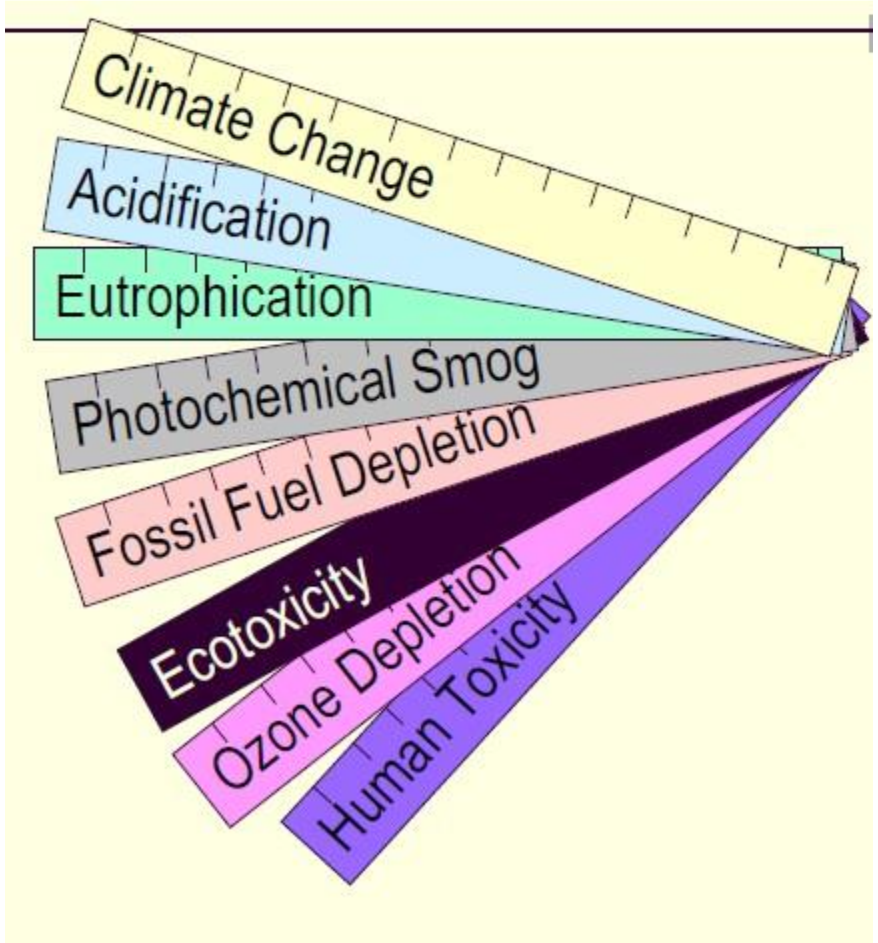
The Life Cycle Assessment

Some impact category indicators



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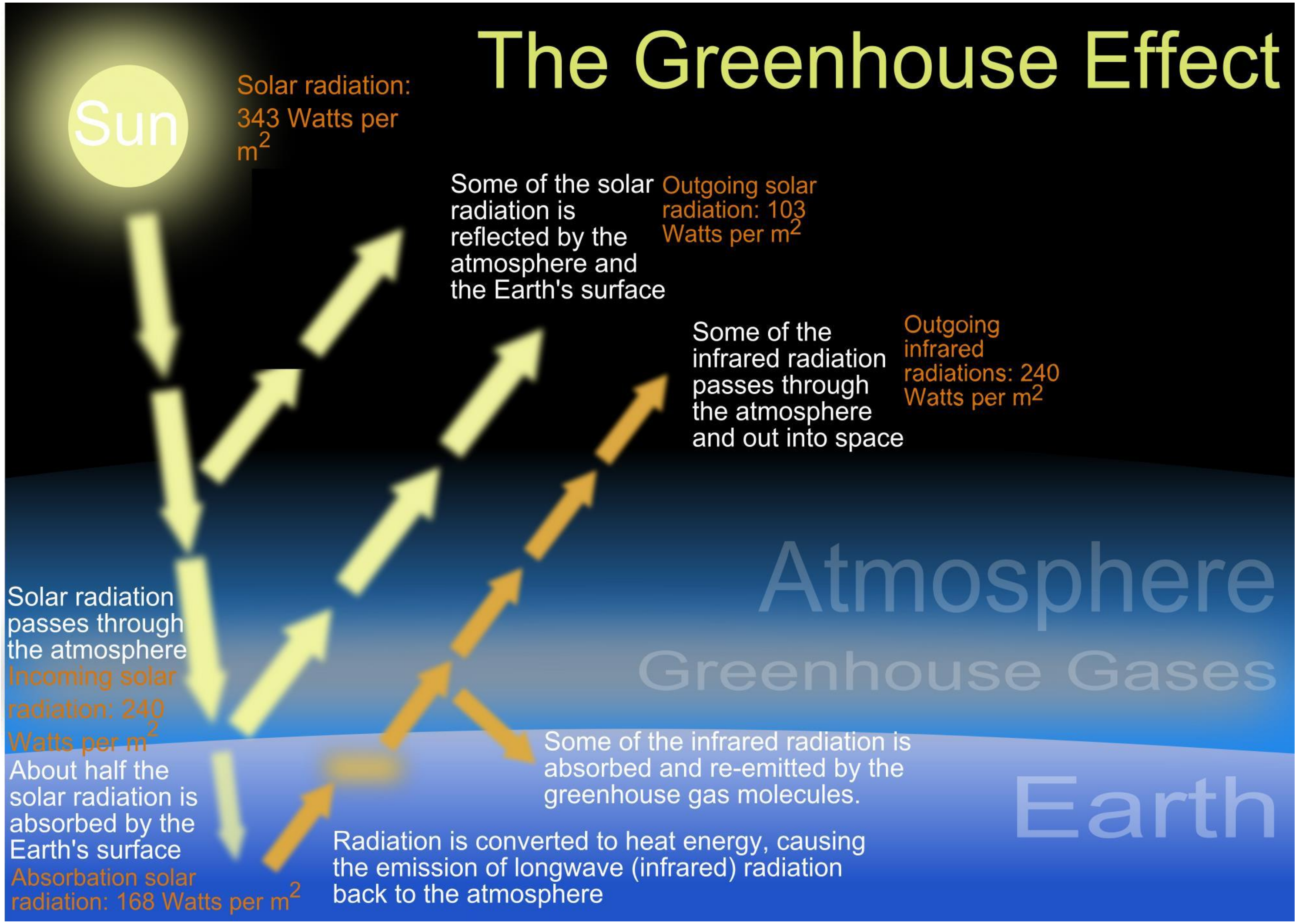

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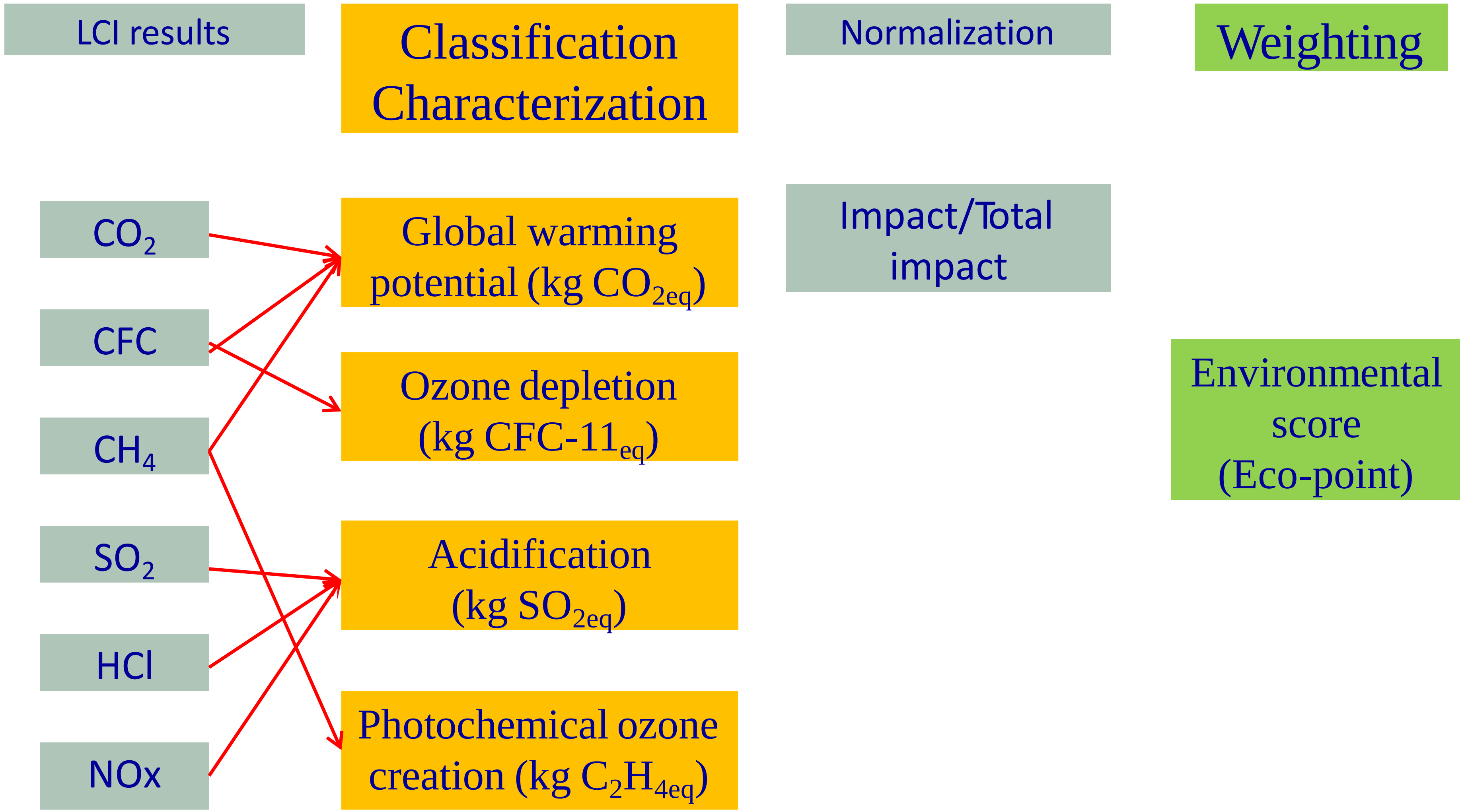
The Life Cycle Assessment



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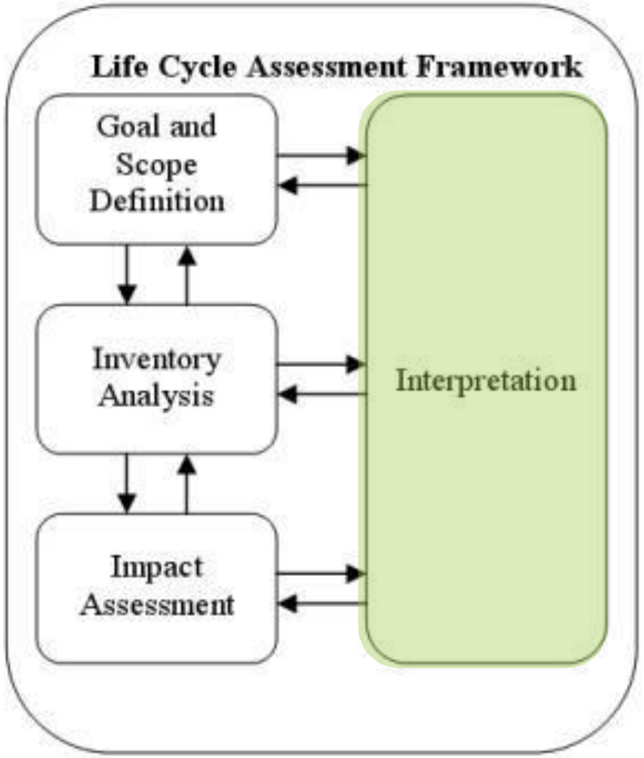
The Life Cycle Assessment

The Life Cycle Assessment Framework

There are four phases in a LCA study.

Life cycle interpretation is the final phase of the LCA procedure, in which the results of an LCI and/or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.



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The building sector …

- … is the main responsible of electricity consumption and, next transport, of fuel consumption.

- At global level, it accounts for 35 to 40% of final energy consumption and contributes to around a third of CO_2 emissions.

- … needs to improve energy efficiency, to reduce energy consumption, to increase the use of renewable energy technologies.

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The Life Cycle Assessment

The key tool to calculate the environmental performance of a building as well as a product or service is the

Life Cycle Assessment (LCA)

'Sustainable buildings' can be defined as those that use resources more efficiently and cause less environmental damage along their life cycle, from the extraction of raw materials, to their production, distribution, use, up to the end of life (including reuse, recycling and recovery) compared to other similar buildings.

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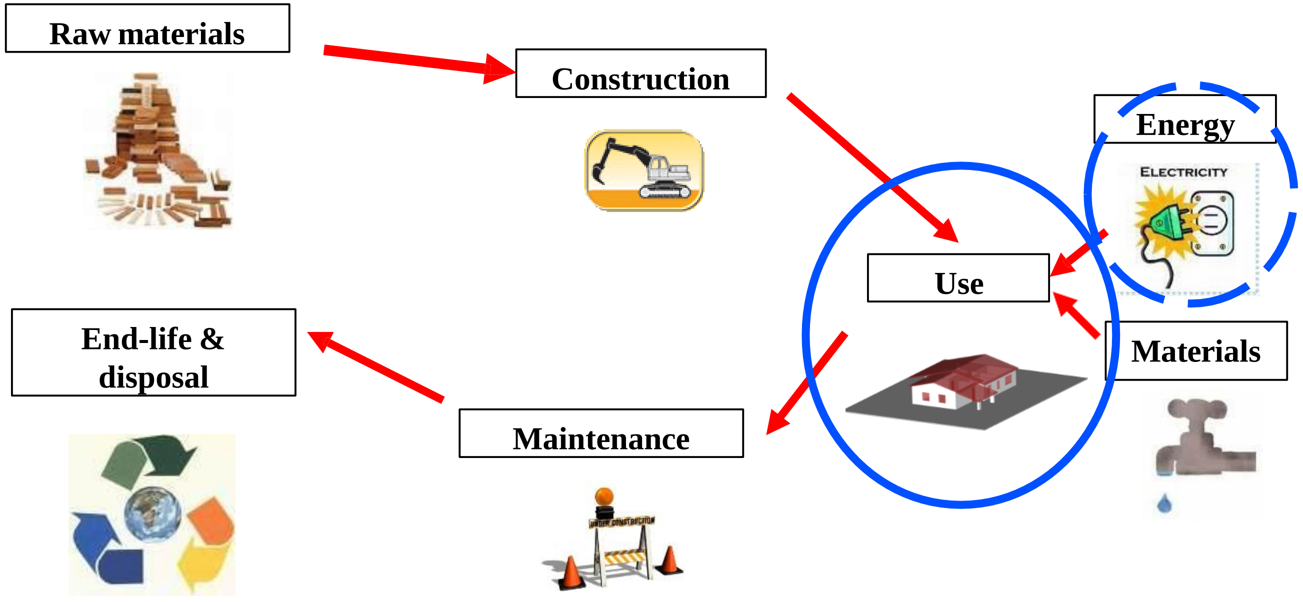
The Life Cycle Assessment

Life Cycle Approach: buildings



❖**Full cycle** should be considered in order to have a global "view" of the building performances

❖Normally analysis are restricted to the use phase, and mostly only on the energy consumption assessment

EMBODIED ENERGY AND EMBODIED IMPACTS

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LCA of building: Case Study

Main aims of the LCA study were:

- to evaluate the global environmental impacts of a single-family house
- to assess peculiarities of houses into the Mediterranean area (mostly the available references are related to North and Central Europe case studies)
- to identify components that are responsible of the largest impacts (key issues)
- to assess the incidence of each life-cycle step and, in particular, of steps generally not adequately investigated (incidence on the global environmental balance of construction materials, maintenance, transports, etc.)
- to focus the attention on components that are responsible of significant impacts in a prospective of an environmental design of the building

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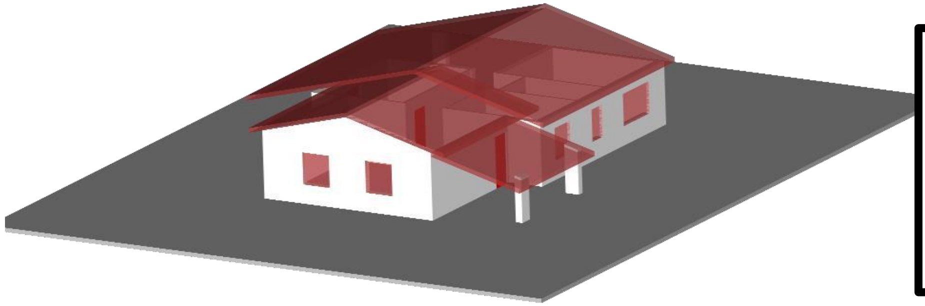
WOOD IN CIRCLE

LCA of building: Case Study

Application of the LCA methodology to an exemplary construction: an Italian case study

The case-study house can be considered as a representative Italian construction of the Mediterranean area.



The house (108 m^2) is located in Palermo (Sicily) at 270 m. above the sea level, and is occupied by three people.

The site is characterized by:

- ✓ a temperate climate, with mild winters and hot summers;
- ✓ no neighboring constructions that modify the direct sun radiation of the building;
- ✓ a typical residential area.

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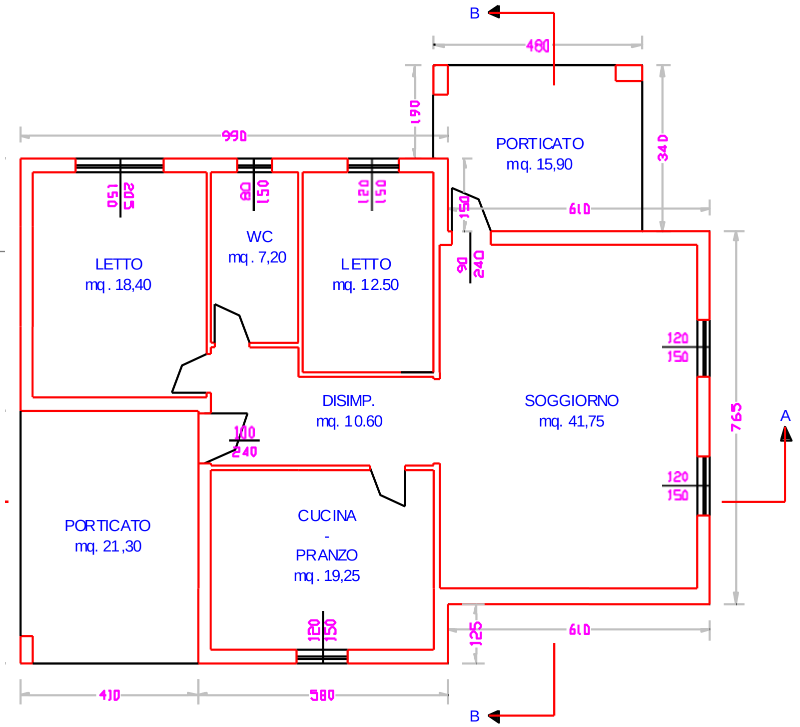
LCA of building: Case Study

The LCA of a building have been developed according to the following scheme:

1. **Analysis of design plants**: collection of structural information and calculation and assessment of the quantity of used construction materials;

Qualitative and quantitative analysis of building components including the main construction materials and the main equipments

Technical documents, planimetry and structural data of case study building were analyzed.



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LCA of building: Case Study

The LCA of a building have been developed according to the following scheme:

2. **Analysis of building components:** technical sheet of building components have been analysed in order to detail their composition and performances;

Material	Unit	
Concrete	[10^3 kg]	276,5
Clay bricks	[10^3 kg]	33,0
Roof tiles	[10^3 kg]	13,6
Ceramic tiles	[10^3 kg]	6,5
Plaster	[10^3 kg]	4,7
Wood boards	[10^3 kg]	4,6
Steel	[10^3 kg]	4,0
Composite membrane	[10^3 kg]	1,0
Galvanized steel	[10 kg]	221
Sanitary ceramics	[10 kg]	151
Glass	[10 kg]	115
PVC	[10 kg]	23
Copper wires	[10 kg]	10

3. **Reference survey:** LCA databases have been consulted in order to acquire information regarding the eco-profile of construction materials, components and plants;

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LCA of building: Case Study

4. **Inventory of construction phase:** A similar single-family house in construction has been studied, in order to estimate the main impacts due to construction machines and transports;

Reference analysis to collect information regarding the construction materials and plant's components.

It was submitted a questionnaire at the builders considering:
materials,
construction machinery,
dump site,
demolition,
transports,
etc.

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LCA of building: Case Study

5. Use phase:

Detailed analysis of the use phase, computing the yearly energy employed for lighting, air conditioning, sanitary water heating, food cooking, etc.;

Questionario delle abitudini

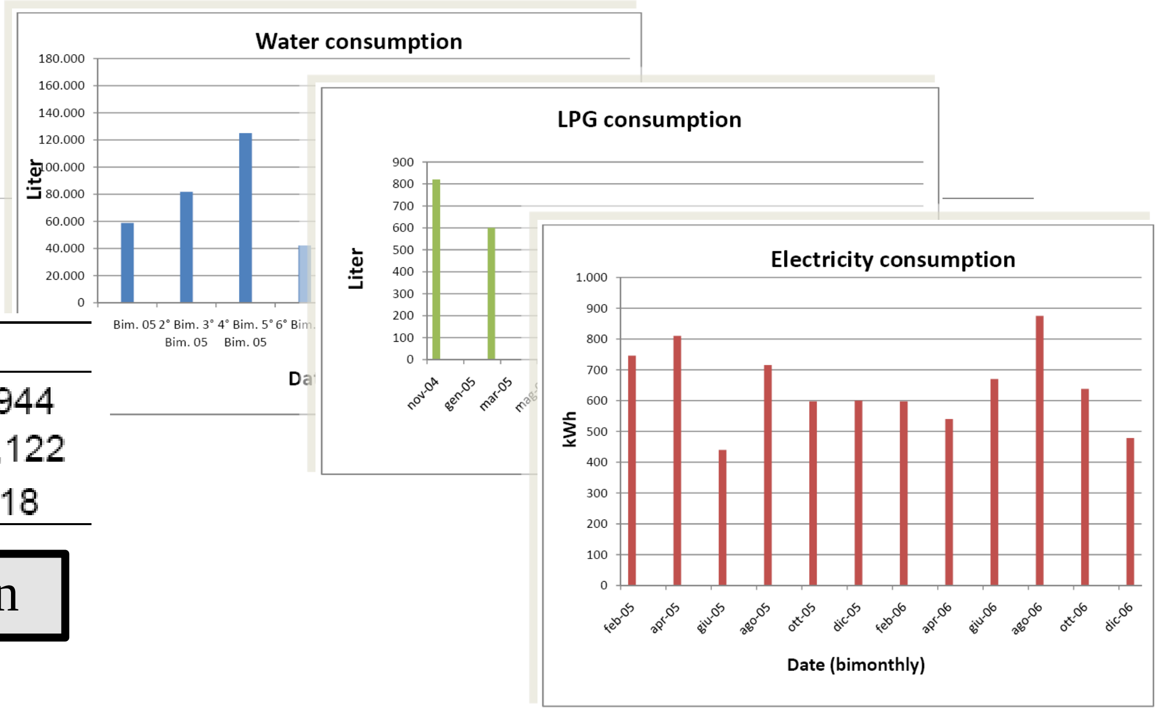
1. Può indicare qual'è la "potenza impegnata" prevista … energia elettrica?

-1,5 kW	☐
-3,0 kW	■
-4,5 kW	☐
-6,0 kW	☐
-10,0 kW	☐
-Oltre 10,0 kW	☐
-Non so	☐

It was submitted a questionnaire about a survey of habits of the house's family on use of equipments and appliances

Consumption	Unit	
Electricity	[kWh]	3,944
LPG	[MJ]	22,122
Water	[m^3]	318

Average annual consumption



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LCA of building: Case Study

6. Maintenance:

Analysis of maintenance operations. We refer to experiences of previous buildings and to local and national statistics

7. Demolition and Disposal:

It include the energy and the environmental impacts related to the building demolition and the final waste disposal or recovery

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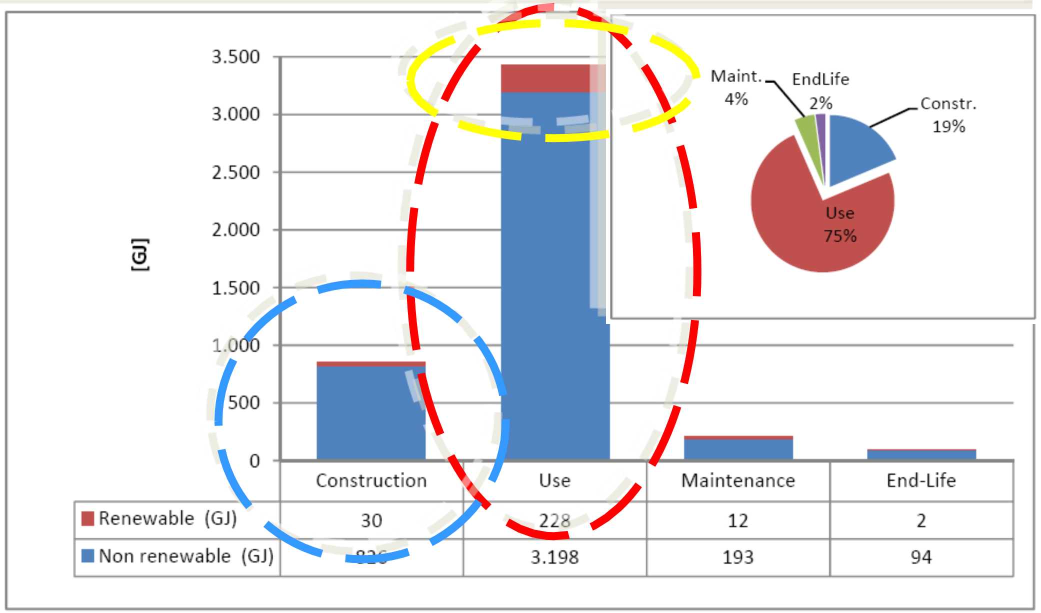
LCA of building: Case Study

The GER amounts to about **4.58** $\cdot 10^3$ GJ of primary energy.

Yearly specific consumption per unit of area is **0.63** GJ/(m² year) less than half of other European referenced value (*1.50* GJ/(m² year).

Use phase is responsible of 75 %of the GER;



The incidence of the construction phase is considerable, moving about 20% of GER, while the other phases are responsible of about 6% of the GER.

The GER consumption is mostly represented by non renewable energy sources. Small quantity of renewable energy are related to the use of electricity, following Italian power energy generation mix.

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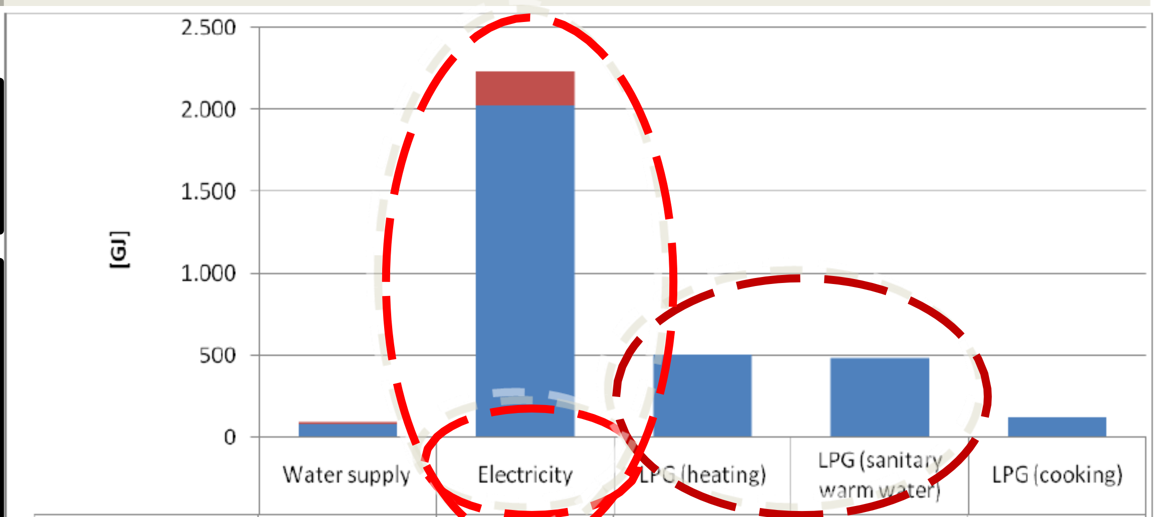
Detail of energy life-cycle consumption during the use phase

It is possible to observe that:

The largest impacts are due to the use of electricity.

The use of electricity is dominant, followed by the use of LPG for heating, hot water demand and cooking.



	Water supply	Electricity	LPG (heating)	LPG (sanitary warm water)	LPG (cooking)
Renewable (GJ)	19	209	0	0	0
Non renewable (GJ)	73	2.029	500	478	118

The consumptions for the winter heating and for the sanitary hot water production are almost the same.

From a more detailed analysis, it was assessed that the energy consumption for **summer air conditioning is about 20%** of global summer electricity input, corresponding to about *7%* of the yearly consumption, as about 157 GJ of primary energy consumption during the life-cycle of the building. This low consumption is also related to energy-saving habits of occupants.

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WOOD IN CIRCLE

LCA of building: Case Study

The energy and the environmental impacts have been assessed on the basis of declaration scheme and characterization factors utilized in the Environmental Product Declaration system:

Data regarding each life cycle step have to be processed in order to obtain global environmental indexes that synthesize the environmental performances.

Life Cycle Impacts

Impact Category		Total
Global Warming Potential (GWP)	[kg $CO_{2\ eq}$]	327.406
Ozone Depletion Potential (ODP)	[kg $CFC_{11\ eq}$]	0,05
Photochemical Ozone Creation Potential (POCP)	[kg C_2H_4]	68
Acidification Potential (AP)	[kg $SO_{2\ eq}$]	1.551
Nutrification Potential (NP)	[kg $PO_{4---\ eq}$]	145

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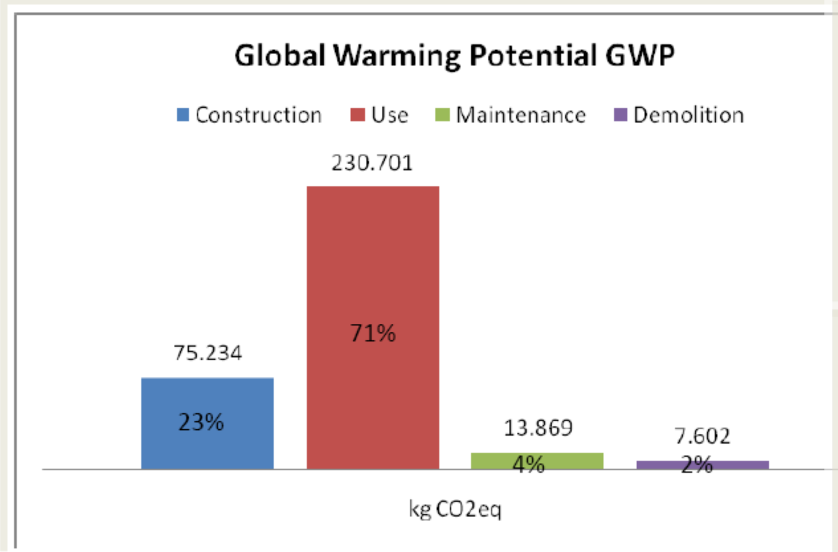
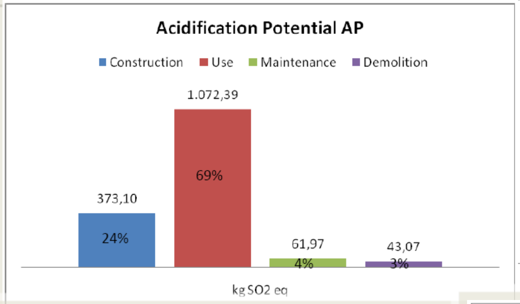
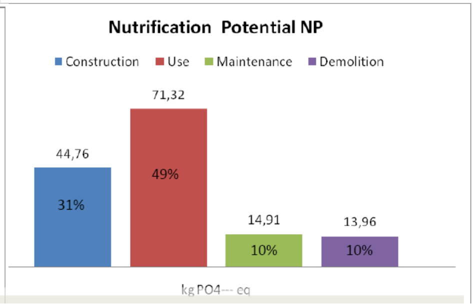
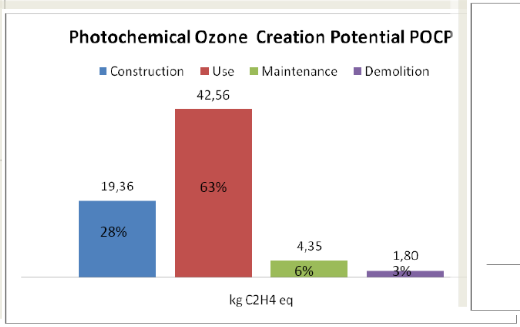
LCA of building: Case Study

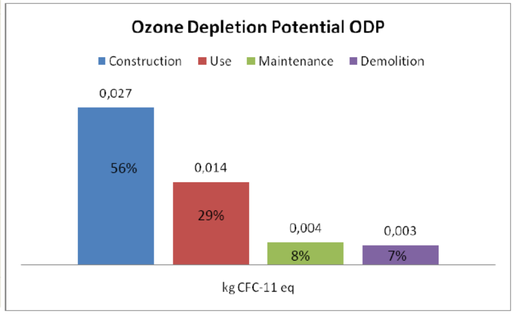
Use is the phase that causes the largest impacts. It is responsible, for each environmental index, of about 50-70% of the global impacts;











Concerning ODP, the highest incidence is related to the production and transport of construction materials;

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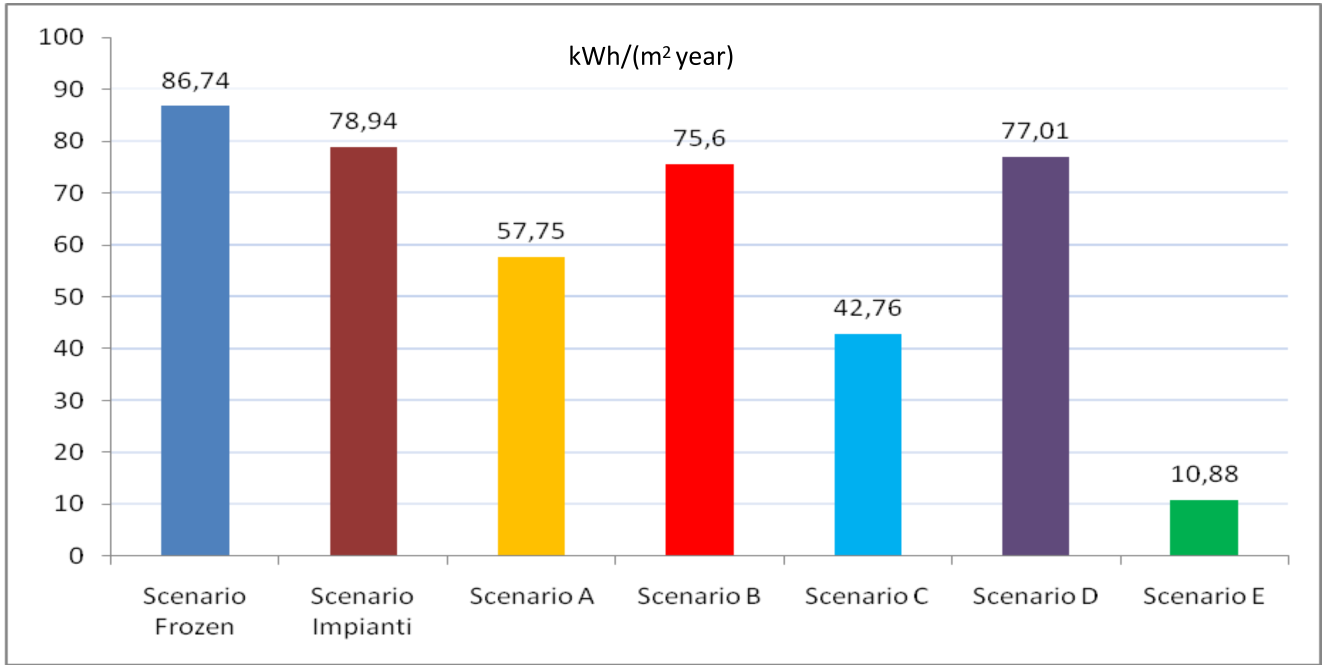
WOOD IN CIRCLE

LCA of Retrofit

The aim of the study is to evaluate and quantify the energy and environmental impacts of retrofit, in reference to the following scenarios and functional units:

- **Scenario A** Insulation of walls (224 m²) with panels of expanded polystyrene (EPS);
- **Scenario B** Insulation of roof (142 m²) by rock wool panels;
- **Scenario C** Insulation of floor (109 m²) with extruded polystyrene insulation boards;
- **Scenario D** Insulation of glass (11,5 m²) with PE films.



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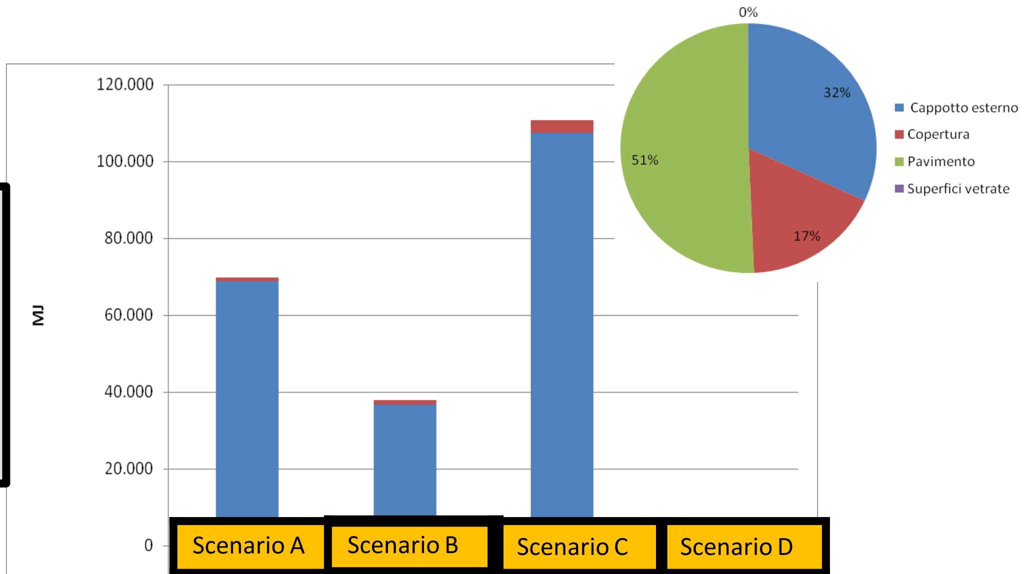
WOOD IN CIRCLE

Comparison of energy impacts

The implementation of all retrofitting scenarios involves a total consumption of primary energy of 218,591 MJ of which only 2.5% from renewable energy sources



	Scenario A	Scenario B	Scenario C	Scenario D
Rinnovabile	958,95	1.206,04	3.332,97	0,68
Non rinnovabile	68.808,67	36.827,62	107.332,99	123,42

The insulation of the floor (Scenario C) is the intervention with greater impact; energy consumption amounted to 110,666 MJ of energy, equivalent to 50.63% of the total energy used for all interventions.

The consumption of electricity for retrofit and raw material transport, are negligible compared to their production.

The second intervention most impactful is insulation of walls (Scenario A) with 69,767 MJ of energy consumed (equal to 31.92%) followed by cenario B - insulation of roof (38,033MJ of total energy equal to 17.40%). Application of film on glass surfaces is negligible.

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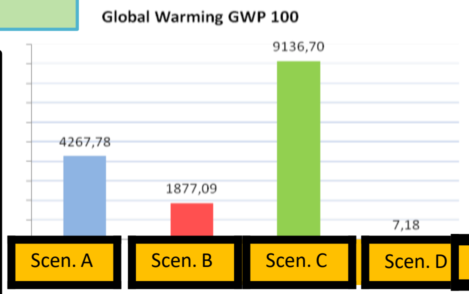
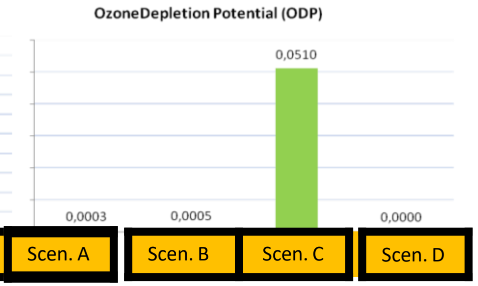
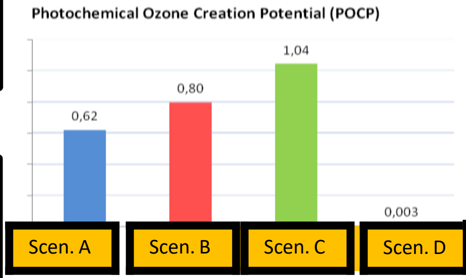
WOOD IN CIRCLE

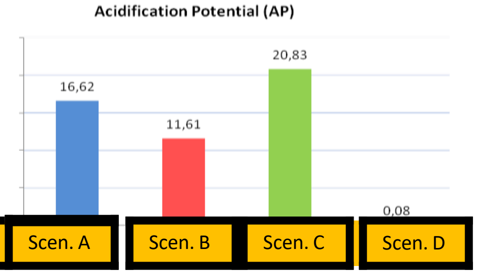
LCA Retrofitting: Environmental impact analysis

The floor insulation is the intervention of retrofitting with higher environmental impacts for all impact categories considered. For all indicators contributes over 40% of the overall impacts.

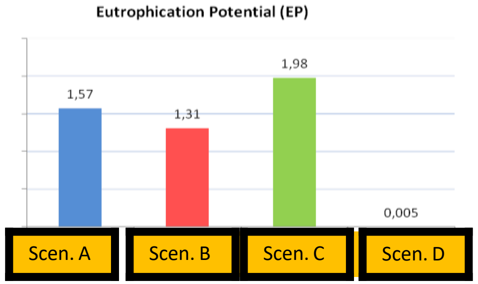








In reference to the ODP, the impacts are negligible with the exception of the insulation of floor, responsible of 99% of the emission of ozone gas.



The isolation of walls and roof are comparable for all indicators considered, (between 25-35% for different impact categories).

The isolation of the glass surfaces, for all impact categories considered closer to 0% except for GWP.

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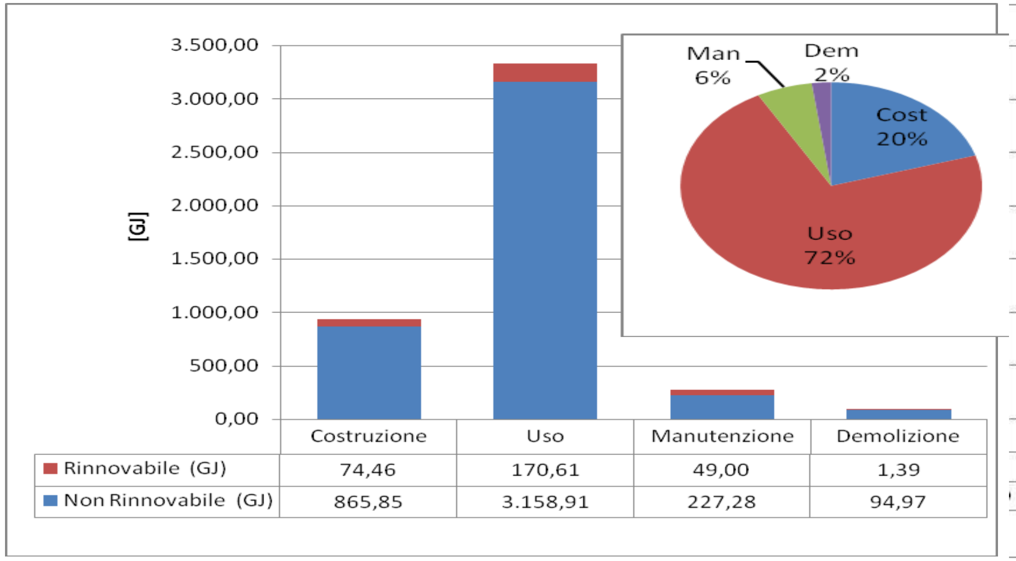
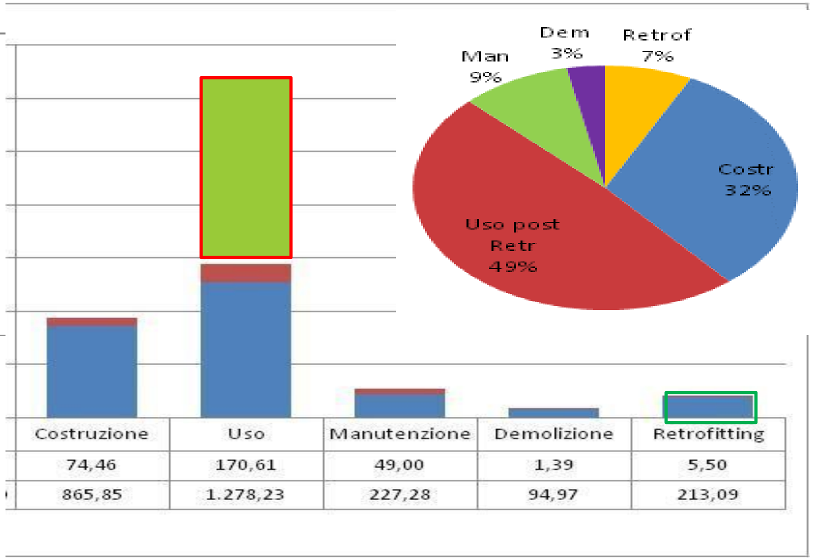
Ecoprofile of building

ECOPROFILE of Building Pre-Retrofitting



ECOPROFILE of Building Post-Retrofitting



The energy consumed for the retrofitting of approximately 218.6 GJ, (6%) is greater than that used for demolition and comparable to that for the maintenance of the building (respectively 96 and 276 GJ)

Even the scenario post-retrofitting the use phase is the most energy-consuming(approximately 49% of total consumption), but less significant than in thepre-retrofitting Scenario (72% of the total). The implementation of retrofitting leads to a reduction in the consumption of this stage of 56.5%

The construction phase represents approximately 32% of total consumption making it more significant than the Ecoprofile of building at Pre-retrofitting.

The specific energy consumption per unit area of the building (as a result of this reduction in Use phase) increased from 0.85 to 0.54 GJ / (m^2 year) with significant improvement Ecoprofile of building.

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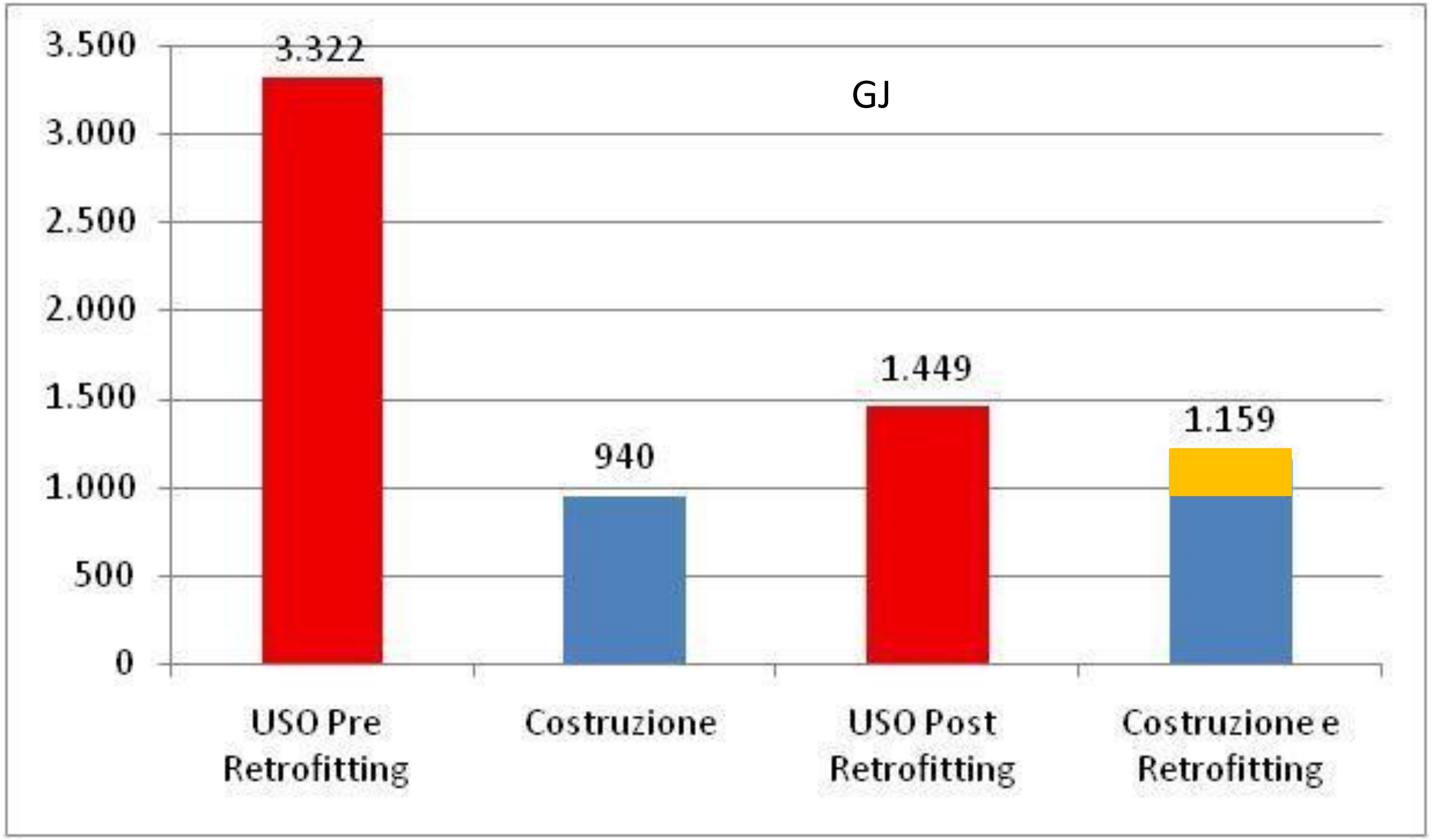
WOOD IN CIRCLE

Comparison of Life Cycle Phases of the building



Comparison between the phase "Use" and "Construction" for the scenarios pre-and post-Retrofitting

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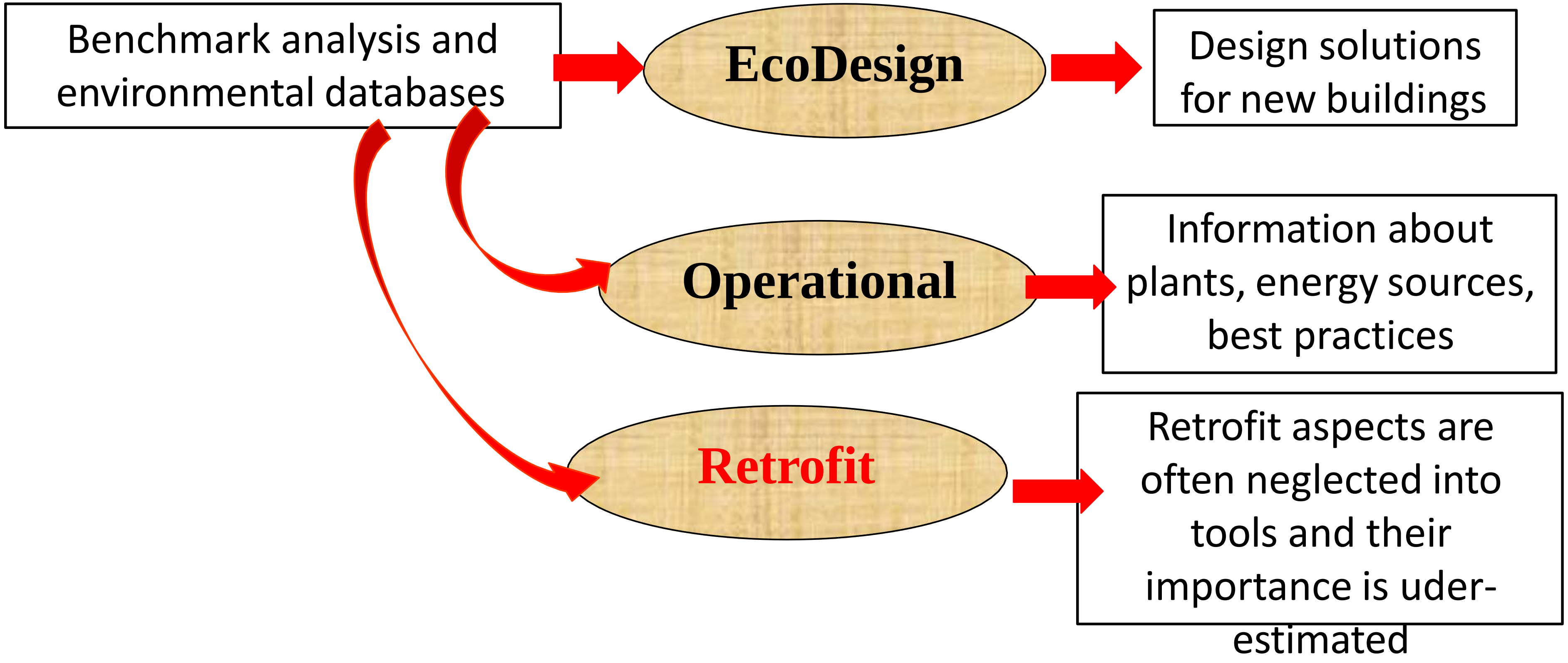
LCA of building: Building Management

It is fundamental furthermore the relationship among life-cycle evaluations and building management



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WOOD IN CIRCLE

Embodied energy vs operation energy

Embodied energy a key issues to assess the energy demand of low energy buildings

- Design of low energy buildings addresses the target of reducing the operating energy, by improving the thermal insulation of the building envelope, reducing infiltration losses, recovering heat from ventilation air and/or waste water, installing renewable energy technologies for heating, domestic hot water and electricity generation. However, the reduction of the operating energy demand involves an increase in embodied energy of the building due to energy intensive materials used in the building shell and technical equipment.

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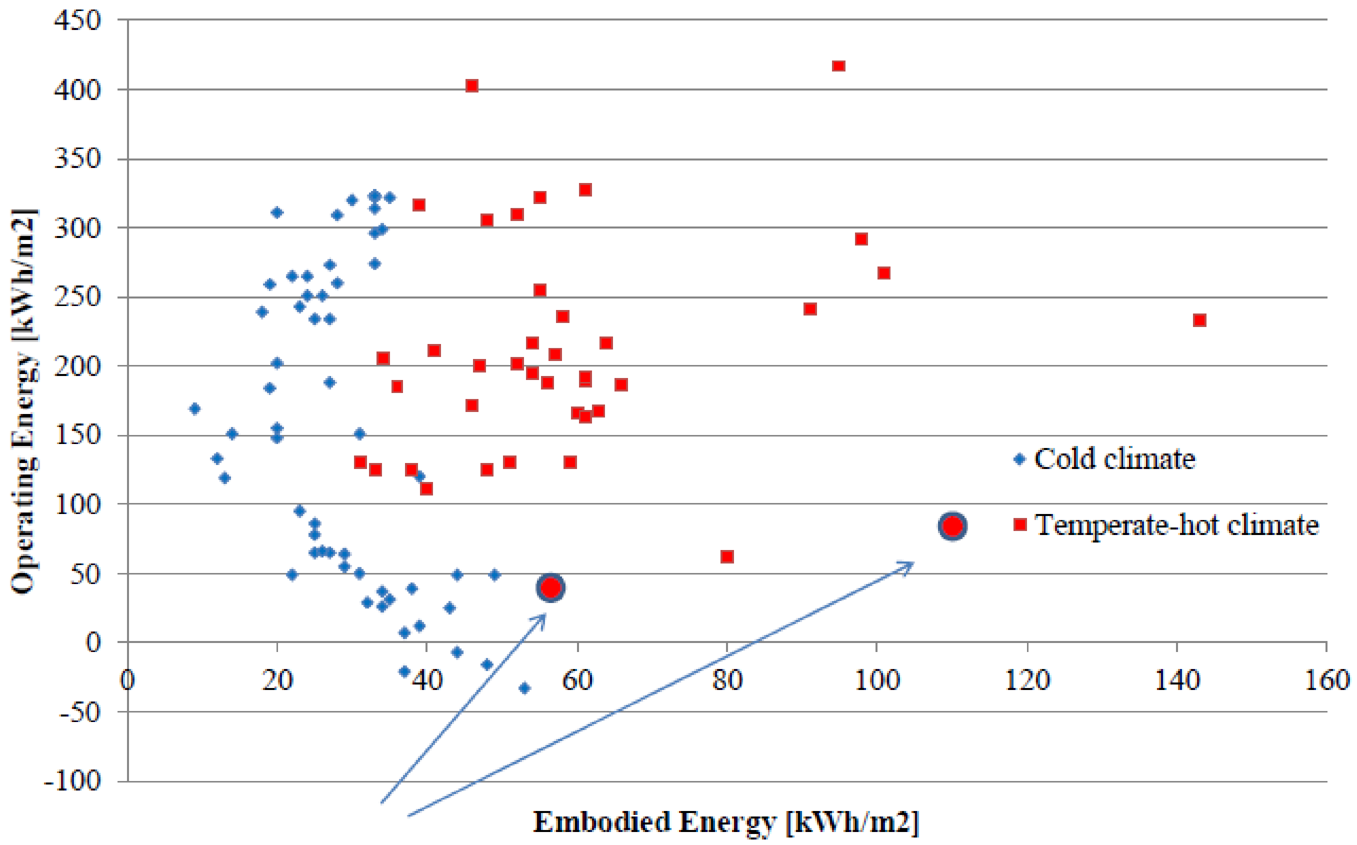
Embodied energy vs operation energy

The definition of low-energy building strictly depends on climate, country, indoor climate and the user behaviour, which affects the energy consumption in each end-use.



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WOOD IN CIRCLE

Embodied energy vs operation energy

Embodied energy a key issues to assess the energy demand of low energy buildings

- When shifting from standard houses to low energy buildings and to Net ZEBs the relative share of operating energy decreases, while the relative share of embodied energy increases.

- Therefore, the lower the operating energy, the more important it is to adopt a life cycle approach to compare the energy savings achieved in the building operation with respect to the overall life-cycle energy consumption

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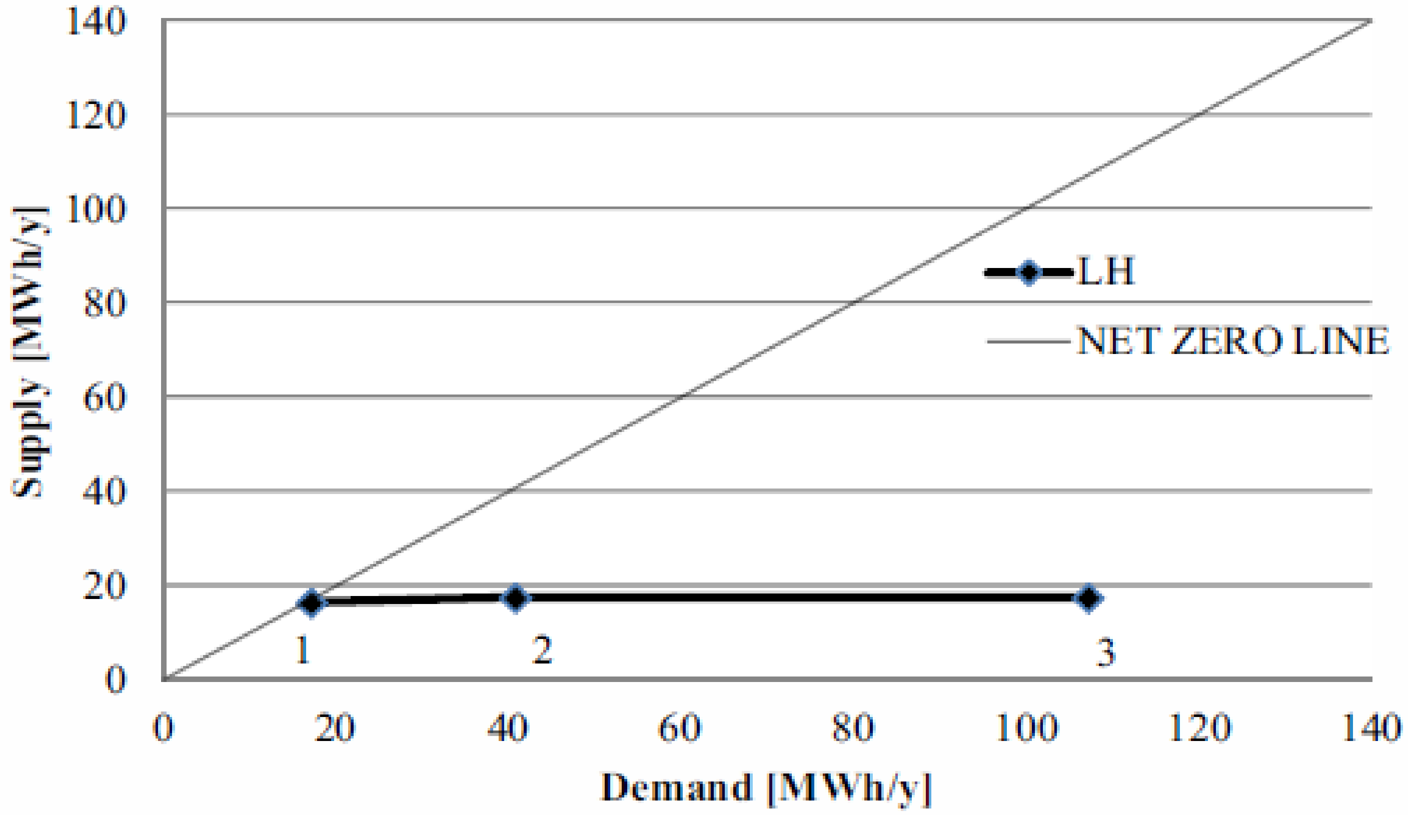
A case study: Net ZEBs & Life Cycle



Final energy (1), primary energy (2), and LCE Net ZEB balances.

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THANK YOU FOR YOUR ATTENTION

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