# D6.2 Technologies benefit impact in terms of emissions

## WP6, T6.1

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# Technical references

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| **Project Title** | **H**e**A**t **P**um**P**s in existing multi-family buildings for achieving union's **EN**ergy and envIro**N**mental **G**oals |
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# Figures

# Versions

| No. | Name SURNAME | Partner | Contribution | Date |
|---|---|---|---|---|
| **0.1** | Patxi HERNANDEZ<br>Irantzu URKOLA | TECNALIA | Definition of the ToC | 2021/11/25 |
| **0.2** | Beatriz SANCHEZ | TECNALIA | Definition of the scope of each chapter | 2022/01/27 |
| **0.3** | Beatriz SANCHEZ<br>Irantzu URKOLA | TECNALIA | Completion (1st version) of chapters 3 and 4 | 2022/02/10 |
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| **0.9** | Irantzu URKOLA | TECNALIA | FINAL VERSION for SUBMISSION | 2022/03/29 |

# Abbreviations and acronyms

| Acronym | Description |
| --- | --- |
| **COP** | Coefficient of Performance |
| **DHW** | Domestic hot water |
| **ESCO** | Energy Services COmpany |
| **GHG** | GreenHouse effect Gases |
| **LCA** | Life Cycle Analysis |
| **MND** | Module Not Declared |
| **PE** | Primary Energy |
| **PV** | Photovoltaics |
| **SCOP** | Seasonal Coefficient of Performance |
| **WP** | Work Package |

# Abstract of the HAPPENING project

Currently, **buildings are responsible for 40 % of the energy demand and 36% of the $CO_2$ emissions in Europe**. Decarbonisation of existing buildings plays a key role in order to reach the overall climate protection targets. However, current renovation rates lie in the order of 1%.

**Heat pumps are a key technology** in bringing renewable shares into heat supply of buildings; especially their combination with onsite renewable electricity production e.g. by PV allows to bring high renewable shares. Their current installation in existing multi-apartment buildings is however still marginal.

The proposed technological solution is based on decentralized heat pumps, in such a way that it results an easy-to-install solution for installers, low-intrusive for the occupants and easily adaptable to a large number of different building situations. This is flanked by developing near-zero planning, implementation and operation processes, in order to facilitate the work during the planning phase, ensure a high-quality installation and effective operation, and reduce the efforts and costs within the whole retrofitting project. The challenge of cost-competitiveness is addressed by developing new financial and business models. Bringing new players (such as financial experts) and financing models to the renovation market is expected to bring the needed paradigm change and boost investments in the residential retrofitting sector. Dissemination of measured performance and system characteristics from HAPPENING will be one of the key results of the project.

Through **3 demo sites (Spain, Italy and Austria)**, the project will demonstrate a highly versatile, scalable and replicable solution package for buildings energy system retrofitting allowing 70-75% of renewable energy fraction, 30-50% of PE and GHG savings, reduction of planning time by 50% and installation/operation time by 30% and payback time for ESCOs and investors of less than 8 years, compared to best available solution existing today.

# 1. Introduction

## 1.1 Objectives of the deliverable D6.2

The goal of the deliverable "***D6.2 Technologies benefit impact in terms of emissions***" (related to the task T6.1) is to **assess the environmental benefits** of the HAPPENING solution. The social benefits of the HAPPENING solution are assessed and reported in the deliverable "*D6.1 Technologies social and market acceptance*".

The environmental performance of the technologies is calculated for GHG-emissions and other relevant air emissions (for instance particles: NOx, VOC and SOx). The environmental performance of the HAPPENING system is compared with relevant conventional technologies for heating and cooling. A life cycle inspired approach is applied when evaluating the GHG-emissions (direct emissions and indirect emissions) also capitalizing such outcomes to evaluate societal benefits.

## 1.2 Deliverable description

In this deliverable D6.2, a method is proposed for the environmental assessment of the HAPPENING system.

The deliverable D6.2 is structured in several chapters:

- Description of the HAPPENING concept and its environmental implications;
- Methodology for environmental performance assessment;
- Life Cycle GHG emissions of the HAPPENING system;
- Discussion and conclusions;
- Annexes, including extra information of the content developed in this deliverable.

## 1.3 Contribution of partners

TECNALIA, as lead beneficiary contributes to the core parts of the deliverable, i.e. to the description of the methodology for environmental performance assessment and the specific transposition of the overall method to the "Life Cycle GHG emissions" analysis of the HAPPENING system (chapters 3 and 4). ANESE, for its part, contributes mainly to the detailed description of the demonstrators (chapter 2), and to the revision of the general content of the document, together with RINA-C.

## 1.4 Relation with other activities in the project

The outcomes of this deliverable (and also in the Deliverable 6.1 linked to social aspects) feeds directly into WP5 and other tasks of WP6, as they are key aspects for business promotion and business models, like those related to municipalities with clear objectives for improving the air quality in the city, which has a deep impact on its building refurbishment strategy as well as pivoting aspect of replication strategy. In turn, this deliverable takes information from WP5 and WP4, for the description of the demo sites, the proposed implementation of HAPPENING in the demo sites, and the estimation of the energy savings obtained by the HAPPENING solutions.

Social and Environmental benefits of the HAPPENING solution will be taken into account for the development of novel business models.

# 2. Description of the HAPPENING concept and its environmental implications

## 2.1 HAPPENING system in the three demo sites

This chapter describes the HAPPENING system through the 3 pilot cases.

### 2.1.1 HAPPENING system in Ispaster

The Spanish Demo Case building for the HAPPENING project is in the municipality of Ispaster, in the province of Biscay, in northern Spain, located in the main district (Elexalde) of the town.

This building was built in 2007. It is a building with both public and private ownership, as it has premises for public use on the ground floor and private dwellings on the first and second floors. It is a multi-family building with 6 dwellings, split in two floors. All the dwellings are similar in size, but there are clearly two types of them regarding size and distribution: two of them about 70 $m^2$/each, “Type A”, and four of them about 85 $m^2$/each, “Type B”. On the ground floor there are various public locals, such as the children playroom and the local pensioners' club. All the dwelling users are private owners. There is also an underground level below consisting of garages and a storage room. This room, which is owned by the municipality, would be suitable for its use as technical room and place new equipment corresponding to the HAPPENING system there. The envelope of the building was retrofitted in 2018.

In regard to the **current hydraulic system**, there is no central solution, neither for heating nor for DHW preparation. At dwelling level, there are individual gas boilers for space heating (with radiators as emitters) and DHW, but there is not any thermal storage at the moment. It is estimated that these boilers could be working at 90% efficiency. There is currently no refrigeration system in any of the dwellings. The dwellings use radiators as heat emitters in the main rooms with supply/return temperatures of 80/60ºC. These radiators are connected to dwelling´s boiler in parallel via manifolds, so that each of them has its own supply and return pipe. There is just a basic control system in each dwelling which controls the water supply by ambient thermostats (on/off control strategy).

Concerning the **electric system**, the dwellings are connected to the electricity distribution system. Every dwelling is supplied by its own energy supplier with a separate electricity contract and the corresponding electricity meter. Each dwelling has its own dedicated electrical panel, located in the entrance corridor, with disconnectors, contactors and protection switches.

In Ispaster, within the HAPPENING project, the **proposed system** will consist of a neutral temperature water loop, the temperature of which will be maintained by means of central air-source heat pumps, and terminal micro water-source heat pumps for space heating / cooling and domestic hot water production. Domestic hot water will be then stored in an individual tank for each dwelling.

According to the work done in the WP5, the expected change of the consumption of the before and after the HAPPENING solution is estimated:

| | Dwelling B (kWh m$^2$.yr) | | Dwelling C (kWh/m$^2$.yr) | |
|---|---|---|---|---|
| | Consumption before HAPPENING | Consumption after HAPPENING (estimated) | Consumption before CHANGE | Consumption after CHANGE (estimated) |
| **Electricity** | 83.8 | 100.34 | 5,54165.2 | 10,478123.3 |
| **LPG** | 35 | 0 | 11,484135.1 | 0 |
| **Total** | 118.8 | 8,529100.34 | 17,025200.3 | 10,478123.3 |

*Table 2.1: Expected change of the consumption of the before and after the HAPPENING solution in Ispaster*

(conversion factors used detailed in "*Annex 1: Primary Energy Conversion Factors in* ")

And finally, some notes about the energy consumption history of the demo building in Ispaster.

Regarding the **gas consumption**, gas bills from November 2018 to November 2019 to one of the dwellings and gas bills from January 2019 to November 2019 to another dwelling have been collected and analysed. The readings and all the calculations are in kWh. The billed amount in gas bills is a "real" amount corresponding to the real value read in the meter.

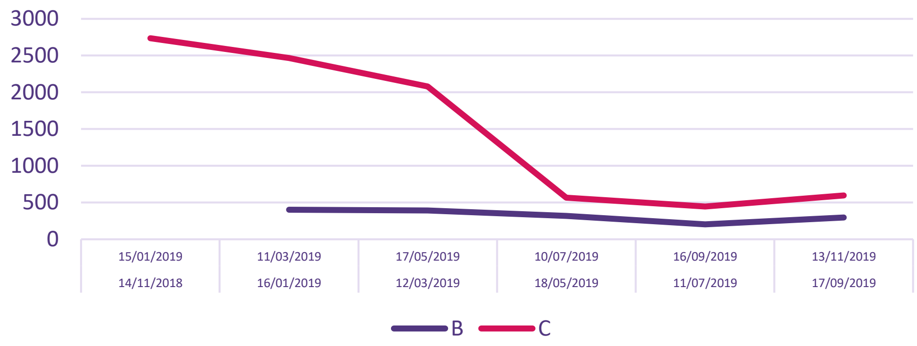


*Figure 2.1: Monthly gas consumption [kWh]*

And concerning the **electricity consumption**, electricity bills from one year, January 2020 to December 2020, for two dwellings have been collected and analysed. All the data refers to the consumption between the first and last days of the month.

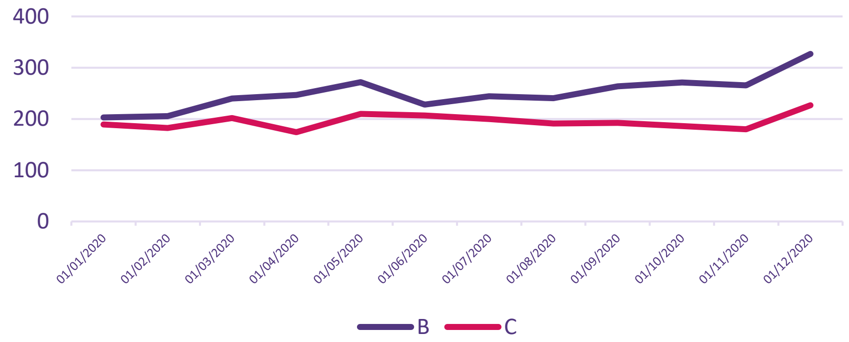


*Figure 2.2: Monthly electricity consumption [kWh]*

### 2.1.2 HAPPENING system in Verzuolo

The Italian Demo Case building for the HAPPENING project is in the municipality of Verzuolo, in the Piedmont region, in northern Italy, located in the historic centre of the town, in a hilly position, along the road that leads to the ancient medieval castle.

The historic building underwent a series of deep interventions in the years 2008-2009 that changed its structure and appearance. The interventions concerned not only the building part, but also the electrical, plumbing, and sanitary systems: from an uninhabitable structure, the works made it possible to obtain a building containing 10 dwellings and a commercial activity on the ground floor we can see today.

Renovated to be the site of a holiday home, in addition to the commercial activity on the ground floor, the apartments are now rented with a lease. The systems each apartment is equipped with are centralized and controlled by a BMS system.

There are 10 apartments, including 5 two-room apartments on the first floor and 5 three-room apartments (2 bedrooms plus the mezzanine used as a sleeping area) on the second floor. They are characterized by modest dimensions, between 32 and 42 square meters and all oriented according to the north-south direction.

In regard to the **current hydraulic and electric system**, the choice of a centralized system was pondered by evaluating the fact that it was more easily maintained, would have allowed a reduction in consumption and energy waste and would have been better adapted to the post-renovation situation of the building, which was designed at that time like a holiday home, with a large turnover of people inside the lodgings, who had to find working systems that were easy to use. In addition, for the heating and DHW production system, the encumbrance of the boiler in the already small apartments was avoided.

The different appliances and devices present in the building are:

- Condensing Gas Boiler
- Circulating pumps
- DHW boiler
- Fan coils
- Electric system
- BMS system

The centralized **hydraulic system** of the Verzuolo building has its heart in the boiler room: here, in fact, the gas piping and the water supply pipe arrive, each one from their own meter. The heat generator consists of a condensing natural gas boiler with 80 kW of nominal power.

The boiler has the dual function of providing hot water for heating and to produce domestic hot water. Its operation is regulated by BMS, so the start takes place based on the winter calendar, with time setting as regards the heating, and on the basis of the temperature of the boiler, as regards the production of domestic hot water.

As regards the heating circuits, a pump with inverter circulates the water in the two circuits: the utilities of the dwellings, and the restaurant and the adjoining kitchen (out of scope for this project). Each circuit is also equipped with shut-off valves, calibration valves, temperature probes and expansion vessels. Each circuit feeds its associated fan coils.

As regards DHW production, a dedicated circulating pump is installed on the supply boiler manifold: when the BMS system detects that the 500-liter boiler used for DHW production drops below the set point, a command is sent to the pump and the boiler in order to restore the desired temperature in the buffer tank. The hot water produced through a coil reaches all the apartments, together with cold water from the freshwater pipe.

The last pump present in the boiler room is the sanitary water recirculation pump, to always guarantee hot water is quickly supplied to all users, the hot water is continuously recirculated thanks to a small pump placed here, connecting the top of the DHW circuit to the inlet in the buffer tank.

In dwellings the emitters are fan coils. These ones are installed horizontally, in the false-ceiling of the corridor in first-floor dwellings (one for the kitchen, one for the bedroom), while in the three-rooms apartments we find wall-mounted fan coils, located in the kitchen, living room and bedroom.

Each fan coil is controlled by BMS through the temperature sensor of the room, and it is hydraulically connected to the manifolds (supply and return) of each dwelling. The drainage pipes are also connected, because of the original predisposition to use them also for cooling purpose.

Focusing now on the **electric system**, the building's electrical system consists of a single Point of Delivery (POD) by the electricity supplier, which therefore has a single meter. The type of supply has a nominal voltage of 400 V and the power used is 50 kW.

In fact, this meter serves all 10 apartments, common services, and the central heating system. Restaurant has its own electrical connections, with a three-phase line dedicated.

There is a centralized electrical panel downstream of the dwellings' energy distributor meter, which contains the switches with the line outlets to the different users of the building, including dedicated circuit breaker protection switch for each dwelling.

Inside the boiler room there is also a switchboard for the electric power supply, with three-phase arrival, of all the equipment for the operation of the heating and domestic hot water production systems present there.

Each apartment then has its own dedicated electrical panel, located in the hallway, with disconnectors, contactors, and protection switches. In dwellings, there are dedicated electrical lines for the power of each fan coil, of the kitchen equipment, sockets, and lighting and for the extraction fan inside the blind bathrooms.

Every electrical panel present in the building (dwellings, restaurant, kitchen, boiler room) is also equipped with a controller of the BMS system.

SCS controllers also interface the electric meters present: to know and share electrical consumption of different dwellings and restaurant electric meters were installed in all dwellings and restaurant electrical panels; by connecting them with BMS system it is possible to visualize these parameters remotely.

In Verzuolo, within the HAPPENING project, the **proposed system** will consist of a primary neutral temperature water loop and several micro heat pumps as terminal units. The primary loop will be served by three air source heat pumps connected in parallel, and it will use the same piping and manifolds that are currently used for central heating. The existing boiler will be left in place as a back-up, and a new water-water heat pump will be installed in order to centrally produce Domestic Hot Water, which will then be stored in a central tank that will also serve as the return point of the DHW distribution loop.

The existing fancoils will be replaced by micro heat pump units of approximately the same overall dimensions, but which will have the ability to independently produce heating or cooling, regardless of the primary loop itself.

The neutral temperature (~25ºC) characteristic of the primary loop means that a significative reduction in distribution losses can be expected from this system. The use of heat pumps with an estimated overall COP of 2 also implies a reduction in the yearly primary energy consumption of the system.

According to the work done in the WP5, the expected change of the consumption of the before and after the HAPPENING solution is estimated:

| | CONSUMPTION BEFORE CHANGE (kWh/m$^2$) | CONSUMPTION AFTER CHANGE (kWh/m$^2$) |
|---|---|---|
| **Electricity** | 79.9 | 167.7 |
| **Natural Gas** | 164.4 | 0 |
| **Total** | 244.4 | 167.7 |

*Table 2.2: Expected change of the consumption of the before and after the HAPPENING solution in Verzuolo*

And finally, some notes about the energy consumption history (collected through utility bills – gas and electricity) of the demo building in Verzuolo.

Regarding the **gas consumption**, gas bills from February 2016 to July 2021 have been collected and analysed. The readings and all the calculations are in $m^3$. They will have to be converted to kWh by using the correction and conversion factors indicated in each of the bills.[1]

The billed amount in gas bills comprises a "real" amount corresponding to the real value read in the meter, plus an "estimated" amount corresponding to the utility's estimation of the consumption between the reading date and the billing date. This estimation is subsequently replaced by the "real" amount in the next bill. In any case, all the bills indicate the most recent meter reading value as well as the previous one, and both corresponding dates, so the actual meter readings and respective dates have been used, instead of the billed amounts and billing dates.

It should be noted that from March 2020 onwards there are no more "real" readings, only estimations. This is probably due to the start of the COVID pandemic and confinement measures. All the data that does not refer to real readings has been disregarded in the analysis.

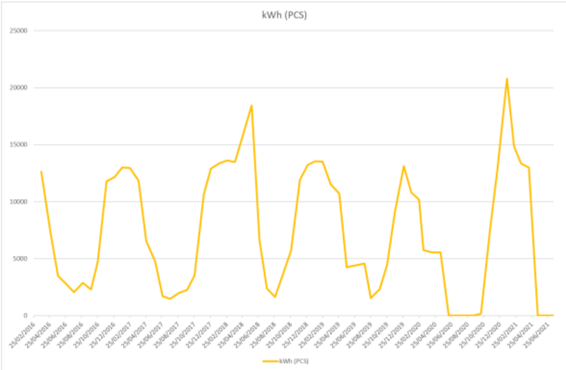


*Figure 2.3: Monthly gas consumption [kWh]*

And finally, regarding the **electricity consumption**, electricity bills from January 2016 to June 2021 have been collected and analysed. Data for the period comprised between December 2016 and June 2017 (both included) was not available.

[1] Each bill indicates the value of the correction factor for conversion to Standard $m^3$ as well as the Gross Calorific Value (GCV)

All the data refers to the consumption between the first and last days of the month, except for the consumption referred to the period between 01/06/2020 and 31/08/2020, which is given as a single value.

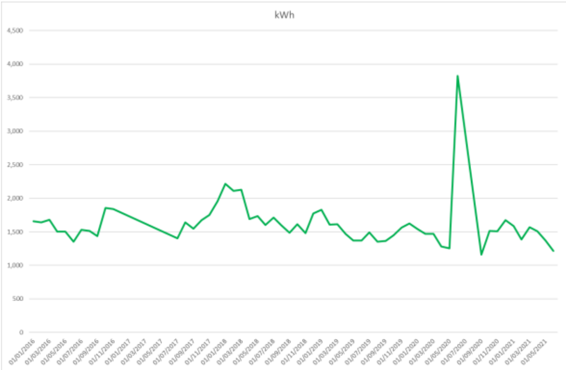


*Figure 2.4: Monthly electricity consumption [kWh]*

### 2.1.3 HAPPENING system in Liezen

The Austrian Demo Case building for the HAPPENING project is in the municipality of Liezen, in the eponymous district of Liezen, in the province of Styria, around 110 kilometres north of the Styrian capital Graz, very central in Austria.

The building under study for the HAPPENING project is located in Liezen (Südtirolergasse) and was built between 1940 and 1945. The entire residential complex has 50 dwelling units in 12 sections of which 20 dwelling units in 5 sections are used for the HAPPENING project. Currently, 6 dwellings are operated with gas heaters. The remaining dwellings either with single oil or wood stoves.

The dwellings are 3 to 4 room apartments with an average residential area of 53.5 m².

Regarding the **current hydraulic system**, the building is not connected to a central heating network. Instead, various heat sources on apartment level are in use, such as single oil, single wood stoves or gas boilers.

The oil and coal stoves are always situated in the apartments. The gas boilers are either situated in the apartments as well as (two out of six) are installed in the attic as well as in the basement directly underneath the corresponding apartment.

Gas boilers for heating purpose work without any kind of monitoring system, but they are only controlled by ambient thermostat, installed in each dwelling, operating as regulation with an on/off strategy.

Regarding domestic hot water, electric water heaters or dedicated gas boilers are installed in dwellings, equipped with a basic control system for the DHW supply regulation.

The 5 sections of the building are not currently connected to a common water circuit, with the only exception of the apartments heated with a gas system.

Concerning the **current electric system**, the dwellings are connected to the electricity distribution system. Every dwelling is supplied by its own energy supply with a separate electricity contract and the corresponding electricity meter.

In regard to the **existing equipment**, it is not possible to reuse most of the existing equipment present in the apartments today. Nevertheless, it has been assessed that some equipment currently present could be suitable for reuse within the projected system:

- DHW system: most dwellings are equipped with a DHW tank installed in the bathroom
- Heating system

According to the data gathered from WP4, and assuming an overall COP of 3 for the HAPPENING system, the expected change of the consumption of the before and after the HAPPENING solution is estimated:

| | CONSUMPTION BEFORE CHANGE (kWh/m².yr) | CONSUMPTION AFTER CHANGE (kWh/m².yr) |
|---|---|---|
| **Electricity** | 123.9 | 102.1 |
| **Wood** | 61 | 17.4 |
| **Natural Gas** | 29 | 4.8 |
| **Total** | 213.9 | 124.3 |

*Table 2.3: Expected change of the consumption of the before and after the HAPPENING solution in Liezen*

# 3. Methodology for environmental performance assessment

## 3.1 Reference framework

The methodology for environmental performance applied within the HAPPENING project is based on these previous stages and the following standards:

- UNE-EN ISO 14040:2006 - Environmental Management. Life-cycle assessment. Principles and framework.
- UNE-EN ISO 14044:2006 - Environmental Management. Life-cycle assessment. Requirements and guidelines.
- UNE-EN ISO 14025:2006 - Environmental labels and declarations. Type III environmental declarations. Principles and procedures.
- PCR: UN CPC 171 and 173 Electricity, steam and hot / cold water generation and distribution.[2]
- UNE-EN 15804:2012 - Sustainability in construction. Environmental product declarations. Basic category rules products for construction products.
- UNE-EN 15978:2011: Sustainability of construction works—Assessment of environmental performance of buildings—Calculation method.

## 3.2 Description of the methodology

The method used to assess the environmental performance of the HAPPENING project developments will be the Life Cycle Assessment (LCA) methodology. The LCA is an internationally accepted and recognised quantitative methodology for assessing the environmental impacts associated with the development of a product or process, taking into account all stages of its life (from raw materials to end of life). The LCA is a decision-making tool commonly used by the scientific world and policy makers as a complement to other methods, which are also necessary for the consumption and production of more sustainable products in an effective and efficient way.

The main characteristic of this tool is its holistic approach, i.e. it is based on the idea that all properties of a system cannot be determined only individually by its component parts. Full integration of all participants is necessary, hence

[2] General Programme Instruction for the international EPD® System.

http://www.environdec.com/es/

the concept of taking into account the entire life cycle of the system. Most importantly, it allows for direct comparison of products, technologies, etc., based on the quantitative functional performance of the alternatives analysed.

The LCA is a scientific, structured and comprehensive method that is internationally standardised in ISO 14040 and 14044. These standards, together with the ILCD handbook[3], provide a guideline for the quantification of environmental impacts of products, technologies, etc., describing the main steps for a life cycle impact assessment.

The LCA assessment follows the following life cycle stages, specified in the standards , and shown in the Figure 3.1:

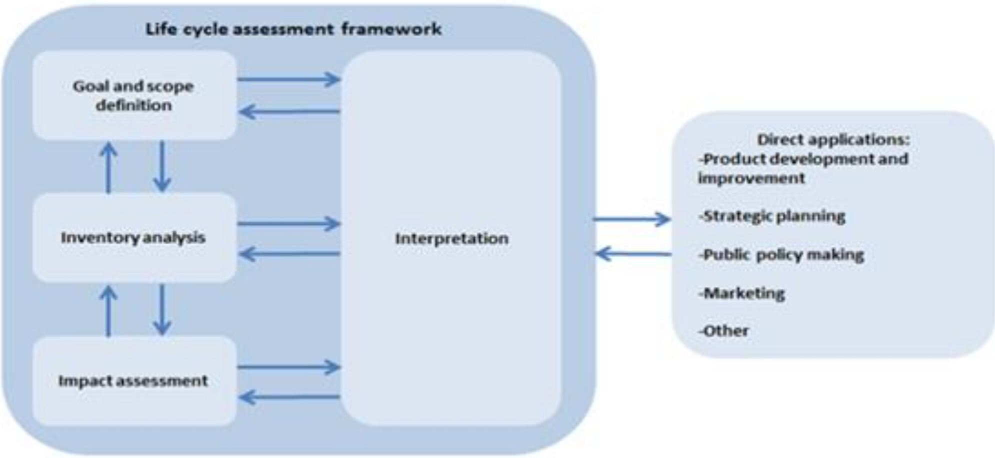


*Figure 3.1: Life Cycle Assessment phases according to ISO 14040[4]*

In the next subchapters, the life cycle phases (as specified in the standards and shown in the Figure 3.1) of the LCA assessment are detailed.

## Goal and scope definition

The objective in LCA is the intended application of the study, including the reasons for conducting the study and the intended audience. The scope in life cycle assessments is related to the function of product, the functional unit and the reference flow. Initial choices, such as system boundaries and data, are also defined at this point.

The LCA of a product should include all the inputs / outputs (see definition in next subchapter "*Inventory analysis*") that take place on the whole life cycle, although there are different scopes, as show in the following Figure 3.2:

[3] ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance. https://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-General-guide-for-LCA-DETAILED-GUIDANCE-12March2010-ISBN-fin-v1.0-EN.pdf

[4] ISO 14040:2016 Environmental management. Life cycle assessment-Principles and framework.

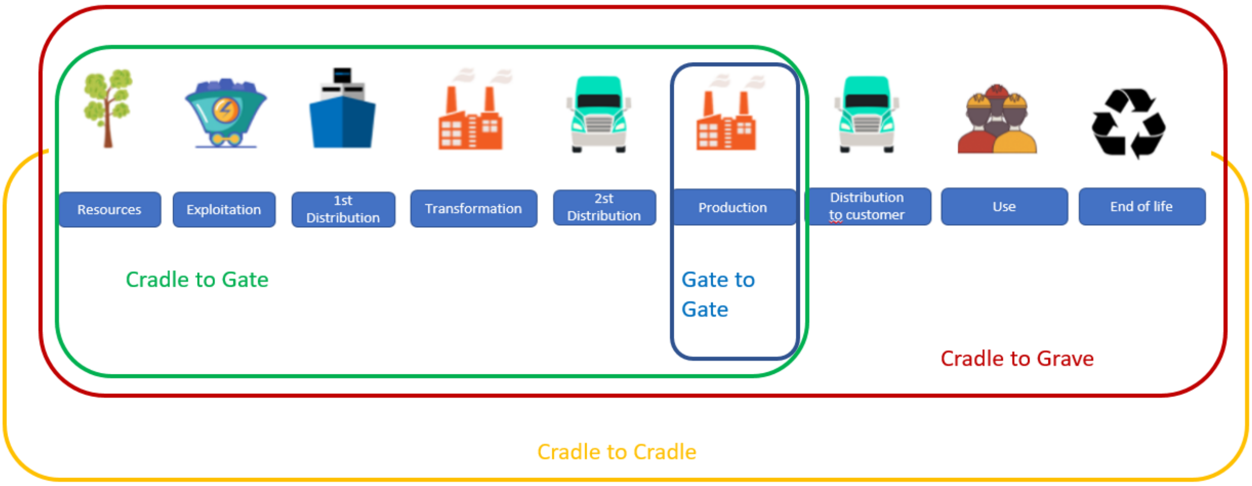


*Figure 3.2: Different scopes of LCA methodology*

The different scopes of the LCA methodology shown in the Figure 3.2 mean:

- **Cradle-to-gate**: is a partial assessment of the product life cycle; when the system scope is limited to inputs/outputs from extraction of raw materials to the output of the product. The use phase and end of life of the product are omitted in this case.
- **Gate-to-gate:** is a partial LCA, only the inputs/outputs system productions are considered.
- **Cradle-to-grave:** is the full LCA, all inputs and outputs of the entire life cycle are considered.
- **Cradle to cradle:** is a cyclical LCA. This type of LCA includes the concept that the end of life of a product is not in the deposition, but that new raw materials can be obtained from the "waste" to restart the product life cycle.

## Inventory analysis (LCI)

The Life Cycle Inventory analysis phase (LCI) is the second phase of the methodology. It is the phase in which data are collected and quantified for inputs and outputs (inputs / outputs) for all system associated with the functional unit, preparation for data collection, calculation procedures and allocation.

The data are classified in inputs and outputs:

- Inputs: Using resources and raw materials, parts and products, transport, electricity, energy ... etc., which are considered in each process / phase of the system.
- Outputs: Emissions to air, water and soil and waste and by-products that are considered in each process / phase of the system.

In the life cycle inventory analysis, energy and material flows are related to the functional unit.

The definition of the goal and scope provide the plan to realize the LCI phase. The qualitative and quantitative data to include in the inventory must be collected for each unit processes included within the limits of the system.

The life cycle inventory analysis forms the basis for the subsequent life cycle impact assessment.

## Impact assessment (LCIA)

In the third stage the assessment of the significance of potential environmental effects is carried out, with the help of the results of the inventory analysis. It is the phase of LCA in which the LCI results and Life Cycle Impact Assessment (LCIA) are assessed according to the objective and scope initially set. In this phase, potential environmental impacts are calculated using the data compiled during the life cycle inventory analysis. For this purpose, the individual material and energy flows resulting from the LCI analysis are assigned to specific impact categories that were selected for the study (classification) and weighted according to their contribution to the environmental impact associated with the impact category.

So, LCIA phase must include the following mandatory items:

- category of environmental indicators studied and models of characterization
- allocation of results of the LCI to the selected impact categories (classification)
- quantification of indicators

There are many categories of environmental impact, and selection of one or the other in the LCA being carried out will depend on the purpose of the study, target audience and level of accuracy required results.

## Interpretation

Conclusions, recommendations, analysis are all related to the objective and scope of the research are part of this phase. Interpretation phase is the final phase of the LCA study.

Within this phase the results of LCIA are summarised and discussed as a basis to get conclusions and recommendations to support decision making according to the goal and scope definition. This phase comprises:

- the identification of the critical points bases on the results of the LCI and LCIA phases

- an evaluation to check the integrity analysis, sensitivity, and consistency
- conclusions and recommendations

Generally, the information developed in an LCA or LCI study can be used as part of a much more comprehensive analysis and decision process.

It is also important to underline that the comparison the results from different LCA studies is only possible when the assumptions and context of each study are equivalent.

# 4. Life Cycle GHG emissions of the HAPPENING system

The method selected to assess the environmental impacts of the HAPPENING system is Life Cycle Assessment (LCA) methodology described in the previous chapter, adapted to the specifications of the HAPPENING concept.

This chapter describes in detail how the method is applied to project purposes. The goal and scope, functional unit, the system boundaries and the hypothesis and methods considered to carry out the HAPPENING system´s analysis are defined in this section.

## 4.1 Goal and scope of the analysis

In general, the scope, including the system boundary and level of detail of an LCA, depends on the subject matter and the intended use of the study.

The objective and scope should be clearly defined and consistent with its purpose. Due to the iterative nature of LCA, the scope may need to be adjusted during the study. To define the purpose of an LCA, the purpose and rationale of the study, the intended audience and whether the results are to be used in comparative statements intended for dissemination to the public should be unambiguously specified.

In the case of this preliminary LCA study applied to the systems developed in the HAPPENING project, the **objective** is to **assess the environmental performance of the systems and to identify potential environmental benefits** as well as possible hotspots with a major contribution to the impact.

## 4.2 Functional Unit

As mentioned previously, the functional unit is the reference in which all data of the life cycle assessment is expressed. The **functional unit** for the environmental analysis of the HAPPENING system will be taken as the **total amount of energy generated and delivered (in kWh) to the building (by the HAPPENING system) for a reference study period of 50 years**.

## 4.3 System boundaries

According to the UNE-EN 15978:2011[5], the system boundaries considered within the environmental performance of building and the building life cycle stages that will be included in this analysis, circled in red.

In the HAPPENING project, the life cycle performance evaluation will be conducted including product stage (Module A) and use stage (Module B), as shown circled in red in the next Figure 4.1:

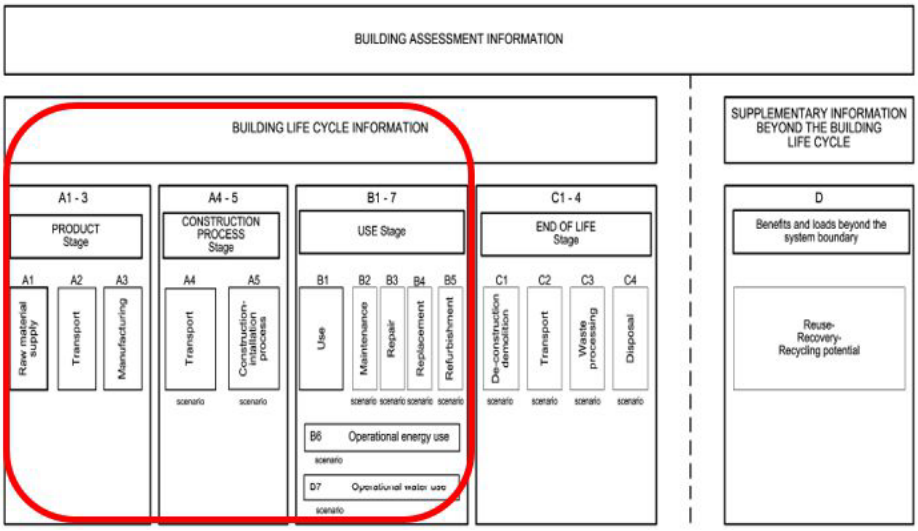


*Figure 4.1: Diagram taken from EN 15978:2011 showing building life cycle stages and phases included in this analysis circled in red*

In order to carry out the environmental study, only the stages considered relevant within the study will be included. The Table 4.1 below shows in detail the phases that will be included within the environmental studies of the HAPPENING project:

[5] UNE-EN 15978:2011: Sustainability of construction works–Assessment of environmental performance of buildings–Calculation method.

| | | | LCA |
|---|---|---|---|
| PRODUCT stage | A1 | Raw material supply | √ |
| | A2 | Transport | √ |
| | A3 | Manufacturing | √ |
| CONSTRUCTION PROCESS stage | A4 | Transport | √ |
| | A5 | Construction-Installation process | √ |
| USE stage | B1 | Use | MND (Module Not Declared) |
| | B2 | Maintenance | MND |
| | B3 | Repair | MND |
| | B4 | Replacement | √ |
| | B5 | Refurbishment | MND |
| | B6 | Operational energy stage | √ |
| | B7 | Operational water stage | MND |

*Table 4.1: Stages that are included in the economic and environmental analysis of HAPPENING with green tick*

## 4.4 Environmental impact indicators

To provide a very detailed assessment results, nine different environmental impact assessment categories are provided. A short description of each of them is provided below:

- **Global Warming Potential (GWP):** Global warming or climate change is defined as the impact of human emissions on the radiative absorption capacity of the atmosphere, which can have adverse impacts on human health and material well-being. These anthropogenic greenhouse gas emissions intensify the earth's radiative forcing by increasing its surface temperature, commonly referred to as the greenhouse effect. The environmental indicator that quantifies this impact is "Global Warming Potential", which is quantified in kg $CO_2$

equivalents. This factor is expressed in this report with a time horizon of 100 years (GWP 100), in kg of carbon dioxide equivalent per kg of emissions. The geographical scope of this indicator is global.

- **Acidification Potential (AP):** Acid pollutants have a wide range of impacts on land, water (surface and groundwater), biological organisms, ecosystems and materials (buildings). Causes of acidification include fish mortality in lakes, forest decline and deterioration of building materials. The major acid pollutants are $SO_2$, $NO_X$ and $HN_X$. The environmental indicator that quantifies this impact is "Potential Acidification" and is expressed in kg SO2 equivalents. The time period is unlimited, and the geographical scale varies from local to continental. In any case, the results come from tabulation and no specific modelling has been carried out as there are no massive emissions from channelled sources.

- **Eutrophication Potential (EP):** Eutrophication covers all impacts that can potentially increase environmental levels of macronutrients, the most important being nitrogen (N) and phosphorus (P). Nutrient enrichment can cause an undesirable change in species composition and increase biomass production in aquatic and terrestrial ecosystems. In addition, high nutrient concentrations can make surface waters unfit for human consumption. In aquatic ecosystems, an increase in biomass can cause a decrease in oxygen levels. The environmental indicator that quantifies this impact is "Potential Eutrophication" and is quantified in kg $PO_4$ equivalents. Fate and exposure are not included. The time period is unlimited, and the geographical scale varies from local to continental.

- **Ozone Layer Depletion Potential (ODP):** Refers to the thinning of the stratospheric ozone layer as a result of human-caused emissions, which primarily cause a fraction of UV-B rays to reach the earth's surface with potentially harmful impacts on human health, animal welfare, terrestrial and aquatic ecosystems, and damage to biochemical and material cycles. The environmental indicator that quantifies this impact is "ozone layer depletion". This indicator is expressed in kg $CFC^{-11}$ equivalents. The geographical scope of this indicator is global, and the time period is unlimited.

- **Photochemical Ozone Creation Potential (POCP):** The formation of reactive chemical compounds such as ozone by the action of sunlight with certain pollutants in the air. These reactions can be harmful to human health and even to crops. Photochemical ozone can be formed in the troposphere under the influence of ultraviolet light by photochemical oxidation of Volatile Organic Compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOX). The environmental indicator that quantifies this impact is "Photochemical ozone formation". The time period of this indicator is 5 years and the geographical scope varies between local and continental. In any case, the results come from tabulation and no specific modelling has been carried out as there are no massive emissions from channelled sources. The indicator is expressed in kg $C_2H_4$ equivalents.

- **Abiotic Depletion (ADP):** This is related to the extraction of minerals and fossil fuels. Its value is determined by the above values measured in kg of antimony equivalent per kg of extraction, based on the concentration of reserves and the rate of deaccumulation. The geographical scope of this indicator is global in scale.

- **Use of Primary Renewable Energy (PER):** The primary renewable energy consumption of a product is the sum of any primary energy from renewable energy sources (e.g. biomass, solar radiation, geothermal energy, etc.) that is used in the production, use and disposal of an economic good (product or service); and that can be attributed to that good. A low value points to a product that used little renewable energy over the course of its lifetime. It is measured in MJ and should always be considered as part of the total energy consumed, i.e. the sum of renewable and non-renewable primary energy.

- **Use of Primary Energy Non-Renewable (PENR):** The primary non-renewable energy consumption of a product is the sum of any primary energy from non-renewable primary energy sources that is used in the production, use and disposal of an economic good (product or service); and can be attributed to that good. A low value points to a product that uses little non-renewable energy in its life cycle. Primary non-renewable energy sources include, among others, hard coal, lignite, oil, natural gas, and uranium. Like renewable sources, it is measured in MJ.

- **Use of fresh water (UFW):** The net water consumption or water footprint quantifies the total water consumption used in the whole life cycle of a product or service and is measured in $m^3$.

## 4.5 Data gathering (process) and assumptions

One of the main challenges of every life cycle assessment is the construction and analysis of a robust life cycle inventory. This involves the management of a large amount of data that must be carefully handled.

In the HAPPENING project, the necessary life cycle data collection inventories will be created, one for each actual case study: Ispaster, Verzuolo, and Liezen. These life cycle inventories will be built according to the information provided by the necessary partners involved in the HAPPENING project. Therefore, the project partners will contribute with their expertise to this study by providing relevant and necessary information to carry out the analysis. In this context, the partners involved shall provide information on:

(1) the types of materials and quantities used in the manufacturing of the HAPPENING systems

(2) distances from the manufacturing site to the case studies

(3) if relevant, energy consumptions and quantities associated with materials and auxiliary machinery for the installation of the HAPPENING system in the case studies

(4) detailed energy performance of the HAPPENING systems implemented in the case studies

(5) service life of HAPPENING systems

(6) information from pilot cases (energy consumptions, $m^2$ temperature-controlled space, etc.)

In general, and due to a potential lack of some data, the following assumptions are considered to be potentially assumed (during the data inventory process, the validity of these assumptions must be assessed):

- The environmental performance of HAPPENING system will be done according to the life cycle phases established in the UNE-EN 15978 standard.
- "Ecoinvent v3.4" [6] database, as reference database to define basic materials and processes
- If the origin of the supplier of the input materials is unknown, in principle, a distance of 50 km to the production site will would be assumed in case of local supplier. For national or international supplier, 500km or 3000 km will be assumed, respectively.
- The impacts quantified within the product stage, construction process stage and replacement are impacts associated to the implemented HAPPENING systems. Thus, the impacts associated to the building will be not included in the environmental assessment.
- Life cycle service of 50 years will be considered for the use phase.
- Flows related to human activities, such as employee transport, are excluded from the study. The production of machines (used for example for HAPPENING system manufacturing) and transportation systems (like highways) are also out of the scope.

In addition to these general assumptions, it may be the case that specific assumptions have to be taken for some of the pilot cases analysed. These hypotheses will be explained later in the analysis of the corresponding pilot case.

[6] Ecoinvent LCI Database V3.4 . Ecoinvent Center joint initiative of the ETH Domain and Swiss Federal Offices. http://www.ecoinvent.org/home.html

## 4.6 First preliminary estimations of the environmental benefits of the HAPPENING solution

The energy consumed in the use phase for heating, cooling, and hot water generation accounts for the largest share of the buildings' energy consumption (70-90% of total energy). The HAPPENING project emerges from the need to reduce the $CO_2$ emissions through the electrification of energy equipment (i.e. HPs) and the generation of local and green energy (i.e. PV). In this way, HAPPENING is a key solution in achieving the EU policy goals for sustainability, such as the Paris meeting, COP21.

The greener energy consumption to be achieved in a building through new thermal and electrical energy requirements will have an additional direct environmental impact. The indirect environmental impact of the HAPPENING solution will be seen in the reduction of $CO_2$ releases in the atmosphere via the electrification of energy equipment (i.e. HPs) and the generation of local and green energy (i.e. PV) in buildings.

According to the preliminary estimations, the substitution of traditional technologies by the HAPPENING system would allow a **reduction of between 60-77% of $CO_2$ emissions per kWh supplied** during the use phase associated with thermal demands. These savings are just preliminary as they depend on different factors such as the final efficiency of the HAPPENING configuration, the percentage of the system's electricity consumption covered by PV as well as the $CO_2$ emission factors of the electricity mix and natural gas.

To carry out this first preliminary estimation of the $CO_2$ savings, different assumptions have been taken. These assumptions are summarized as follow:

- SCOP of the HAPPENING system: 3-4
- Percentage of the HPs' electric demand covered by PV: 60%-70%
- $CO_2$ emission factor of electricity: 0,81 Kg $CO_2$ eq/kWh[7]
- $CO_2$ emission factor of natural gas: 0,26 Kg $CO_2$ eq /kWh[8]

[7] Emission factor from Ecoinvent 3.5 data base for Europe "Heat production, natural gas, at boiler modulating".

[8] Emission factor from Ecoinvent 3.5 data base for Europe "Electricity, high voltage, production mix".

# 5. Conclusions

This deliverable "D6.2 Technologies benefit impact in terms of emissions" presents a method to assess the environmental benefits of the HAPPENING solution as well as preliminary estimation about reduction of $CO_2$ emission per kWh supplied.

After the brief and summarized description of the HAPPENING concept and its environmental implications in the 3 demo sites, the general methodology for environmental performance assessment is presented, i.e. the Life Cycle Assessment (LCA) methodology. This LCA, which is a holistic approach, is an internationally accepted and recognised quantitative methodology for assessing the environmental impacts associated with the development of a product or process, taking into account all stages of its life (from raw materials to end of life) and it is taken as basis for the methodology to be applied in HAPPENING.

The Life Cycle Assessment (LCA) method is adapted to the specifications of the HAPPENING concept or system to assess its environmental impacts, describing in detail how the method is applied to project purposes.

The objective of the LCA study applied to the HAPPENING system is to assess the environmental performance of the systems and to identify potential environmental benefits as well as possible hotspots with a major contribution to the impact, taking as functional unit the total amount of energy generated and delivered (in kWh) to the building (by the HAPPENING system) for a reference study period of 50 years. Several key environmental impact indicators are proposed and the data gathering process (and some key assumptions) are suggested.

Finally, a preliminary estimation is made resulting in the substitution of traditional technologies by the HAPPENING system allowing a reduction of between 60-77%[9] of $CO_2$ emissions per kWh supplied during the use phase associated with thermal demands.

The results of the LCA will be reported as Appendix of the deliverable D6.3 "Business and ESCO Model", once data on the HAPPENING solution, as well as on monitoring campaign, will be available. Notwithstanding, periodic updates will be provided in order to take into consideration the environmental benefits of the HAPPENING solution in the definition of the business model, in the replication strategy as well as in the definition of the route to market.

[9] Check the hypothesis assumed in chapter 4.6.

# Annexes

## Annex 1: Primary Energy Conversion Factors in Ispaster, Verzuolo and Liezen

In order to work with energy values that can be added and easily compared, all the values have been converted to Primary Energy using conversion factors. These are the conversion factor in Ispaster and Verzuolo demos:

| | ENERGY FORM | PRIMARY ENERGY CONVERSION FACTOR |
|---|---|---|
| ISPASTER | LPG | 1.195 |
| | Electricity | 2.368 |
| VERZUOLO | Natural Gas | 1.05 |
| | Electricity | 2.42 |
| LIEZEN | Gas | 1,14 |
| | Electricity | 1,13 |
| | Oil | 1,13 |
| | Biomass (wood) | 0,06-0,14 |

*Primary Energy Conversion Factor in Ispaster, Verzuolo and Liezen demos*

# Annex 2: Terms and definitions

- **Life cycle**: consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.
- **Life cycle assessment (LCA)**: compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.
- **Life cycle inventory analysis (LCI)**: phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.
- **Life cycle impact assessment (LCIA)**: phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product
- **Life cycle interpretation**: phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations.
- **Product**: any goods or service.
- **Elementary Flow**: material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation.
- **Raw material**: primary or secondary material that is used to produce a product.
- **Allocation**: partitioning the input or output flows of a process or a product system between the product system under
- study and one or more other product Systems.
- **Data quality**: characteristics of data that relate to their ability to satisfy stated requirements.
- **Functional unit**: quantified performance of a product system for use as a reference unit.
- **Input**: product, material or energy flow that enters a unit process.
- **Output**: product, material or energy flow that leaves a unit process
- **Reference Flow**: measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit.

- **System boundary**: set of criteria specifying which unit processes are part of a product System.
- **Impact category**: class representing environmental issues of concern to which life cycle inventory analysis results may be assigned impact category indicator: quantifiable representation of an impact category.
- **Function**: Function selected of the product. A product may have a number of possible and the one(s) selected for a study depend(s) on the goal and scope of the LCA.
- **Life cycle service**: period during which the time-dependent characteristics of the object of the assessment are analysed.

# Annex 3: References

UNE-EN ISO 14040:2006 - Environmental Management. Life-cycle assessment. Principles and framework.

UNE-EN ISO 14044:2006 - Environmental Management. Life-cycle assessment. Requirements and guidelines.

UNE-EN ISO 14025:2006 - Environmental labels and declarations. Type III environmental declarations. Principles and procedures.

PCR: UN CPC 171 and 173 Electricity, steam and hot / cold water generation and distribution.[10]

UNE-EN 15804:2012 - Sustainability in construction. Environmental product declarations. Basic category rules products for construction products.

UNE-EN 15978:2011: Sustainability of construction works—Assessment of environmental performance of buildings—Calculation method.

[10] General Programme Instruction for the international EPD® System.

http://www.environdec.com/es/