Low valued energy sources UPgrading for buildings and industry uses

LowUP Life Cycle Analysis

Deliverable D4.16

Lead Beneficiary: CARTIF
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About LowUP

LowUP – Low valued energy sources UPgrading for buildings and industry uses – is developing efficient alternatives to supply heating and cooling for building and industries, based on the use of renewable free energy and heat recovery from non-valuated residual energy sources that are currently wasted. As a result, these technologies will contribute to reducing significantly CO_2 emissions and primary energy consumption, and increasing the energy efficiency in buildings.

Led by the Spanish firm ACCIONA, the LowUP project gathers 13 partners (3 large companies, 3 research and technology organisations and 7 SMEs) from 7 European countries. During 48 months, the consortium will develop efficient alternatives to supply heating and cooling for buildings and industries based on renewable free energy as well as non-valuated wasted thermal sources:

- 3 technologies will be developed and demonstrated: one heating and one cooling system for buildings, and one heat recovery system for industrial processes.
- The three systems will be demonstrated at four demo sites: a pilot office building in Seville (Spain, ACCIONA Construction); a water treatment plant in Madrid (Canal de Isabel II & ACCIONA Water); a Pulp and Paper mill in Setubal (Portugal, The Navigator Company); and a student hall in Badajoz (Spain, University of Extremadura).

For more information visit: www.lowup-h2020.eu

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Executive Summary

The goal of project LowUP is to develop and demonstrate three novel technologies for efficient and sustainable cooling and heating. As part of the Work Package 4 “Installation, operation and validation in a relevant environment”, this deliverable will focus on the environmental and economic effects and impacts resulting from the deployment of the different technologies across 3 demonstration sites: office building in Seville (Spain), wastewater treatment plant in Madrid (Spain) and a pulp and paper plant in Setubal (Portugal).

This report follows a Life Cycle Assessment approach for the evaluation of the environmental and economic aspects of the different technologies and demo sites under study. The deliverable has been structured around 2 main concepts, as stated in the DoA:

- Environmental Product Declarations: Based on existing Product Category Rules for construction products, the report has modelled a sample EPD for each of the products using the available information for the partners.
- Life Cycle Assessment: LCA methodology has been used for the evaluation of the environmental (LCA) and economic (LCC) aspects of the project, performing a comparative assessment between a baseline scenario and a “LowUP scenario” for each demo site, assessing the benefits and burdens resulting from the implementation of the different technologies that have been developed in this project.

The first sections of the deliverable present the methodology for both the LCA and LCC (Chapters 2 and 3) followed by an introduction to the basis of the EPD system and the sample EPDs for each product involved in the project (Chapter 4). The next stage was to develop the LCA and LCC for the comparative assessment of the different demo sites (Chapter 5) followed by a final set of general guidelines for the optimal environmental and economic performance of LowUP’s technologies (Chapter 6) and the outcomes of the study (Chapter 7).

Keywords

Life Cycle Assessment, Life Cycle Costing, Low Up Systems, Environmental Product Declaration

Abbreviations

LCA	Life Cycle Assessment
FU	Functional Unit
EPD	Environmental Product Declaration
PCR	Product Category Rules
EN	European Norm
ISO	International Organization for Standardization
PV	Photovoltaics
PCM	Phase change material
SETAC	Society of Environmental Toxicology and Chemistry

1 Introduction

The goal of project LowUP is to develop and demonstrate three novel technologies for efficient and sustainable cooling and heating. As part of the Work Package 4 “Installation, operation and validation in a relevant environment”, this deliverable will focus on the environmental and economic effects and impacts resulting from the deployment of the different technologies across 3 demonstration sites: office building in Seville (Spain), wastewater treatment plant in Madrid (Spain) and a pulp and paper plant in Setubal (Portugal).

1.1 Global approach

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1.2 Main objectives

The goal of this report was the evaluate the environmental and economic aspects of the project from al life cycle perspective to identify potential benefits and burdens. Additional objectives that have been addressed included:

- Introduction to the LCA and LCC methodologies following international standards.
- Introduction to the EPD and PCR concepts.
- Development of sample EPDs for the different products according to existing PCRs.
- Comparative assessment of LowUP’s technologies and baseline scenarios for each demo.
- Development of a general set of guidelines for the optimum environmental and economic performance of the different technologies.

2 Environmental assessment. Life Cycle Assessment methodology and protocol

The environmental assessment protocols and methodologies have been increasing since the development of the official standards in Life Cycle Assessment (LCA) (ISO 14040 and 14044), becoming more and more specific depending on the product category to be assessed.

In the frame of the LowUp Project, different technologies have been assessed for different applications in order to improve energy efficiency in different building environments. Considering the particularities of the Project, several standards have been used in order to cover the different sectors involved in the project (buildings and construction products), always under the frame of the official LCA global standard.

2.1 Life Cycle Assessment methodology

The deployment of the Life Cycle Assessment methodology is described in the following standards, including general regulations and specific rules for building and construction products.

- ISO 14040-44 describes the LCA methodology in a general way, as a methodological approach for LCA developers.
- EN 15978 is more focused on building performance from an environmental point of view including the LCA methodology.
- EN 15804 is the appropriate standard in order to develop environmental product declarations of construction works.

The three of them (Table 1) have been used in the frame of the Low Up project in order to provide relevant information about the environmental implications of the three systems developed and the different applications.

Table 1: Standards describing the methodologies involved in the LCA sustainability assessment

Methodology	Standard
Life Cycle Assessment	ISO 14040:2006. Environmental management. Life Cycle Assessment. Principles and framework. ISO 14044:2006. Environmental management. Life Cycle Assessment. Requirements and guidelines.
Sustainability assessment in buildings	EN 15978:2011. Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method.
Sustainability in construction products	EN 15804. Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products

In order to assess the environmental situation and implications regarding the Project, the three of them have been used, as it is described in Figure 1.

Working this way, the environmental impact of the system included has been assessed using the *Construction product approach (EN 15804)*, while the implications in the building has been assessed using the *Building sustainability approach (EN 15978).* In any case, both of them are under the frame of the ISO 14040 and 14044

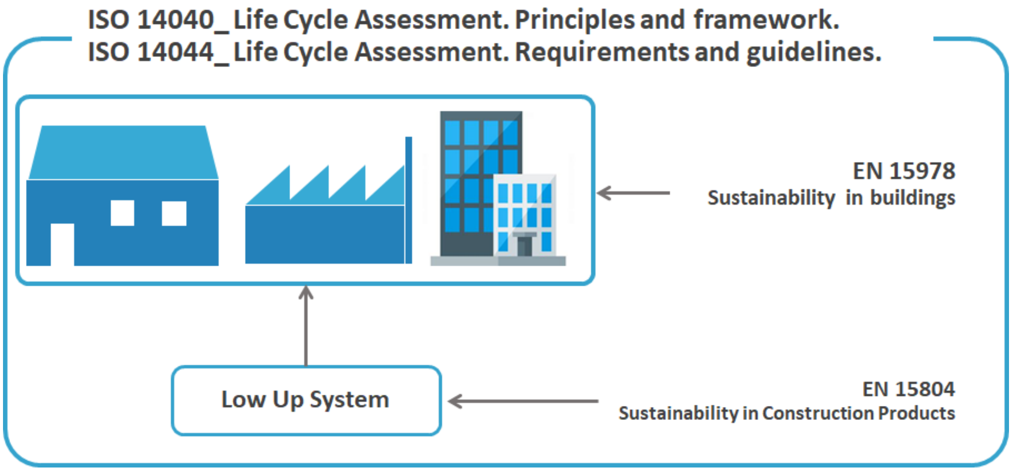


Figure 1. Standards coverage of the Project scope.

The methodologies are briefly described in the following sections.

2.1.1 LCA and ISO 14040-44. The methodology

Life Cycle Assessment is an environmental tool that allows the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle [1]. The LCA methodology is clearly described by the following standards:

- ISO 14040:2006. Environmental management. Life Cycle Assessment. Principles and framework.
- ISO 14044:2006. Environmental management. Life Cycle Assessment. Requirements and guidelines.

The LCA methodology is structured in four steps, as it can be seen in Figure 2 [2].

a. - Goal and scope:

The first stage of the LCA methodology defines why the assessment is developed, which the target audience is, and some important decisions, among others, as:

- Functional unit selection
- System boundaries
- Impact indicators selection

b. - Inventory analysis:

In this stage, the complete information about the system studied is collected, including energy and material inputs and outputs, as well as emissions to air, soil and water. Special attention must be paid to the data quality and the acquisition methods.

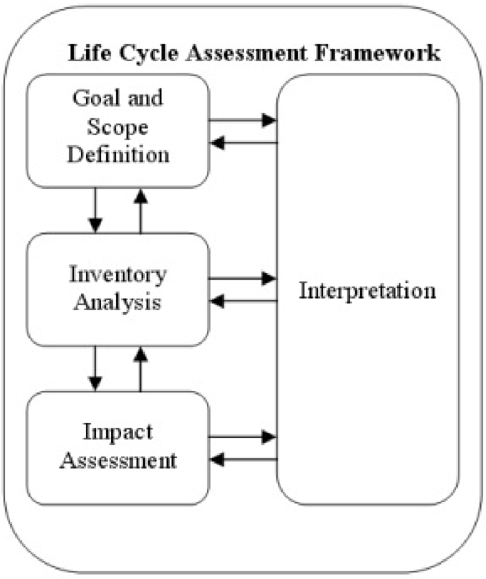


Figure 2: Life Cycle assessment framework

c. - Impact assessment:

After inventory compilation, classification and characterization are developed in this stage, in order to sort the inventory according to the effect on the environment and the multiplication by a factor in order to evaluate its contribution to that effect. Depending on the indicators selected, other stages (normalization or weighting) are optional.

d. - Interpretation:

The final conclusions of the study are obtained in order to select strategies to improve the environmental performance of the system evaluated, make comparisons, etc.

2.1.2 LCA and EN 15978. Sustainability in buildings.

Although the project is focused in the three Low UP technologies, the most important point in the study will be the effect of the three techniques in the global energy consumption compared to the impact of the systems (construction of the systems). That is the main reason that EN 15978:2011 has been selected. The study will be developed comparing a baseline scenario (performing considering no Low UP project intervention) and a project scenario (considering the Low Up systems incorporation).

Working under the framework of the Life Cycle Assessment methodology (**ISO 14040** and **ISO 14044**), the LCA deployment has been developed according to the **EN 15978** scheme.

The four previous stages of the LCA methodology have been articulated according to the following seven main stages reported in the EN 15978:

i. - Objective of the study

A clear definition of what are the main objectives of the LCA study must be detailed.

ii. - System definition

Functional unit: According to the ISO 14044, the functional unit should be defined as the reference unit through which system performance is quantified in an LCA. The protocol has clearly described the functional unit selected.

Reference study period: Definition of the time to be reported in the environmental assessment. It must be the same for the baseline and the Project scenario.

System boundaries: In this case, considering that the influence of one system is the key point of the study, only energy consumption and the Low Up system have been considered to be included in the system boundaries.

iii. - Description and configuration of scenarios for the baseline and project scenario

The *baseline scenario* is the energy performance of the buildings considering no Low Up system incorporation and considering only the current thermal/electricity sources.

The *project scenario* involves the energy scheme to be used in the project scenario, as well as the incorporation of the Low Up systems and their influence in energy consumption. As a reference lifetime period has been considered, maintenance and replacement operations for the system have also been included in the study.

Life cycle stages: It consists of the stages to be included in the analysis (e.g. product stage, construction process stage, use stage and end-of-life stage).

iv.- System quantification

The quantification of all materials, products, energy, wastes, etc. is determined based on the intended description of the evaluation object.

Net amount: It corresponds with the net units of products, components, materials energy, and elements of the building.

Gross amount: This coincides with the previous value but including also the losses.

Type of data: Different types of data can be collected, depending on the Life Cycle Stage, availability, geographical sources, suppliers' sources, real values, estimated values, generic data, proxy data, selection and preferences.

v. - Environmental data selection (<u>for the baseline and the project scenarios)</u>

Environmental Product Declaration use: Use of Environmental Product Declarations (EPD) when they are available. It is a document that provides quantified and verifiable information on the environmental performance of a product, material or service.

Other info use: Selection and identification of other required information.

Data quality and consistency: Current data, geographical, annual average, technological validity, etc., in order to have robust data for the assessment.

vi. - Environmental calculation (<u>for the baseline and the project scenarios)</u>

Environmental aspects and impacts: According to EN 15978.

Evaluation methods: Available on the evaluation software and the inventory.

vii. - Reporting and communication

General information & Evaluation results: According to EN 15978, section 12.6.

Following these steps, the LCA of the three technologies and their different applications have been developed considering not only the environmental impact of the system but also the implications in the energy savings of the building performance.

EN 15978 covers a list of several indicators (Table 2). The partners have decided what the most interesting environmental indicators to be calculated are, considering that an Environmental Product Declaration (EPD) has been being developed after the LCA calculation for the three Low Up systems.

Table 2: Indicators according to EN 15978

Type of indicator	Code	Indicator	Unit
Environmental impact	EI_1	Global warming potential	kg CO_2 eq
	EI_2	Depletion potential of the stratospheric ozone layer	kg CFC 11 eq
	EI_3	Acidification potential of land and water	kg SO_2 eq
	EI_4	Eutrophication potential	kg PO_4^{-3} eq
	EI_5	Formation potential of tropospheric ozone photochemical oxidants	kg C_2H_2 eq
	EI_6	Abiotic resources depletion potential of elements	kg Sb eq
	EI_7	Abiotic resources depletion potential of fossil fuels	MJ
Resources use	RU_1	Use of renewable primary energy excluding energy resources used as raw material	MJ
	RU_2	Use of renewable primary energy resources used as raw material	MJ
	RU_3	Use of non-renewable primary energy excluding energy resources used as raw material	MJ
	RU_4	Use of non-renewable primary energy resources used as raw material	MJ
	RU_5	Use of secondary material	kg
	RU_6	Use of renewable secondary fuel	MJ

Table 2: Indicators according to EN 15978

Type of indicator	Code	Indicator	Unit
	RU_7	Use of non-renewable secondary fuel	MJ
	RU_8	Net use of fresh water	m^3
Waste categories	WC_1	Hazardous wastes disposed	kg
	WC_2	Non-hazardous wastes disposed	kg
	WC_3	Radioactive waste disposed	kg
Output flows	OF_1	Components for re-use	kg
	OF_2	Materials for recycling	kg
	OF_3	Materials for energy recovery (not being waste	kg
	OF_4	Exported energy	MJ

2.1.3 LCA and EN 15804. Sustainability in construction products.

After developing the LCA assessment according to the ISO 14040-44 and the evaluation of the building performance in terms of energy use including the Low Up systems following the EN 15978, the final step is developing an Environmental Product Declaration (EPD) according to EN 15804 standard and ISO 14025.

This standard provides de Product Category Rules (PCR) for construction products and services.

The LCA methodology described in section 2.1.1 is implemented according to EN 15804 following this scheme:

i. - Selection of the product stages covered

- Cradle to gate (product stage), including Raw materials, transportation and manufacturing (A1-A3)
- Cradle to gate with options, including the product stage and other modules (A1-A3 and including others).
- Cradle to grave, including the whole life cycle of the product (A, B, C and D).

Figure 3 shows the different life cycle stages that must be covered by the assessment in order to assess all the life cycle stages according to the ISO 14040-44.

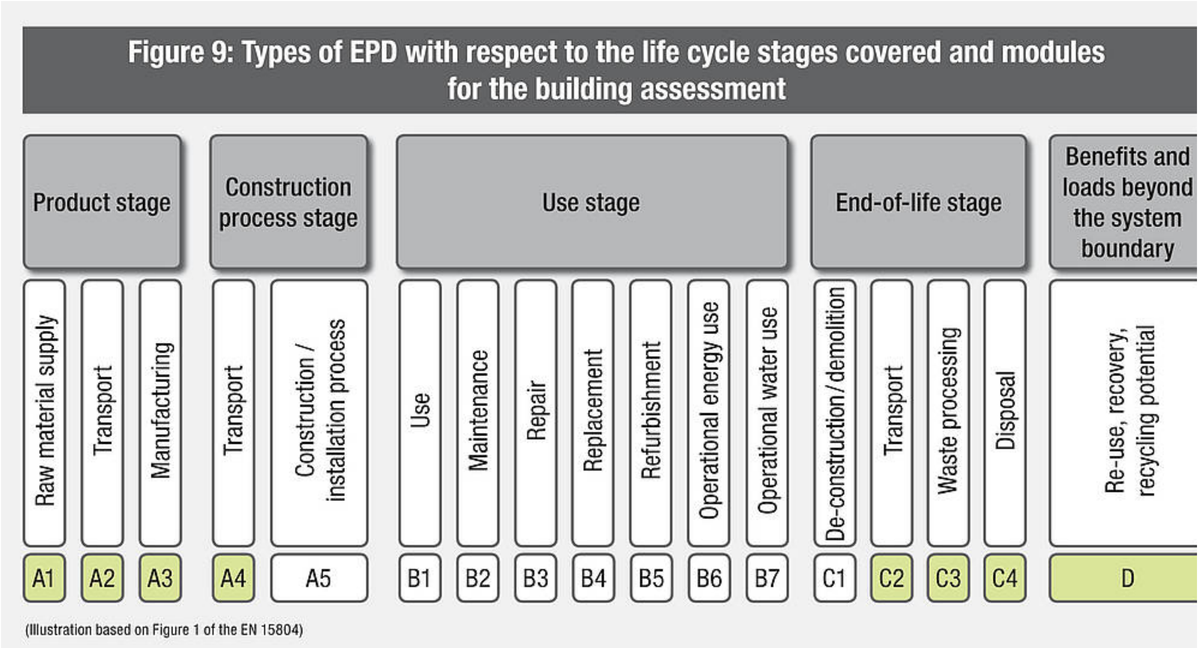


Figure 3: Life cycle stages to be covered based on EN 15804.

ii. - System definition

Functional unit: According to the ISO 14044, the functional unit should be defined as the reference unit through which system performance is quantified in an LCA. The protocol has clearly described the functional unit selected.

Reference study period: Definition of the time to be reported in the environmental assessment. It must be the same for the baseline and the Project scenario.

System boundaries: In this case, considering that the influence of one system is the key point of the study, only energy consumption and the Low Up system will be considered to be included in the system boundaries.

iii.- Different information modules

The following structure is almost the same as it is described in EN 15978.

The three Low Up technologies and their applications have been evaluated considering this scheme and the following modular stages.

A1-A3: Includes Raw material supply, transport and manufacturing

A4-A5: Includes transport and construction process

B1-B7: Use, maintenance, repair, replacement, refurbishment, operational energy use and operational water use

C1-C4: De-construction and demolition, transport, waste processing and disposal

D: Benefits and loads beyond the system boundaries

iv.- Data quality requirements

The data collection must respect the following rules:

- Updated data (10 years for generic and 5 years for specific data)

- Local data is preferred in terms of geographical data
- Annual average data are recommended
- The technology must correspond to the reality processes
- Generic data must be in accordance with CEN/TR 15941

v.- Life cycle inventory

Life Cycle inventory has been completed according to section 4.3.2 from EN ISO 14044:2006.

vi.- Impact assessment

The same 22 indicators reported in **Table 2** must be compiled and calculated, categorized as:

- Environmental impact
- Resources use
- Waste categories
- Output flows

vii.- EPD contents

General information: In this section, data from the manufacturer, description of the construction product, life cycle stages considered, EPD program scheme, date, validity, etc.

Environmental data form the LCA. A flow diagram of the process including the life cycle stages must be completed.

The environmental information must be provided by modules (cradle to gate, cradle to gate with options or cradle to grave). The same indicators described in **Table 2** must be detailed.

Sections 7 and 8 from EN 15804 provide information about additional data and information to be included in the process of the Environmental Product Declaration generation.

2.2 Life Cycle Assessment protocol

In this section, a simplified scheme of how LCA development is going to be managed is presented.

Several stages are included in order to develop the assessment according to the standards and incorporating the participation of different partners involved in the Project.

More specific issues will be solved directly by the LCA practitioner and the rest of the partners working in each of the applications of the Low Up systems.

1.- Scenarios to be evaluated

The first step to be developed is to define the scenarios that are going to be assessed.

In the context of the Low Up project, three technologies are going to be implemented in different applications and in different building environments.

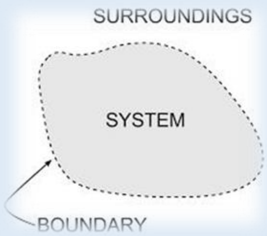
These scenarios must be clearly defined, including a brief summary and description of the Low Up technology used, the specific application, the building environment.

2.-Partners roles for each scenario

In each scenario to be evaluated, the role of each partner must be clearly identified. The main roles that must be covered in this stage are:

- The data provider: the responsibility of the data provider is the compilation of the data inventory according to the data quality requirements established.
- The LCA practitioner: this partner is responsible for developing the methodological part of the LCA, including the data collection, modelling, evaluation and reporting.
- The monitoring responsible: in this particular case, the system evaluated includes potential savings in the energy consumption of buildings. Energy, as a key stage of any system evaluated, must be correctly monitored in the baseline scenario but also after the intervention of the Low Up project. Although modelled data can be used in specific cases, it is preferred to use real values from monitoring (also the monitoring methodology must be reported).
- The reviewer: it is strongly recommended an external review in order to incorporate an extra point of view in the assessment.

3.- System limits and boundaries. Functional unit



In this stage of the protocol, it must be defined what it is included and what is not in the study, why, and how the boundaries of the system assessed have been defined.

Also, the functional unit (F.U.) has to be defined at this moment. The F.U. is a quantified description of the performance of a product system. The definition of the F.U. can be complex sometimes, and the selection must be carefully selected because all the results will be expressed in that basis.

For the particular case of Low Up project, it must be considered the context in which the different technologies are applied. It is recommended that all the applications select a similar F.U., in order to have the possibility to make some comparisons. Maybe it is a good option not to focus on the Low Up system itself (as a machine or infrastructure) but in its performance in the context of a building. It is also important to evaluate the temporal horizon of the functional unit, considering that it is a product with influence in energy consumption.

4.- Modules to be included

As it has been reported in section 2.1 of this report, the environmental assessment of the different applications follows some European norms that are focused on the building and construction products sector. These norms include the following modules:

- Product stage
- Construction process stage
- Use stage
- End of life stage
- Benefits and loads beyond the systems boundaries

Although the evidence that the more modules are included the more complete is the assessment, it must be agreed with the partners which modules are included or not. This stage is close linked to the system boundary determination.

5.- Life cycle inventory

The life cycle inventory stage is the most time consuming one in the LCA. In this stage all the data included in the system boundaries that define the functional unit must be collected, including the use of materials, transportation, manufacturing processes, energy consumption, wastes generated. Also, emissions to air, soil and water can be collected to be part of the assessment.

The *LCA practitioner* will facilitate a template in order to facilitate the *data provider* in the data collection process.

The template will be structured as it is reported in the EN used for the assessment. According to the experience in other projects, it is almost impossible to collect the inventory information at once, so it will be an iterative process until the inventory is fully completed.

The inventory must include the source of the data collected, date, if it is based of real values or if it is assumption, etc. The inventory will be improved during the project timeline, until the final version of the LCI is accepted by both the data provider and the LCA practitioner.

6.- Environmental modelling

The environemntal modelling will be developed by the LCA practitioner. It will be carried out using specific LCA software and comercial databases.

The modelling will be structured according to the modules previously defined, in order to communicate the environmental results in a clear a simplified way.

The model must be also validated by the data provider, ensuring that the model includes all the data required by the F.U.

The environmental modelling is a big time consuming task. Selecting similar F.U. for all the scenarios would simplify a lot the process, as it can be replicated and accordingly adjusted depending on the scenario assessed.

The environmental model can be also improved according to the different data compilation moments, so from the first version to the last one, the model will be improved.

7.- Selection of the environmental indicators to be calculated

In order to communicate the environmental results of the assessment, the appropriate impact categories must be selected. The impact categories selected will express their results in terms of the corresponding environmental indicators.

Some indicators are obtained from the inventory, but others are calculated according to different methodologies.

It is important to make the right selection of indicators, because if an Environmental Product Declaration is going to be developed, the communication of some indicators is mandatory.

8.- Environmental impact assessment

Once than the Life Cycle Inventory has been fully completed, and the environmental model has been developed in the evaluation software, it is the moment for developing the environmental assessment, obtaining the results in the different impact categories and the corresponding environmental indicators.

It is important to elaborate a comprehensive report in order to be able to communicate to both experts and non-experts on environmental assessment.

9.- Conclusions

The final stage in the environmental assessment is developing the final conclusions, in which it will be described:

- The impacts of the system
- Hierarchy on the environmental burdens
- Identification of hot spots
- Potential improvements after burdens identification (eco-design)

10.- EPD generation process

An Environmental Product Declaration (EPD) is a document that communicates verified, transparent and comparable information about the life-cycle environmental impact of products.

In this case, a especific report following the recommendations of the corresponding EN or Product Category Rules (PCR) must be developed.

A certified third party is inovlved in the process, validating that the LCA has been developed according to the methodology stablished. After this process, the EPD will be published and free available for anyone, and the products selected (different Low Up systems) will be comunicating their environemtnal impacts according to a scientific and verified methodology.

3 Economic assessment. Life Cycle Costing methodology and protocol

3.1 Life Cycle Costing methodology

Life Cycle Costing (LCC hereafter) was first used in the United States by the Department of Defense (US DoD) in the mid-1960s [6] The US DoD applied LCC in the procurement of military equipment, as they found that acquisition costs only accounted for a small part of the total cost for the weapons systems while operation and support costs comprised as much as 75% [7].

Since then, many different backgrounds and disciplines have been interested in calculating the optimal allocation of budget by estimating the costs that incur during the whole life cycle of a product, service, project, investment, etc. All the different fields, scopes and aims behind LCC have laid down to a large number of different LCC definitions:

- "Life cycle costing is a powerful technique that supports the analytical processes by which managers can make the most cost-effective decisions on options presented to them at differing life cycle stages and at different levels of the life cycle cost estimate". Code of Practice for Life Cycle Costing *[NATO RTO, 2009].*[3]
- "All costs associated with the product, system or structure as applied over the defined life cycle". *[Fabrycky and Blanchard,1991].*[4]
- "The life cycle cost analysis is the economic analysis process that assesses the total cost of acquisition, ownership and disposal of a product" *[IEC 60300-3-3:2004].* [5]

There are three different types of LCCs (Figure 4):

- Conventional LCC: The assessment of all costs associated with the life cycle of a product that are directly covered by the main producer or user in the product life cycle. Focused on real internal costs.
- Environmental LCC: The assessment of all costs associated with the life cycle of a product that are directly covered by one or more of the actors in the product life cycle with the inclusion of externalities that are anticipated to be internalized in the decision relevant future.
- Societal LCC: The assessment of all costs associated with the life cycle of a product that is covered by anyone in the society, whether today or in the long-term future.

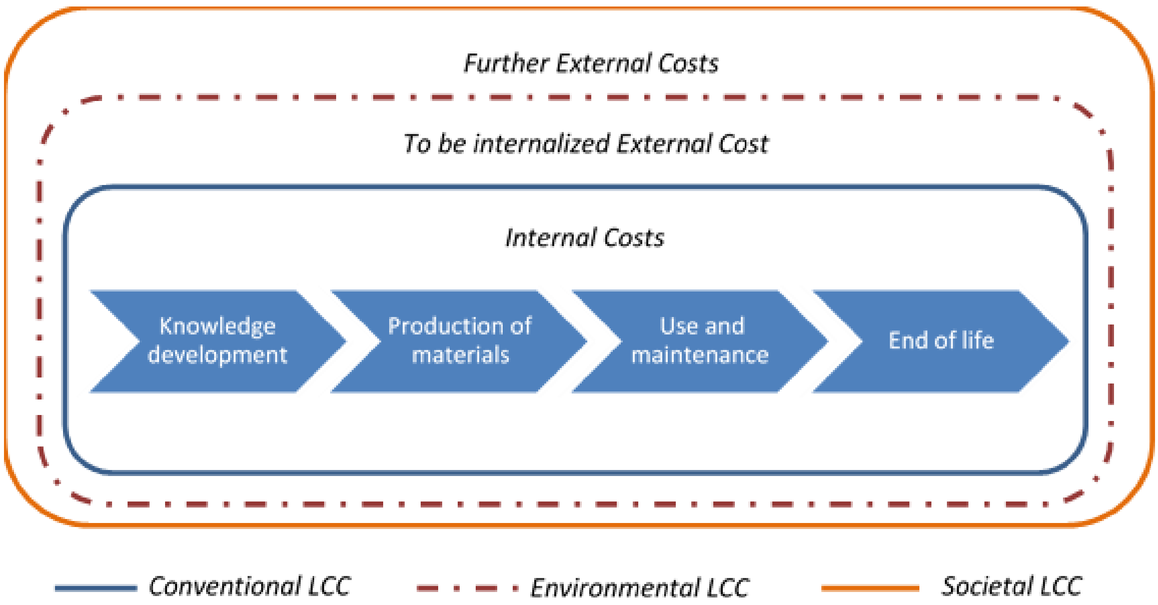


Figure 4. LCC types scheme

The LCC is structured in 4 steps similarly to the LCA:

- Goal and scope definition: goal and scope need to be defined before a study takes place. It is necessary to define the system boundaries and the functional unit as well as the selection of alternatives.
- Information gathering: even the field of cost estimation is very well established it can exist data not available, so some estimation methods have to be employed. Other important topic is the allocation of costs to the different outputs.
- Interpretation and identification of hotspots: these hotspots, that usually become evident as a result of the analysis, can be interpreted in a quantitative or in a qualitative way. Assessment of alternatives can be influenced by nonmonetary criteria, and even an alternative that is optimal from a quantitative point of view can be rejected based on other aspects, possibly qualitative.

- Sensitivity analysis and discussion: recommended in the interpretation phase. It serves to reveal the connections between uncertain parameters and the calculated outputs, how sensitive they are to deviations and their variations, and to see to what extent can the input values vary without impacting the conclusions.

As defined by the IEC 60300-3-3 standard [5][IEC 60300-3-3, 2004], which provides a general introduction to the concept of life cycle cost analysis and covers all its application, the most common applications of the LCC assessment include: evaluation and comparative analysis between alternative design approaches, assessment of the economic viability of a project, identification of the costs and resource planning. The norm defines six steps in the life cycle of a product, see Figure 5.

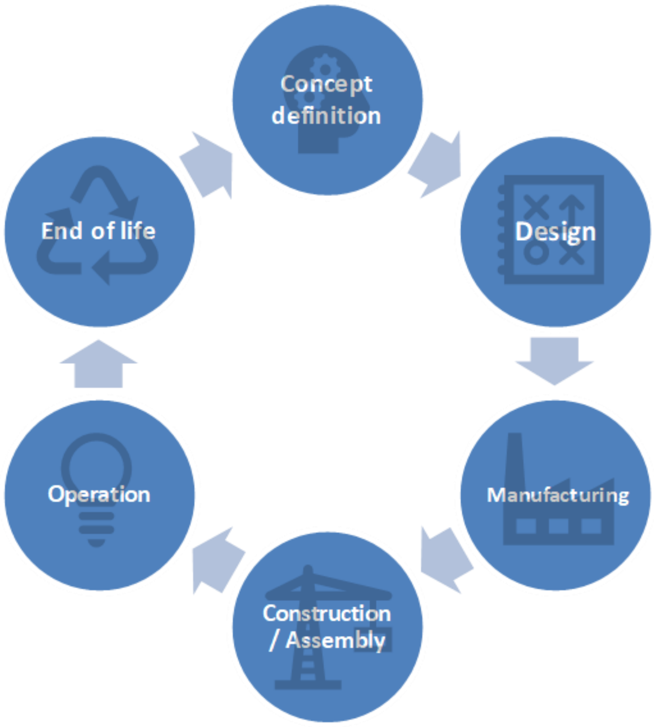


Figure 5. LCC process scheme

The selection of the stages to be included in each assessment depends on the scope and the requirements of each particular case. Decisions made in the early stages of the LCC have a greater influence on the outcomes than those taken later since as the product advances in its life cycle, the opportunities to make assumptions are more limited.

The reliability of a product determines its performance along the use stage and depends on diverse factors such as durability, maintenance logistics and lifetime. This kind of considerations should be included in an LCC as maintenance operations can have a significant impact on the cost of the product. The costs associated with the reliability elements may cover: the cost of restoration of the system (including the cost linked to corrective maintenance), the cost of preventive maintenance and the costs derived from failure or breakdown.

The latter stem from the charges incurred when a product or service is unavailable, such as the price of providing an alternative service, costs due to loss of income, guarantee costs (protection for customers), liability costs (cost of compensation for breaking the law) …

As for the LCC model, it is a simplified representation of reality. To be realistic, it would have to represent all the characteristics of the product, highlight all the relevant factors, be simple and understandable and be designed to allow the evaluation of specific elements.

In practice, it may be necessary to develop a specific model for the problem in question with estimations and assumptions, while in other cases, the commercial models available may be used, although these must be accordingly validated. The LCC model includes cost breakdown structure, breakdown structure of the product or work, the selection of cost categories and cost elements, the estimation of the costs and a report of the results. Additionally, if required, the model may cover environmental and safety aspects, uncertainties, risks and a sensitivity analysis to identify cost levers.

To estimate the total cost of the life cycle it is necessary to decompose the total LCC into the different elements that constitute it. These cost elements, which are the link between the cost categories and the breakdown structure of the product or work, must be individually identified so that they can be clearly defined and estimated. One approach to this top-down method could start by decomposing the product into individual subassemblies or activities identifying the point in the life cycle where they take part. As a result, the estimation of the costs associated to the low-level categories can be more readily applicable.

At this point, it is important to mention that there are several methods for cost estimation:

- Engineering cost methods: the economic attributes of the particular cost elements are estimated directly by examining the product component by component.
- Cost methods by analogy: cost estimation is based on the experience of previous assessments of similar products or technologies.
- Parametric cost methods: use parameters and variables to develop relationships for estimating costs.

The life cycle cost assessment should be completed with a sensitivity analysis to identify the influence of the steps with higher contribution to the total costs. This evaluation could also include the influence of volatile factors such as taxes, inflation and the real value of money.

3.2 Life Cycle Costing protocol

1.- Scenarios to be evaluated

The first step to be developed is to define the scenarios that are going to be assessed.

In the context of the Low Up project, three technologies are going to be implemented in different applications and in different building environments.

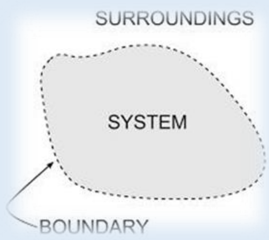
These scenarios must be clearly defined, including a brief summary and description of the Low Up technology used, the specific application, the building environment.

2.-Partners' roles for each scenario

In each scenario to be evaluated, the role of each partner must be clearly identified. The main roles that must be covered at this point are:

- The data provider: the responsibility of the data provider is the compilation of the inventory according to the data quality requirements stablished.
- The LCC pratitioner: this partner is responsible of developing the methodological part of the LCC, including the data collection, modeling, evaluation and reporting.
- The monitoring responsible: in this particualr case, the system evaluated includes potential savings in the energy consumption of buildings. Energy, as a key stage of any system evaluated, must be correctly monitored in the baseline scenario but also after the intervention of the Low Up project. Although modelled data can be used in specific cases, it is preferred to use real values from monitoring (also the monitoring methodology must be reported).
- The reviewer: it is strongly recommended an external review in order to incorporate extra point of view of the assessment.

3.- Objectives and scope definition



In this stage of the protocol, it must be defined what it is included and what is not in the study, why, and how the boundaries of the system assessed has been defined.

Also, the functional unit (F.U.) has to be defined at this moment. The F.U. is a quantified description of the performance of a product system. The definition of the F.U. can be complex sometimes, and the selection must be carefully selected, because all the results will be expressed in that basis.

For the particular case of Low Up project, it must be considered the context in which the different technologies are applied. It is recommended that all the applications select a similar F.U., in order to have the possibility to make some comparisons. Maybe it is a good option not to focus on the Low Up system itself (as a machine or infrastructure) but in its performance in the context of a building. It is also important to evaluate the temporal horizon of the functional unit considering that is a product with influence in energy consumption

4.- Selection of the LCC type

As it has been reported in the section 2.1 of this report, the environmental assessment of the different applications will follow some European norms that are focused on the building and construction products sector. These norms include the following modules:

- Product stage
- Construction process stage
- Use stage
- End of life stage
- Benefits and loads beyond the systems boundaries

Although the evidence that the more modules are included the more complete is the assessment, it must be agreed with the partners which modules are included or not. This stage is close linked to the system boundary determination.

5.- Life cycle inventory and data collection

The life cycle inventory stage is the most time consuming one in the LCA. In this stage all the data included in the system boundaries that define the functional unit must be collected, including the use of materials, transportation, manufacturing processes, energy consumption, wastes generated. Also, emissions to air, soil and water can be collected to be part of the assessment.

The *LCC practitioner* will facilitate a template in order to facilitate the *data provider* in the data collection process.

The template will be structured as it is reported in the EN used for the assessment. According to the experience in other projects, it is almost impossible to collect the inventory information at once, so it will be an iterative process until the inventory is fully completed.

The inventory must include the source of the data collected, date, if it is based of real values or if it is assumption, etc. The inventory will be improved during the project timeline, until the final version of the LCI is accepted by both the data provider and the LCC practitioner.

6.- LCC modelling

The economic modelling will be developed by the LCC practitioner. It will be carried out using specific LCC tools and comercial databases.

The modelling will be structured according to the modules previously defined, in order to communicate the environemtnal results in a clear a simplified way.

The model must be also validated by the data provider, ensuring that the model includes all the data required by the F.U.

The economic modelling is a big time consuming task. Selecting similar F.U. for all the scenarios would simplify a lot the process, as it can be replicated and slightly corrected depending on the scenario assessed.

The economic model can also be improved according to the different project stage, so from the first version to the last one, the model will be improved and refined.

9.- Conclusions

The final stage in the economic assessment is developing the final conclusions, in which the following aspects should be addressed:

- The impacts of the system
- Cost hierarchy
- Identification of hot spots
- Potential improvements after burdens identification

4 EPD procedure

4.1 Product Categories Rules reference

The first step in EPD procedure is checking the development of a specific EPD for the products or services object of analysis.

A PCR is defined in ISO 14025 as a set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories. The PCR document specifies the rules for the underlying life cycle assessment (LCA) and sets minimum requirements on EPDs for a specific product group that are more detailed than the standards and the General Programme Instructions (Figure 7). [8]

Figure 6. *PCR example* [**10**]

In this case, it was considered to develop a PCR within the program "The International EPD® system" because it is the pioneer program of EPD at an international level and is considered the most internationally recognized program, since EPD are available in more than 15 different countries, being a valid program for any type of product and / or service. The program operator is the Swedish Environmental Management Council SEMCo, and there is reciprocity with the IBU EPD (Germany). Furthermore, in December 2013 The International EPD® System reached a reciprocity agreement with the DAP AENOR Global EPD program.

Therefore, in this case we had the reference PCR "Construction products and construction services. Product group classification: multiple UN CPC codes 2012:01 version 2.01".

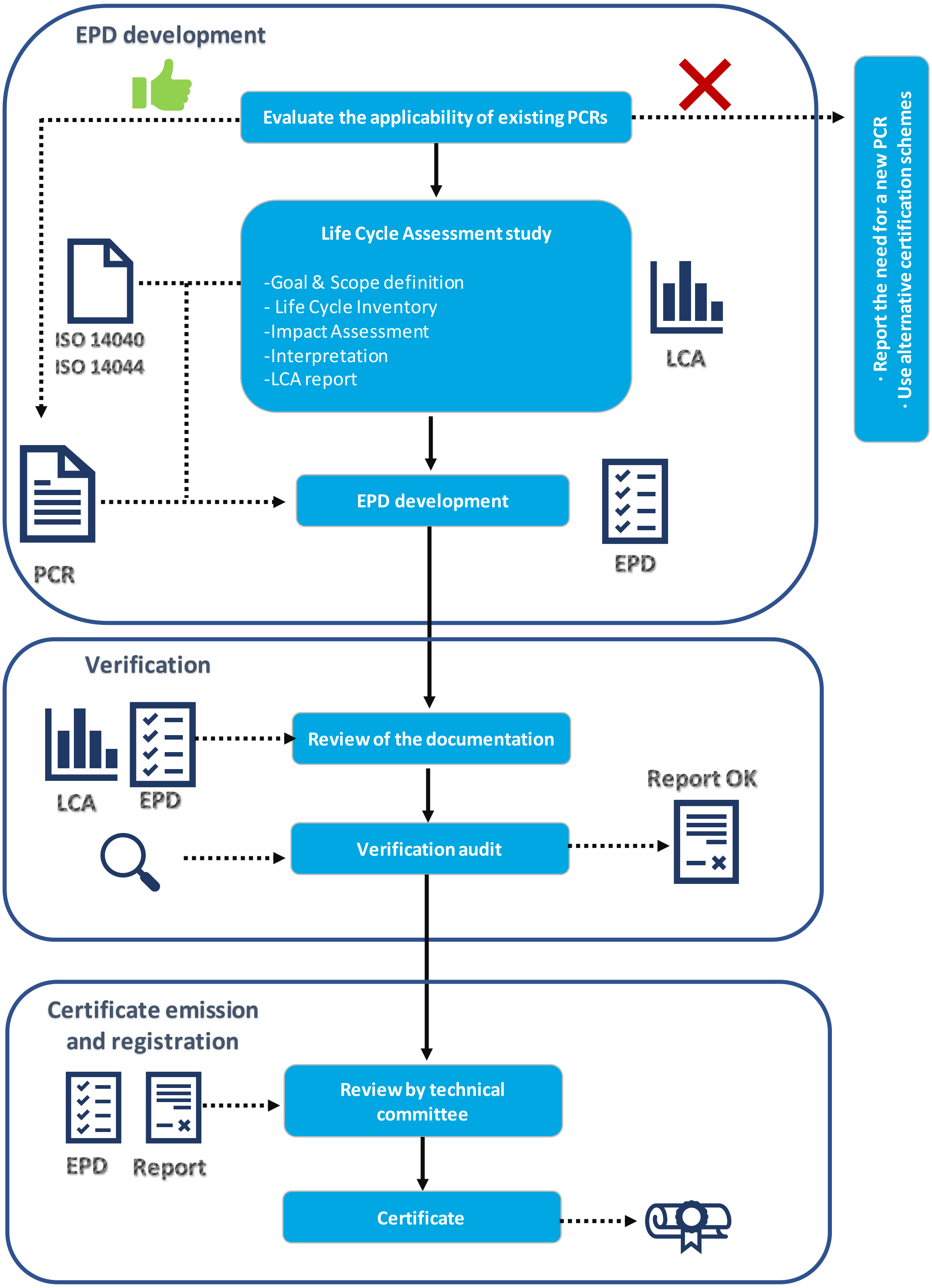


Figure 7. EPD procedure scheme

4.2 LCA Scope, boundaries and functional unit

Once the PCR to be applied is known, the next step is to establish the boundaries of the system and the functional unit to which the entire analysis will refer. In order to determine these parameters, the reference PCR specifications must be considered due to these documents specify the details around this type of decision to be made.

In accordance with the reference program, The International EPD® system an LCA calculations procedure which is separated into three different life cycle stages:

- Upstream processes (from cradle-to-gate)
- Core processes (from gate-to-gate)
- Downstream processes (from gate-to-grave)

In the EPD®, the environmental performance associated with each of the three life-cycle stages above shall be reported separately. In the European standard EN 15804, a different nomenclature is used based on "information modules" A1-C4 and D, see Figure 9

The general system boundary for a construction product or service is defined by its intended use. This PCR allows optional scope of the LCA reported in the EPD if the declared unit is applied. Then the following scopes are available using this document as a PCR:

- "Cradle-to-gate" EPD (declared unit): Modules A1 to A3
- "Cradle-to-gate with options" EPD (declared unit): Modules A1 to A3 plus other selected optional modules, e.g. end-of-life information modules C1 to C4
- "Cradle-to-grave" EPD (functional unit): All Modules A to C based on a sub-oriented PCR including scenarios for handling the usage and end of life stage in order to meet comparability within the specific application of the product group.

Therefore, considering the characteristic of this study and the product involve on it, the system boundaries considered in this work have been a "**Cradle-to-gate" EPD**. Thus, this study has evaluated the impact from the extraction of raw materials until the product leaves the factory, see Figure 8.

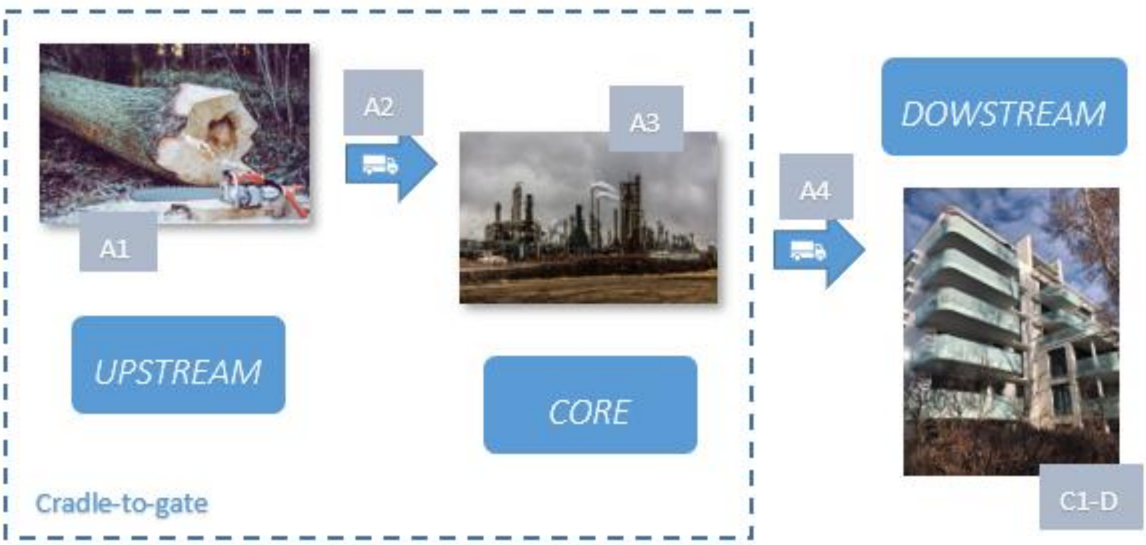


Figure 8. System boundaries

The following processes are not accounted for in the LCI:

- Environmental impact from infrastructure, construction, production equipment, and tools that are not directly consumed in the production process.
- Personnel-related impacts, such as transportation to and from work.

Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
Raw materials	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D

Upstream processes Core processes Downstream processes

Figure 9. International EPD® system Life Cycle stages

In order to provide a reference by means of which the material flows of the information module of a construction product are normalised (in a mathematical sense) to produce data a declared or functional unit has been stablished. The EPD shall either be based on a declared unit or a functional unit. The declared unit is used instead of the functional unit when the precise function of the product or scenarios at the building level is not stated, unknown or is not taken into account for in the EPD. The declared unit is applicable for an EPD that covers a "cradle to gate" and "cradle to gate with options". Thus, a declared unit has been used to developed this work. Due to the difference between the product the declared unit for the LowUP technologies are shown in Table 3.

Table 3. Declared unit technologies

MANUFACTURER	DECLARED UNIT
ENDEF	1 photovoltaic panel with connexions
RDZ	100 (m2) of low-thickness radiant floor
WASENCO	1 hybrid heat recovery system
ENTROPY	1 stratified accumulation tank
FAFCO	1 PCM storage system for space cooling
HALTON	1 high-efficiency chilled beam
POZZI	1 rotating heat exchanger
GEA	1 heat pump
ENTROPY	1 photovoltaic panel with connexions

4.3 Life Cycle Inventory (LCI)

In following sections, the Life Cycle Inventory (LCI) of each LowUP technology are shown. The information gathered is the result of the collaboration between the partners involved of each technology and CARTIF.

4.3.1 ENDEF

Table 4 shows the inventory for the ENDEF equipment. The material has been disaggregated in the three stages that has been assessed in the EPD developed: Raw materials, Transport and manufacturing.

Table 4. ENDEF Life Cycle inventory

Stage	Flow	Amount	Unit
A1 – Raw materials	PV laminate	15	kg
	Aluminum (absorber)	6	
	Aluminum (frame)	4	
	Polyurethane foam	4	
	Aluminum (Rear-sheet)	2	
A1 – Raw materials	PCM C48	16	

Table 4. ENDEF Life Cycle inventory

Stage	Flow	Amount	Unit
	Conexion box	0.5	
A2 - Transport	PV laminate	24.93	tkm
	Aluminum (absorber)	9.89	
	Aluminum (frame)	3.47	
	Polyurethane foam	0.08	
	Aluminum (Rear-sheet)	0.04	
	PCM C48	42.82	
	Conexion box	0.83	
A3 - Manufacturing	Drill/riveter consumption	0.264	kWh

4.3.2 RDZ

Table 5 shows the inventory for the RDZ equipment. The material has been disaggregated in the three stages that has been assessed in the EPD developed: Raw materials, Transport and manufacturing.

Table 5. RDZ Life Cycle inventory

Stage	Flow	Amount	Unit
A1 – Raw materials	DRY TECH PANEL HP - LINEAR	87	m^2
	DRY TECH PANEL HP - HEAD	22	m^2
	WEDGE FOR DRY TECH PANEL HP	1034	Pcs
	DRY-TECH GLUE	12,5	kg
	MULTILAYER PIPE	1200	m
	CONTROL PRE-ASSEMBLED MANIFOLD 8+8 Ø14	2	Pcs
	ALUMINIUM PLATES 250mm * 500mm	9	m^2
	ALUMINIUM PLATES 500mm * 500mm	95	m^2
A1 – Raw materials	ALUMINIUM PLATES 500mm * 500mm - WITH GLUE	101	m^2

Table 5. RDZ Life Cycle inventory

Stage	Flow	Amount	Unit
	THERMAL DIFFUSERS 14Ø - LINEAR	828	Pcs
	THERMAL DIFFUSERS 14Ø - CURVE - 180°	112	Pcs
	THERMAL DIFFUSERS 14Ø - CURVE - 90°	34	Pcs
	HUMIDITY BARRIER SHEET	112	MQ
	SLIM PERIMETER BELT	86	Mt
	OPEN ELBOW 14 Ø	28	Pcs
	CABINET BODY FOR CONTROL MANIFOLD - WITH DOOR	2	Pcs
A2 – Transport	DRY TECH PANEL HP - LINEAR	3.43	tkm
	DRY TECH PANEL HP - HEAD	0.866	tkm
	WEDGE FOR DRY TECH PANEL HP	0.464	tkm
	DRY-TECH GLUE	0.188	tkm
	MULTILAYER PIPE	61	tkm
	CONTROL PRE-ASSEMBLED MANIFOLD 8+8 Ø14	0.05	tkm
	ALUMINIUM PLATES 250mm * 500mm	5.1	tkm
	ALUMINIUM PLATES 500mm * 500mm	53.9	tkm
	ALUMINIUM PLATES 500mm * 500mm - WITH GLUE	74.9	tkm
	THERMAL DIFFUSERS 14Ø - LINEAR	0.31	tkm
	THERMAL DIFFUSERS 14Ø - CURVE - 180°	0.0127	tkm
A2 – Transport	THERMAL DIFFUSERS 14Ø - CURVE - 90°	0.042	tkm
	HUMIDITY BARRIER SHEET	12.2	tkm

Table 5. RDZ Life Cycle inventory

Stage	Flow	Amount	Unit
	SLIM PERIMETER BELT	11.2	tkm
	OPEN ELBOW 14 Ø	0.742	tkm
	CABINET BODY FOR CONTROL MANIFOLD - WITH DOOR	0.36	tkm
A3 - Manufacturing	No data available		

4.3.3 WASENCO

Table 6 shows the inventory for the WASENCO equipment. The material has been disaggregated in the three stages that has been assessed in the EPD developed: Raw materials, Transport and manufacturing.

Table 6. WASENCO Life Cycle inventory

Stage	Flow	Amount	Unit
A1 – Raw materials	Waste water heat recovery vessel	80	kg
	Heat exchangers in the vessel	75	
A2 – Transport	Waste water heat recovery vessel	51.44	tkm
	Heat exchangers in the vessel	48.23	
A3 - Manufacturing	Metal sheet forming	20	kWh
	Metal tube bending	40	
	Laser cutting	80	

4.3.4 ENTROPY

Table 7 shows the inventory for the ENTROPY equipment. The material has been disaggregated in the three stages that has been assessed in the EPD developed: Raw materials, Transport and manufacturing.

Table 7. ENTROPY Life Cycle inventory

Stage	Flow	Amount	Unit
A1 – Raw materials	Steel	561.7	kg
	Steel	4.0	
	PP-RCT 125mm	26.14	
	PP-RCT 32 mm	0.93	
	PP-RCT 69 mm	4.79	
	Polyamide 12	21,2	
	Polyester fiber	50.6	
A2 – Transport	Steel	56.17	tkm
	Steel	0.04	
	PP-RCT 125mm	0.2614	
	PP-RCT 32 mm	0.093	
	PP-RCT 69 mm	0.479	
	Polyamide 12	2.12	
	Polyester fiber	5.06	
A3 - Manufacturing	Global assembly process	200	kWh

4.3.5 FAFCO

Table 8 shows the inventory for the FAFCO equipment. The material has been disaggregated in the three stages that has been assessed in the EPD developed: Raw materials, Transport and manufacturing.

Table 8. FAFCO Life Cycle inventory

Stage	Flow	Amount	Unit
A1 – Raw materials	Polypropylene	68	kg
	Polybatch natur (clear)	1	
	Polyblack schwarz (black)	1	
	Waste heat exchanger	11	
	Inox collectors	37.5	
	EPDM for liner	25	
	Extruded Polystyrene (insulating)	47.4	
	PCP10	3,000	
	Steel of trapezoidal sheet	294	
	Steel used for frame	365	
A2 – Transport	Polypropylene	33.184	tkm
	Polybatch natur (clear)	0.488	
	Polyblack schwarz (black)	0.488	
	Waste heat exchanger	0.143	
	Inox collectors	0.4875	
	EPDM for liner	38.375	
	Extruded Polystyrene (insulating)	25.833	
	PCP10	1,947	
	Steel of trapezoidal sheet	241.33098	
	Steel used for frame	4.74721	
A3 - Manufacturing	No data available		

4.3.6 HALTON

Table 9 shows the inventory for the HALTON equipment. The material has been disaggregated in the three stages that has been assessed in the EPD developed: Raw materials, Transport and manufacturing.

Table 9. HALTON Life Cycle inventory

Stage	Flow	Amount	Unit
A1 – Raw materials	Hot galvanized steel	963.4	kg
	Prepainted Steel	531.6	
	Aluminum	193.2	
	Copper	134	
	Polyacetal	10.8	
	Polyethylene foam	5	
A2 – Transport	Hot galvanized steel	96.34	tkm
	Prepainted Steel	53.16	
	Aluminum	19.32	
	Copper	13.4	
	Polyacetal	0.108	
	Polyethylene foam	0.05	
A3 - Manufacturing	No data available		

4.3.7 POZZI LEOPOLDO

Table 10 shows the inventory for the POZZI LEOPOLDO equipment. The material has been disaggregated in the three stages that has been assessed in the EPD developed: Raw materials, Transport and manufacturing.

Table 10. POZZILAOPOLDO Life Cycle inventory

Stage	Flow	Amount	Unit
A1 – Raw materials	Stainless Steel 316L 2B Sheet	88	kg
	Stainless Steel 304L Piping	4	
	Stainless Steel 316L Shells	99	
	Stainless Steel 304 Plates	33	
	Stainless Steel 316 Heads	28.4	
	Stainless Steel 316 Flanges	5	
	Stainless Steel Shafts	9.7	
	Stainless Steel Pressure Dumper	5	
A1 – Raw materials	Stainless Steel Greaser ⅛''	0.2	kg
	Galvanized Stainless Steel Joints	1	
	Composite Flexible Pipes	1.4	
	Mechanichal Seals	2.7	

Table 10. POZZILAOPOLDO Life Cycle inventory

Stage	Flow	Amount	Unit
		0.3	
	Bronze Safety Valve	2	
	Stainless Steel Drain Valve	2	
	FKM O Rings	0.03	
	Iron Pulleys	6	
	Cast Iron Supports	23	
	Roller Bearings	8	
	Rotating Joint	15	
	Rubber Toothed Belt	0.02	
	Electrichal Motoreducer	23	
	Stainless Steel 316 Screws	0.5	
	Inverter	1	
	PLC	1	
	Various electrical component	5	
A2 – Transport	Stainless Steel 316L 2B Sheet	13.64	tkm
	Stainless Steel 304L Piping	0.204	
	Stainless Steel 316L Shells	1.881	
	Stainless Steel 304 Plates	1.683	
	Stainless Steel 316 Heads	2.2152	
	Stainless Steel 316 Flanges	0.53	
	Stainless Steel Shafts	1.0282	
	Stainless Steel Pressure Dumper	0.095	
	Stainless Steel Greaser ⅛''	0	
	Galvanized Stainless Steel Joints	0.013	
	Composite Flexible Pipes	0.088	
	Mechanical Seals	0.753	
	Bronze Safety Valve	0.128	tkm
	Stainless Steel Drain Valve	0.044	
	FKM O Rings	0.00105	
A2 – Transport	Iron Pulleys	0.126	
	Cast Iron Supports	0.483	
	Roller Bearings	0.168	
	Rotating Joint	0.69	

Table 10. POZZILAOPOLDO Life Cycle inventory

Stage	Flow	Amount	Unit
	Rubber Toothed Belt	0.00042	
	Electrical Motoreducer	4.6	
	Stainless Steel 316 Screws	0.086	tkm
	Inverter	0.016	
	PLC	0.008	
	Various electrical component	0.04	
A3 - Manufacturing	No data available		

4.3.8 GEA

Table 11 shows the inventory for the GEA equipment. The material has been disaggregated in the three stages that has been assessed in the EPD developed: Raw materials, Transport and manufacturing.

Table 11. GEA Life Cycle inventory

Stage	Flow	Amount	Unit
A1 – Raw materials	Carbon steel	10,000	kg
	Stainless steel	5,000	
	Rockwool	10	
	Aluminum	20	
	Copper	300	
	Synthetic oil	40	
A2 – Transport	Carbon steel	1,000	tkm
	Stainless steel	500	
	Rockwool	1	
	Aluminum	2	
	Copper	30	
	Synthetic oil	4	
A3 - Manufacturing	No data available		

4.4 Impact assessment

The impact assessment methodology used in this EPD has been CML-IA. This methodology was developed, in 2001, by a group of scientists under the lead of CML (Center of Environmental Science of Leiden University) and proposes a set of impact categories and characterization methods for the impact assessment step. The impact assessment method implemented as CML-IA methodology is defined for the midpoint approach. Normalization is provided but there is neither weighting nor addition. In the following paragraphs, the impact categories evaluated are defined [9]

- **Global warming, kg CO2e equivalents (GWP100).** Climate change can result in adverse effects upon ecosystem health, human health and material welfare. Climate change is related to emissions of greenhouse gases to air. The characterization model as developed by the Intergovernmental Panel on Climate Change (IPCC) is selected for development of characterization factors. Factors are expressed as Global Warming Potential for time horizon 100 years (GWP100), in kg CO_2/kg emission. The geographic scope of this indicator is at global scale.
- **Ozone depletion, kg CFC 11 equivalents**. Because of stratospheric ozone depletion, a larger fraction of UV-B radiation reaches the earth surface. This can have harmful effects upon human health, animal health, terrestrial and aquatic ecosystems, biochemical cycles and on materials. This category is output-related and at global scale. The characterization model is developed by the World Meteorological Organization (WMO) and defines ozone depletion potential of different gasses (kg CFC^{-11} equivalent/ kg emission). The geographic scope of this indicator is at global scale. The time span is infinity.
- **Acidification of land and water, SO_2 equivalents.** Acidifying substances cause a wide range of impacts on soil, groundwater, surface water, organisms, ecosystems and materials (buildings). Acidification Potential (AP) for emissions to air is calculated with the adapted RAINS 10 model, describing the fate and deposition of acidifying substances. AP is expressed as kg SO_2 equivalents/ kg emission. The time span is eternity and the geographical scale varies between local scale and continental scale.
- **Eutrophication, $PO4^{3-}$ equivalents.** Eutrophication includes all impacts due to excessive levels of macro-nutrients in the environment caused by emissions of nutrients to air, water and soil. Nutrification potential (NP) is based on the stoichiometric procedure of Heijungs (1992), and expressed as kg PO_4 equivalents per kg emission. Fate and exposure are not included, time span is eternity, and the geographical scale varies between local and continental scale.
- **Photochemical ozone creation, C_2H_4 equivalents.** Photo-oxidant formation is the formation of reactive substances (mainly ozone) which are injurious to human health and ecosystems and which also may damage crops. This problem is also indicated with “summer smog”. Winter smog is outside the scope of this category. Photochemical Ozone Creation Potential (POCP) for emission of substances to air is calculated with the UNECE Trajectory model (including fate), and expressed in kg C_2H_4 equivalents/kg emission. The time span is 5 days and the geographical scale varies between local and continental scale.
- **Depletion of abiotic resources (elements / fossil), kg Sb equivalents/ MJ net calorific value.** This impact category is concerned with protection of human welfare, human health and ecosystem health. This impact category indicator is related to extraction of minerals and fossil fuels due to inputs in the system. The Abiotic Depletion Factor (ADF) is determined for each extraction of minerals and fossil fuels (kg antimony equivalents/kg extraction) based on concentration reserves and rate of de-accumulation. The geographic scope of this indicator is at global scale.

4.5 LCA report

This stage of EPD procedure consists in the LCA report redaction. The structure of LCA report follows the standard ISO- 14040/44 and it includes:

- Goal and scope definition
- Life Cycle inventory
- Impact assessment
- Interpretation

The content of these reports have been adapted in this deliverable on previous sections 4.2, 4.3 and 4.4 consequently LCA report for each technology has not included in this deliverable.

4.6 EPD report

In this phase, the information obtained in the LCA study has been extracted, adapted and written to respond to the requirements of the EPD verification program and the requirements set out in the reference PCR. According to the reference PCR "Construction products and construction services. Product group classification: multiple UN CPC codes 2012:01 version 2.01" as a general rule the EPD® content:

- Must be verifiable;
- Must not include rating, judgements or direct comparison with other products.

EPD content must include the following information [8]:

1. Declaration of general information
    - 1.1.1.Specification of the product
    - 1.1.2.Functional or declared unit
    - 1.1.3.Content declaration
    - 1.1.4.Flow diagram
    - 1.1.5.Technical information
2. Environmental performance-related information
    - 2.1.1.Rules for declaring information per module derived from lca
    - 2.1.2.Aggregation of information modules
    - 2.1.3.Potential environmental impact
    - 2.1.4.Use of resources
    - 2.1.5.Other indicators describing waste categories
    - 2.1.6.Release of dangerous substances during the use stage
3. Additional environmental information
4. Programme related information and mandatory statements
    - 4.1.1.Differences versus previous versions of the EPD
    - 4.1.2.Verification and registration

4.1.3.References

Finally, in the following sections a virtual EPD model for each product involved in LowUP project has been developed to simulate an estimate of how a real EPD would look and set the foundations for the potential development of an EPD for LowUP's products.

4.6.1 ENDEF

Environmental Product Declaration

"1 HYBRID PV PANEL"

Version 1.0

PCR - "Construction products and construction services, version 2.01".

CPC 546

ENDEF Solar Solutions

Address: Polígono Ciudad del Transporte, C/PA nº11San Juan de Mozarrifar, 50820

Zaragoza

Phone: +34 976 365 811

E-mail: info@endef.com

Program: The International EPD System, www.emvironde.com

Program operator: EPD International AB

Number registration: S-P-XXXXX

Issue date: dd/mm/year

Validity: dd/mm/year

H2020 Research and Innovation Actions (RIA)

723930_LowUP

"Low valued energy sources and industry uses"

1. DECLARATION OF GENERAL INFORMATION

1.1. SPECIFICATION OF THE PRODUCT

Hybrid solar panels simultaneously produce electricity and hot water. The combination of both technologies allows a better use of irradiation, producing more energy per surface than both technologies separately.

This EPD complies with the product's relevant materials and substances. In addition, the gross weight of material declared in this EPD is more than 99%, as stated by the regulation.

The main raw materials that constitute the PV panel are listed below, Table 12:

Table 12. ENDEF component resume

COMPONENT	AMOUNT	UNIT
PV laminate	38.0	% in mass
Aluminum for absorber, frame and rear-sheet	30.4	
Polyurethane foam	10.1	
PCM component	20.3	
Electronics	1.20	

1.2. FUNCTIONAL OR DECLARED UNIT

The Declared Unit considered in this EPD is "1 hybrid PV panel"

1.3. CONTENT DECLARATION

N.A.

1.4. FLOW DIAGRAM

The Table X below describes the scope of the inventory performed in the LCA. The EPD-type declared is a “Cradle-to gate” EPD

Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
Raw materials	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND
X: module is accounted in EPD; MND: module is not accounted in EPD																

Figure 10. International EPD® system Life Cycle stages

1.5. TECHNICAL INFORMATION

N.A

2. ENVIRONMENTAL PERFORMANCE-RELATED INFORMATION

2.1. RULES FOR DECLARING INFORMATION PER MODULE DERIVED FROM LCA

The system boundaries considered in this work have been a **“Cradle-to-gate” EPD**. Thus, this study has evaluated the impact from the extraction of raw materials until the product leaves the factory, see Figure 11. :

A1) Supply of raw materials:

- Extraction and processing of raw materials
- Extraction and processing of fuels.

A2) Transport to factory:

- External transportation of raw materials to the factory.

A3) Manufacturing:

- Manufacture of the product under analysis: energy and material consumption.
- Emissions from the plant.

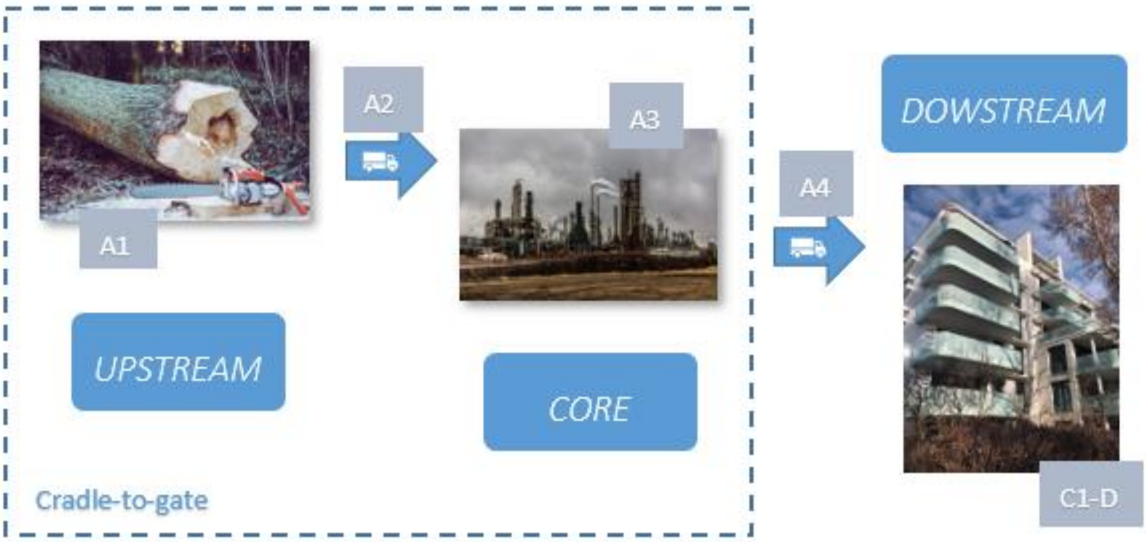


Figure 11. ENDEF EPD Boundaries

The geographic scope of this EPD is Europe.

2.2. AGGREGATION OF INFORMATION MODULES

No aggregation of information modules has been done.

2.3. POTENTIAL ENVIRONMENTAL IMPACT

According to reference PCR document and considering the geographical scope of this EPD the methodology used for the assessment of the environmental burdens has been CML-IA.

The assumptions considered in the LCA are listed below:

- Due to the lack of information of some transports has been assume 100 km
- The weight of connexion has been considered 0,5 kg

Finally, Table 13 shows the environmental profile of declared unit of this EPD.

Table 13. ENDEF Impact assessment

IMPACT CATEGORY	UNITS	STAGE			
		A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Global warming (GWP100)	kg CO2 equivalents	3.75E+02	1.84E+01	8.16E-02	3.93E+02
Ozone depletion	kg CFC ^{11} equivalents	9.65E-05	3.36E-06	1.21E-08	9.99E-05
Acidification of land and water	kg SO^2 equivalents	1.66E+00	4.35E-02	6.21E-04	1.70E+00
Eutrophication	$PO4^{3-}$ equivalents	8.44E-01	9.57E-03	1.42E-04	8.53E-01
Photochemical ozone creation	C2H4 equivalents	1.35E-01	2.22E-03	2.28E-05	1.37E-01
Depletion of abiotic resources (elements)	kg Sb equivalents	4.72E-02	4.59E-04	2.22E-07	4.77E-02
Depletion of abiotic resources (fossil)	MJ net calorific value	4.73E+03	2.73E+02	9.61E-01	5.01E+03

EPD of construction products may not be comparable if they do not comply with EN 15804 Environmental product declarations within the same product category from different programs may not be comparable

2.4. USE OF RESOURCES

Table 14 shows the use of renewable and nonrenewable material resources, renewable and non-renewable primary energy and water divided into the stages considered (A1 to A3).

Table 14. ENDEF use of resources

PARAMETER		UNITS	STAGE			
			A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Primary energy resources - Renewable	Use as energy carrier	MJ, net calorific value	1.52E+03	9.39E-01	4.65E-01	1,52E+03
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	0.00E+00	0,00E+00
	TOTAL	MJ, net calorific value	1.52E+03	9.39E-01	4.65E-01	0,00E+00
Primary energy resources – Non-Renewable	Use as energy carrier	MJ, net calorific value	6.44E+03	2.96E+02	2.05E+00	6,74E+03
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	0.00E+00	0,00E+00
	TOTAL	MJ, net calorific value	6.44E+03	2.96E+02	2.05E+00	6,74E+03
Secondary material		kg	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Net fresh water		m3	3,09	0.03	5.10E-04	3.12

2.5. OTHER INDICATORS DESCRIBING WASTE CATERGORIES

Table 15. ENDEF other indicators

Parameter	Unit (expressed per functional unit or per declared unit)
Hazardous waste disposed	3.35E-01
Non-hazardous waste disposed	7.27E+01
Radioactive waste disposed	2.58E-02

2.6. RELEASE OF DANGEROUS SUBSTANCES DURING THE USE STAGE

Use stage is not include in the scope

3. ADDITIONAL ENVIRONMENTAL INFORMATION

N.A.

4. PROGRAMME RELATED INFORMATION AND MANDATORY STATEMENTS

4.1. DIFFERENCES VERSUS PREVIOUS VERSIONS OF THE EPD

No previous EPD has been published.

4.2. VERIFICATION AND REGISTRATION

Table 16.CEN standard EN 15804 served as the core PCR

PCR:	PCR 2012:01 Construction products and Construction services, Version 2.01, 2016-03-09 *<name and date of sub-oriented PCR, if applicable>*
PCR review was conducted by:	The Technical Committee of the International EPD® System. Chair: Massimo Marino. Contact via info@environdec.com
Independent verification of the declaration and data, according to ISO 14025:	□ EPD process certification (Internal) □ EPD verification (External)
Third party verifier:	*<Name and contact information>*
Accredited or approved by:	*<Name of the accreditation body. >* *For individual verifiers: "The International EPD® System"*

4.3. REFERENCES

- ISO14040:2006. Environmental management. Life cycle assessment. Principles and framework.
- ISO14044:2006. Environmental management. Life cycle assessment. Requirements and guidelines.
- ISO 14025:2006: Environmental labels and declarations. Type III environmental declarations. Principles and
- procedures.
- General Programme Instructions of the International EPD® System. Version 3.0.
- PCR - “Construction products and construction services. Product group classification: multiple un CPC codes 2012:01 version 2.01".
- EN 15804:2012+A1:2014. Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

4.6.2 RDZ

Environmental Product Declaration

"100 m² of low thickness radiant floor"

Version 1.0

PCR - "Construction products and construction services, version 2.01".

CPC 546

RDZ S. p. A.

Address: Viale Trento, 101, 33077 SACILE (PN) ITALY

Phone: +39 0434 787511

E-mail: info@rdz.it

Program: The International EPD System, www.emvironde.com

Program operator: EPD International AB

Number registration: S-P-XXXXX

Issue date: dd/mm/year

Validity: dd/mm/year

European Commission | Horizon 2020 European Union funding for Research & Innovation

H2020 Research and Innovation Actions (RIA)

723930_LowUP

"Low valued energy sources and industry uses"

1. DECLARATION OF GENERAL INFORMATION

1.1. SPECIFICATION OF THE PRODUCT

DRY system is RDZ radiant floor system without concrete, representing the ideal solution for applications with minimal height (30 mm, flooring excluded). The panel made of sintered polystyrene is characterized by studs and special grooves to contain thermal diffusers holding the pipe. The supporting base consists of a double layer of zinc-plated steel plates, stuck one onto the other. This makes it possible to replace the concrete and ensures uniform distribution of the load.

This EPD complies with the product's relevant materials and substances. In addition, the gross weight of material declared in this EPD is more than 99%, as stated by the regulation.

The main raw materials that constitute the radiant floor system are listed below, Table 17:

Table 17.RDZ component resume

COMPONENT	AMOUNT	UNITS
Dry-tech panels	13.7	% in mass
Polyethylene piping	8.55	
Aluminum plates	61.4	
Humidity barrier and insulation perimeter belt	1.75	
Control cabinet	1.08	
Thermal diffusers	12.1	
Auxiliary materials	1.46	

1.2. FUNCTIONAL OR DECLARED UNIT

The Declared Unit considered in this EPD is "100 m^2 of low thickness radiant floor"

1.3. CONTENT DECLARATION

N.A.

1.4. FLOW DIAGRAM

Figure 12 describes the scope of the inventory performed in the LCA. The EPD-type declared is a “Cradle-to gate” EPD

Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
Raw materials	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND
X: module is accounted in EPD; MND: module is not accounted in EPD																

Figure 12. International EPD® system Life Cycle stages

1.5. TECHNICAL INFORMATION

N.A.

2. ENVIRONMENTAL PERFORMANCE-RELATED INFORMATION

2.1. RULES FOR DECLARING INFORMATION PER MODULE DERIVED FROM LCA

The system boundaries considered in this work have been a "**Cradle-to-gate" EPD**. Thus, this study has evaluated the impact from the extraction of raw materials until the product leaves the factory, see Figure 13:

A1) Supply of raw materials:

- Extraction and processing of raw materials
- Extraction and processing of fuels.

A2) Transport to factory:

- External transportation of raw materials to the factory.

A3) Manufacturing: No data is available, thus this stage has been not included in the assessment

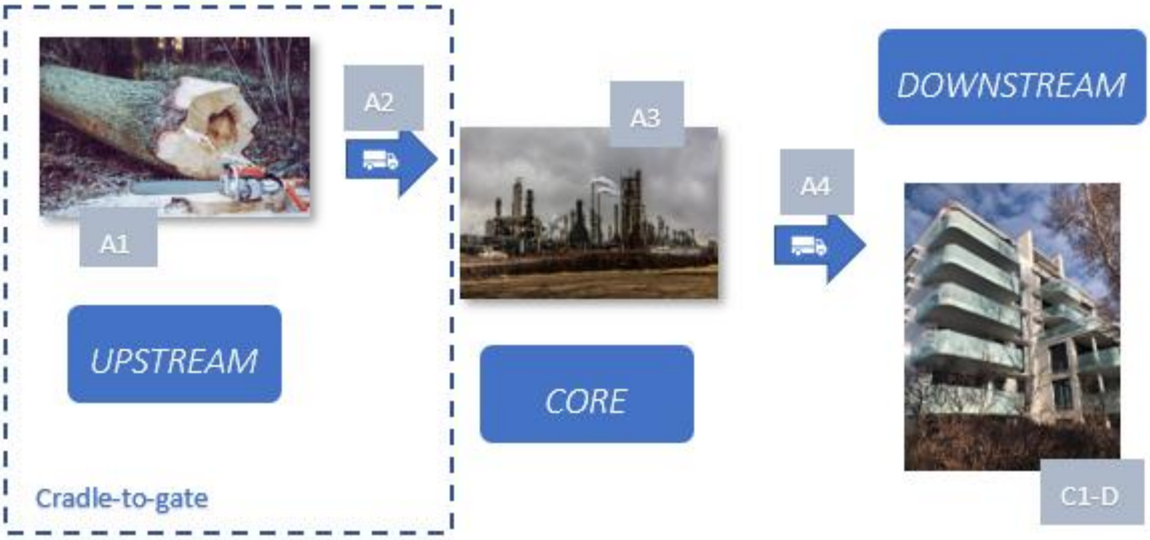


Figure 13. RDZ EPD boundaries

The geographic scope of this EPD is Europe.

2.2. AGGREGATION OF INFORMATION MODULES

No aggregation of information modules has been done.

2.3. POTENTIAL ENVIRONMENTAL IMPACT

According to reference PCR document and considering the geographical scope of this EPD the methodology used for the assessment of the environmental burdens has been CML-IA.

Finally, Table 18 shows the environmental profile of declared unit of this EPD.

Table 18. RDZ Impact assessment

IMPACT CATEGORY	UNITS	STAGE			
		A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Global warming (GWP100)	kg CO2 equivalents	8.57E+03	3.71E+02	-	8.94E+03
Ozone depletion	kg CFC ^{11} equivalents	8.64E-04	6.79E-05	-	9.32E-04
Acidification of land and water	kg SO^2 equivalents	4.85E+01	8.78E-01	-	4.94E+01
Eutrophication	$PO4^{3-}$ equivalents	1.85E+01	1.93E-01	-	1.87E+01
Photochemical ozone creation	C2H4 equivalents	4.46E+00	4.48E-02	-	4.50E+00
Depletion of abiotic resources (elements)	kg Sb equivalents	4.52E-01	9.32E-03	-	4.61E-01
Depletion of abiotic resources (fossil)	MJ net calorific value	1.08E+05	5.50E+03	-	1.14E+05

EPD of construction products may not be comparable if they do not comply with EN 15804 Environmental product declarations within the same product category from different programs may not be comparable

2.4. USE OF RESOURCES

Table 19 shows the use of renewable and nonrenewable material resources, renewable and non-renewable primary energy and water divided into the stages considered (A1 to A3).

Table 19. RDZ use of resources

PARAMETER		UNITS	STAGE			
			A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Primary energy resources - Renewable	Use as energy carrier	MJ, net calorific value	3.81E+04	8.59E+01	-	3,82E+04
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	-	0,00E+00
	TOTAL	MJ, net calorific value	3.81E+04	8.59E+01	0.00E+00	3,82E+04
Primary energy resources – Non-Renewable	Use as energy carrier	MJ, net calorific value	1.51E+05	5.97E+03	-	1,57E+05
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	-	0,00E+00
	TOTAL	MJ, net calorific value	1.51E+05	5.97E+03	0.00E+00	1,57E+05
Secondary material		kg	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Net fresh water		m3	73,7	0.978	-	74.7

2.5. OTHER INDICATORS DESCRIBING WASTE CATERGORIES

Table 20. RDZ other indicators

Parameter	Unit (expressed per functional unit or per declared unit)
Hazardous waste disposed	4.22E+00
Non-hazardous waste disposed	2.16E+03
Radioactive waste disposed	6.60E-01

2.6. RELEASE OF DANGEROUS SUBSTANCES DURING THE USE STAGE

Use stage is not include in the scope

3. ADDITIONAL ENVIRONMENTAL INFORMATION

N.A.

4. PROGRAMME RELATED INFORMATION AND MANDATORY STATEMENTS

4.1. DIFFERENCES VERSUS PREVIOUS VERSIONS OF THE EPD

No previous EPD has been published.

4.2. VERIFICATION AND REGISTRATION

Table 21.CEN standard EN 15804 served as the core PCR

PCR:	PCR 2012:01 Construction products and Construction services, Version 2.01, 2016-03-09 *<name and date of sub-oriented PCR, if applicable>*
PCR review was conducted by:	The Technical Committee of the International EPD® System. Chair: Massimo Marino. Contact via info@environdec.com
Independent verification of the declaration and data, according to ISO 14025:	□ EPD process certification (Internal) □ EPD verification (External)
Third party verifier:	*<Name and contact information>*
Accredited or approved by:	*<Name of the accreditation body. >* *For individual verifiers: "The International EPD® System"*

4.3. REFERENCES

- ISO14040:2006. Environmental management. Life cycle assessment. Principles and framework.
- ISO14044:2006. Environmental management. Life cycle assessment. Requirements and guidelines.
- ISO 14025:2006: Environmental labels and declarations. Type III environmental declarations. Principles and
- procedures.
- General Programme Instructions of the International EPD® System. Version 3.0.
- PCR - "Construction products and construction services. Product group classification: multiple un CPC codes 2012:01 version 2.01".
- EN 15804:2012+A1:2014. Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

4.6.3 WASENCO

Environmental Product Declaration

“1 hybrid heat recovery system”

Version 1.0

PCR - “Construction products and construction services, version 2.01".

CPC 546

Wasenco Oy.

Address: Lakkilantie 4, 15150 Lahti, Finland

Phone: +358 40 824 8823

E-mail: info@wasenco.com

Program: The International EPD System, www.emvironde.com

Program operator: EPD International AB

Number registration: S-P-XXXXX

Issue date: dd/mm/year

Validity: dd/mm/year

H2020 Research and Innovation Actions (RIA)

723930_LowUP

“Low valued energy sources and industry uses”

1. DECLARATION OF GENERAL INFORMATION

1.1. SPECIFICATION OF THE PRODUCT

WASENCO's hybrid heat exchanger has been conceived to improve the efficiency in recovering thermal energy from wastewater and other sources of residual heat, including exhaust air, cooling processes, and auxiliary power systems. Depending on the heating system connection types and a direction of waste water flow, the heat recovery efficiency varies between 20 – 80 % of waste water.

This EPD complies with the product's relevant materials and substances. In addition, the gross weight of material declared in this EPD is more than 99%, as stated by the regulation.

The main raw materials that constitute the heat recovery system are listed below, see Table 22:

Table 22. WASENCO component resume

COMPONENT	AMOUNT	UNITS
Stainless steel	100	% in mass

1.2. FUNCTIONAL OR DECLARED UNIT

The Declared Unit considered in this EPD is "1 hybrid heat recovery system"

1.3. CONTENT DECLARATION

N.A.

1.4. FLOW DIAGRAM

The **Figure 14. International EPD® system Life Cycle stages** below describes the scope of the inventory performed in the LCA. The EPD-type declared is a "Cradle-to gate" EPD

Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
Raw materials	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND
X: module is accounted in EPD; MND: module is not accounted in EPD																

Figure 14. International EPD® system Life Cycle stages

1.5. TECHNICAL INFORMATION

N.A.

2. ENVIRONMENTAL PERFORMANCE-RELATED INFORMATION

2.1. RULES FOR DECLARING INFORMATION PER MODULE DERIVED FROM LCA

The system boundaries considered in this work have been a “**Cradle-to-gate” EPD**. Thus, this study has evaluated the impact from the extraction of raw materials until the product leaves the factory, see **Figure 15**

A1) Supply of raw materials:

- Extraction and processing of raw materials
- Extraction and processing of fuels.

A2) Transport to factory:

- External transportation of raw materials to the factory.

A3) Manufacturing:

- Manufacture of the product under analysis: energy and material consumption.
- Emissions from the plant.

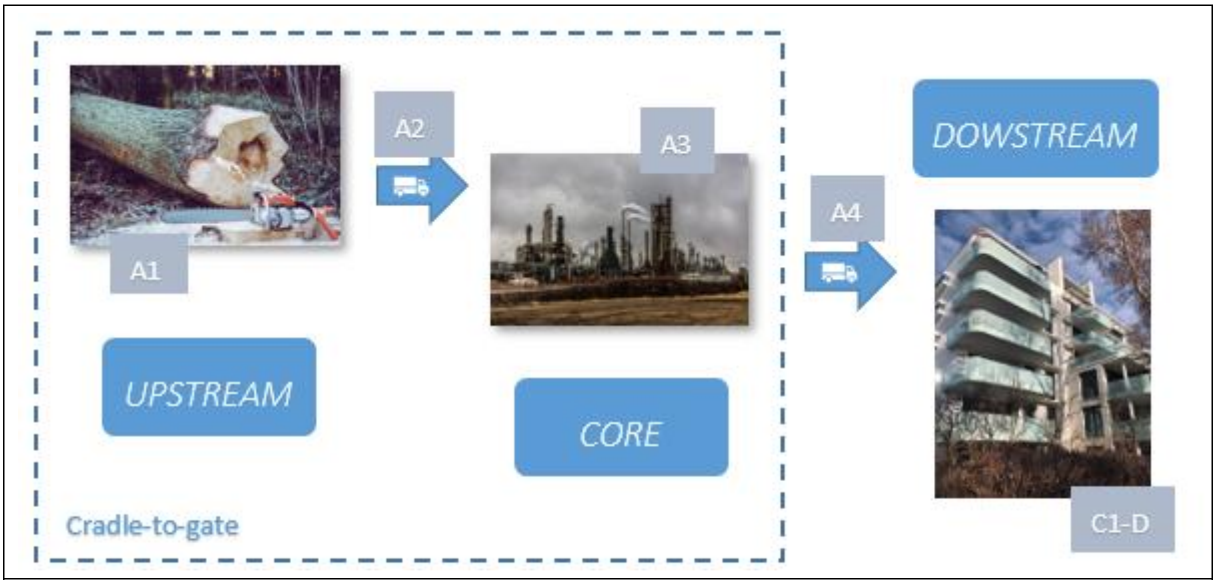


Figure 15. WASENCO EPD boundaries

The geographic scope of this EPD is Europe.

2.2. AGGREGATION OF INFORMATION MODULES

No aggregation of information modules has been done.

2.3. POTENTIAL ENVIRONMENTAL IMPACT

According to reference PCR document and considering the geographical scope of this EPD the methodology used to assess the environmental burdens has been CML-IA.

Finally, **Table 23** shows the environmental profile of declared unit of this EPD.

Table 23. WASENCO impact assessment

IMPACT CATEGORY	UNITS	STAGE			
		A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Global warming (gwp_{100})	kg CO_2 equivalents	7.33E+02	1.98E+01	3.26E+01	7.85E+02
Ozone depletion	kg CFC ^{11} equivalents	3.62E-05	3.63E-06	7.34E-06	4.72E-05
Acidification of land and water	kg SO^2 equivalents	3.84E+00	4.70E-02	1.18E-01	4.00E+00
Eutrophication	PO_4^{3-} equivalents	1.27E+00	1.03E-02	5.13E-02	1.34E+00
Photochemical ozone creation	C_2H_4 equivalents	2.37E-01	2.39E-03	5.52E-03	2.45E-01
Depletion of abiotic resources (elements)	kg Sb equivalents	2.72E-02	4.99E-04	1.41E-04	2.78E-02
Depletion of abiotic resources (fossil)	MJ net calorific value	7.18E+03	2.94E+02	3.25E+02	7.80E+03

EPD of construction products may not be comparable if they do not comply with EN 15804 Environmental product declarations within the same product category from different programs may not be comparable

2.4. USE OF RESOURCES

Table 24 shows the use of renewable and nonrenewable material resources, renewable and non-renewable primary energy and water divided into the stages considered (A1 to A3).

Table 24.WASENCO use of resources

PARAMETER		UNITS	STAGE			
			A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Primary energy resources - Renewable	Use as energy carrier	MJ, net calorific value	2.03E+03	4.64E+00	3.30E+02	2,37E+03
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	0.00E+00	0,00E+00
	TOTAL	MJ, net calorific value	2.03E+03	4.64E+00	3.30E+02	2,37E+03
Primary energy resources – Non-Renewable	Use as energy carrier	MJ, net calorific value	8.35E+03	3.20E+02	1.12E+03	9,79E+03
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	0.00E+00	0,00E+00
	TOTAL	MJ, net calorific value	8.35E+03	3.20E+02	1.12E+03	9,79E+03
Secondary material		kg	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Net fresh water		m3	4,67	0.031	0.287	4.99

2.5. OTHER INDICATORS DESCRIBING WASTE CATERGORIES

Table 25. WASENCO Other indicators

Parameter	Unit (expressed per functional unit or per declared unit)
Hazardous waste disposed	1.64E-02
Non-hazardous waste disposed	8.65E+02
Radioactive waste disposed	3.25E-02

2.6. RELEASE OF DANGEROUS SUBSTANCES DURING THE USE STAGE

Use stage is not include in the scope

3. ADDITIONAL ENVIRONMENTAL INFORMATION

N.A.

4. PROGRAMME RELATED INFORMATION AND MANDATORY STATEMENTS

4.1. DIFFERENCES VERSUS PREVIOUS VERSIONS OF THE EPD

No previous EPD has been published.

4.2. VERIFICATION AND REGISTRATION

Table 26.CEN standard EN 15804 served as the core PCR

PCR:	PCR 2012:01 Construction products and Construction services, Version 2.01, 2016-03-09 *<name and date of sub-oriented PCR, if applicable>*
PCR review was conducted by:	The Technical Committee of the International EPD® System. Chair: Massimo Marino. Contact via info@environdec.com
Independent verification of the declaration and data, according to ISO 14025:	□ EPD process certification (Internal) □ EPD verification (External)
Third party verifier:	*<Name and contact information>*
Accredited or approved by:	*<Name of the accreditation body. >* *For individual verifiers: "The International EPD® System"*

4.3. REFERENCES

- ISO14040:2006. Environmental management. Life cycle assessment. Principles and framework.
- ISO14044:2006. Environmental management. Life cycle assessment. Requirements and guidelines.
- ISO 14025:2006: Environmental labels and declarations. Type III environmental declarations. Principles and
- procedures.
- General Programme Instructions of the International EPD® System. Version 3.0.
- PCR - "Construction products and construction services. Product group classification: multiple un CPC codes 2012:01 version 2.01".
- EN 15804:2012+A1:2014. Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

4.6.4 ENTROPY

Environmental Product Declaration

“1 STRATIFIED ACCUMULATION TANK”

Version 1.0

PCR - “Construction products and construction services, version 2.01".

CPC 546

Entropy Care Systems

Address: Avinguda Anoia, Número 2 08787, La Pobla de Claramunt, Barcelona.

Email: contacto@entropycs.eu

Program: The International EPD System, www.emvironde.com

Program operator: EPD International AB

Number registration: S-P-XXXXX

Issue date: dd/mm/year

Validity: dd/mm/year

H2020 Research and Innovation Actions (RIA)

723930_LowUP

“Low valued energy sources and industry uses”

1. DECLARATION OF GENERAL INFORMATION

1.1. SPECIFICATION OF THE PRODUCT

Entropy's stratification tank is designed to store heat from water for later releasing it as water heating or space heating. As a result, it achieves optimum management of the different heat sources and sinks through the stratified storage of the water.

This EPD complies with the product's relevant materials and substances. In addition, the gross weight of material declared in this EPD is more than 99%, as stated by the regulation.

The main raw materials that constitute the stratified accumulation tank are listed below, see **Table 27**:

Table 27.ENTROPY component resume

COMPONENT	AMOUNT	UNITS
Steel	86.78	% in mass
Polypropylene	2.20	
Polyamide	3.25	
Polyester fibres	7.77	

1.2. FUNCTIONAL OR DECLARED UNIT

The Declared Unit considered in this EPD is "1 stratified accumulation tank".

1.3. CONTENT DECLARATION

N.A.

1.4. FLOW DIAGRAM

Figure 16 describes the scope of the inventory performed in the LCA. The EPD-type declared is a "Cradle-to gate" EPD

Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
Raw materials	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND
X: module is accounted in EPD; MND: module is not accounted in EPD																

Figure 16. International EPD® system Life Cycle stages

1.5. TECHNICAL INFORMATION

N.A.

2. ENVIRONMENTAL PERFORMANCE-RELATED INFORMATION

2.1. RULES FOR DECLARING INFORMATION PER MODULE DERIVED FROM LCA

The system boundaries considered in this work have been a **"Cradle-to-gate" EPD**. Thus, this study has evaluated the impact from the extraction of raw materials until the product leaves the factory, see Figure 17:

A1) Supply of raw materials:

- Extraction and processing of raw materials
- Extraction and processing of fuels.

A2) Transport to factory:

- External transportation of raw materials to the factory.

A3) Manufacturing:

- Manufacture of the product under analysis: energy and material consumption.
- Emissions from the plant.

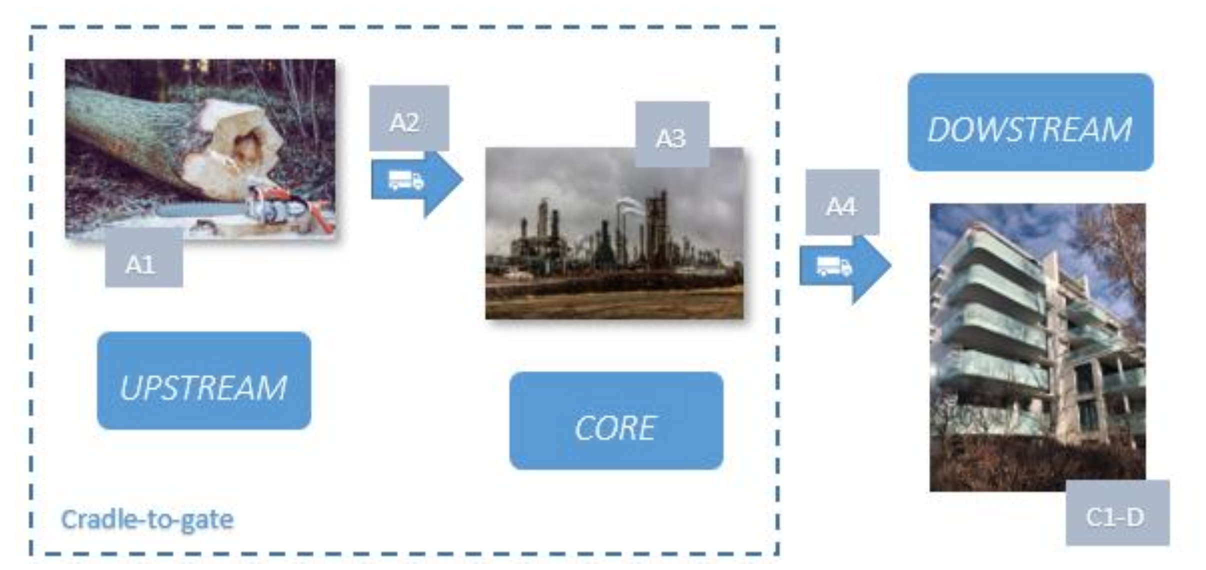


Figure 17. ENTROPY EPD boundaries

The geographic scope of this EPD is Europe.

2.2. AGGREGATION OF INFORMATION MODULES

No aggregation of information modules has been done.

2.3. POTENTIAL ENVIRONMENTAL IMPACT

According to reference PCR document and considering the geographical scope of this EPD the methodology used for the assessment of the environmental burdens has been CML-IA.
The assumptions considered in the LCA are listed below:

- PP Density: 905 kg/m3;
- PP-RCT 125mm: Volume: 0.029 m3
- PP-RCT 32 mm: Volume: 0.001 m3
- PP-RCT 69 mm: Volume: 0.05 m3

Finally, Table 28 shows the environmental profile of declared unit of this EPD.

Table 28. ENTROPY impact assessment

IMPACT CATEGORY	UNITS	STAGE			
		A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Global warming (gwp100)	kg CO_2 equivalents	3.09E+03	4.65E+01	6.18E+01	3.20E+03
Ozone depletion	kg CFC ^{11} equivalents	1.48E-04	8.50E-06	9.17E-06	1.66E-04
Acidification of land and water	kg SO^2 equivalents	1.53E+01	1.10E-01	4.70E-01	1.59E+01
Eutrophication	PO_4^{3-} equivalents	5.10E+00	2.42E-02	1.08E-01	5.23E+00
Photochemical ozone creation	C_2H_4 equivalents	9.36E-01	5.61E-03	1.73E-02	9.59E-01
Depletion of abiotic resources (elements)	kg Sb equivalents	1.03E-01	1.17E-03	1.68E-04	1.05E-01
Depletion of abiotic resources (fossil)	MJ net calorific value	3.47E+04	6.90E+02	7.28E+02	3.61E+04

EPD of construction products may not be comparable if they do not comply with EN 15804 Environmental product declarations within the same product category from different programs may not be comparable

2.4. USE OF RESOURCES

Table 29 shows the use of renewable and nonrenewable material resources, renewable and non-renewable primary energy and water divided into the stages considered (A1 to A3).

Table 29.ENTROPY use of resources

PARAMETER		UNITS	STAGE			
			A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Primary energy resources - Renewable	Use as energy carrier	MJ, net calorific value	7.68E+03	1.08E+01	3.52E+02	8,05E+03
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	0.00E+00	0,00E+00
	TOTAL	MJ, net calorific value	7.68E+03	1.08E+01	3.52E+02	8,05E+03
Primary energy resources – Non-Renewable	Use as energy carrier	MJ, net calorific value	4.03E+04	7.48E+02	1.55E+03	4,26E+04
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	0.00E+00	0,00E+00
	TOTAL	MJ, net calorific value	7.68E+03	1.08E+01	3.52E+02	8,05E+03
Secondary material		kg	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Net fresh water		m3	24,4	0.075	0.291	24.7

2.5. OTHER INDICATORS DESCRIBING WASTE CATERGORIES

Table 30. ENTROPY other indicators

Parameter	Unit (expressed per functional unit or per declared unit)
Hazardous waste disposed	3.18E-01
Non-hazardous waste disposed	3.15E+03
Radioactive waste disposed	9.28E-02

2.6. RELEASE OF DANGEROUS SUBSTANCES DURING THE USE STAGE

The “Use” stage is not included in the scope of this EPD.

3. ADDITIONAL ENVIRONMENTAL INFORMATION

N.A.

4. PROGRAMME RELATED INFORMATION AND MANDATORY STATEMENTS

4.1. DIFFERENCES VERSUS PREVIOUS VERSIONS OF THE EPD

No previous EPD has been published.

4.2. VERIFICATION AND REGISTRATION

Table 31.CEN standard EN 15804 served as the core PCR

PCR:	PCR 2012:01 Construction products and Construction services, Version 2.01, 2016-03-09 *<name and date of sub-oriented PCR, if applicable>*
PCR review was conducted by:	The Technical Committee of the International EPD® System. Chair: Massimo Marino. Contact via info@environdec.com
Independent verification of the declaration and data, according to ISO 14025:	□ EPD process certification (Internal) □ EPD verification (External)
Third party verifier:	*<Name and contact information>*
Accredited or approved by:	*<Name of the accreditation body. >* *For individual verifiers: “The International EPD® System”*

4.3. REFERENCES

- ISO14040:2006. Environmental management. Life cycle assessment. Principles and framework.
- ISO14044:2006. Environmental management. Life cycle assessment. Requirements and guidelines.
- ISO 14025:2006: Environmental labels and declarations. Type III environmental declarations. Principles and
- procedures.
- General Programme Instructions of the International EPD® System. Version 3.0.
- PCR - "Construction products and construction services. Product group classification: multiple un CPC codes 2012:01 version 2.01".
- EN 15804:2012+A1:2014. Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

4.6.5 FAFCO

Environmental Product Declaration

"1 PCM STORAGE SYSTEM FOR SPACE COOLING"

Version 1.0

PCR - "Construction products and construction services, version 2.01".

CPC 546

FAFCO
Address: 5c street of the day's point
21800 Chevigny-Saint-Sauveur
France.
Teléfono: 33 3 80 44 90 60
Email: contact@fafco.fr

Program: The International EPD System, www.emvironde.com

Program operator: EPD International AB

Number registration: S-P-XXXXX

Issue date: dd/mm/year

Validity: dd/mm/year

European Commission | Horizon 2020 European Union funding for Research & Innovation

H2020 Research and Innovation Actions (RIA)
723930_LowUP
"Low valued energy sources and industry uses"

1. DECLARATION OF GENERAL INFORMATION

1.1. SPECIFICATION OF THE PRODUCT

FAFCO's thermal storage system accumulates energy using a Phase Change Material with a low fusion temperature.

This EPD complies with the product's relevant materials and substances. In addition, the gross weight of material declared in this EPD is more than 99%, as stated by the regulation.

The main raw materials that constitute the PCM system are listed below, see **Table 32**:

Table 32. FAFCO component resume

COMPONENT	AMOUNT	UNITS
Polypropylene	1.77	% in mass
Phase change material PCP10.	77.9	
Stainless steel	18.4	
Polystyrene for insulation	1.23	
EPDM for lining	0.65	
Coating and pigments.	0.06	

1.2. FUNCTIONAL OR DECLARED UNIT

The Declared Unit considered in this EPD is "1 PCM storage system for space cooling".

1.3. CONTENT DECLARATION

N.A.

1.4. FLOW DIAGRAM

Figure 18 describes the scope of the inventory performed in the LCA. The EPD-type declared is a “Cradle-to gate” EPD

Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
Raw materials	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND
X: module is accounted in EPD; MND: module is not accounted in EPD																

Figure 18. International EPD® system Life Cycle stages

1.5. TECHNICAL INFORMATION

N.A.

2. ENVIRONMENTAL PERFORMANCE-RELATED INFORMATION

2.1. RULES FOR DECLARING INFORMATION PER MODULE DERIVED FROM LCA

The system boundaries considered in this work have been a "**Cradle-to-gate" EPD**. Thus, this study has evaluated the impact from the extraction of raw materials until the product leaves the factory, see Figure 19:

A1) Supply of raw materials:

- Extraction and processing of raw materials
- Extraction and processing of fuels.

A2) Transport to factory:

- External transportation of raw materials to the factory.

A3) Manufacturing: No data is available, thus, this stage has been not included in the assessment

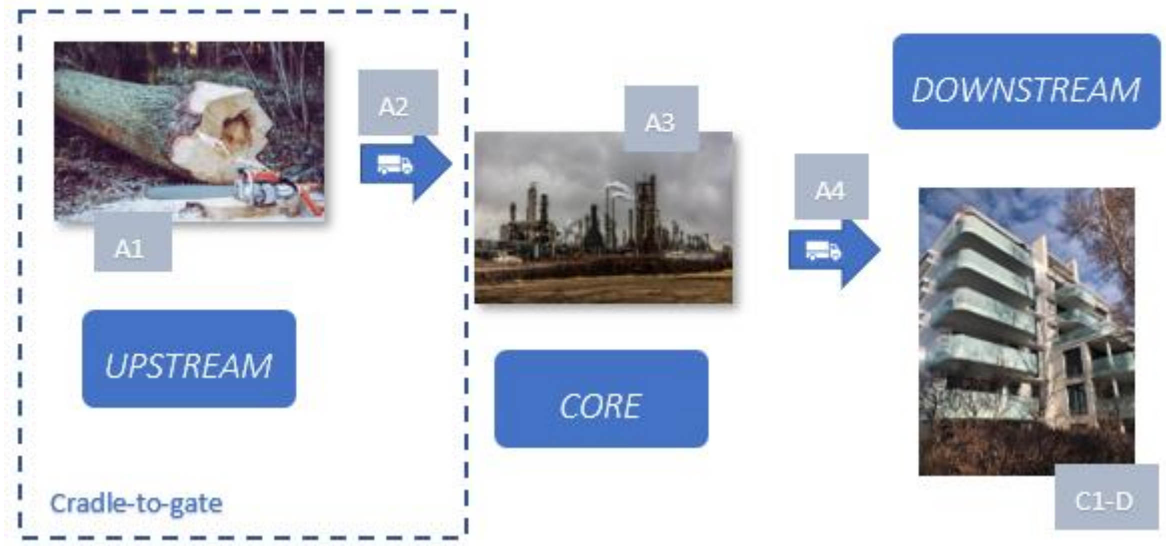


Figure 19. FAFCO EPD boundaries

The geographic scope of this EPD is Europe.

2.2. AGGREGATION OF INFORMATION MODULES

No aggregation of information modules has been done.

2.3. POTENTIAL ENVIRONMENTAL IMPACT

According to reference PCR document and considering the geographical scope of this EPD the methodology used for the assessment of the environmental burdens has been CML-IA.

The assumptions considered in the LCA are listed below:

- Phase change material. Sodium formate used as proxy material.

Finally, Table 33**Table 1** shows the environmental profile of declared unit of this EPD.

Table 33. FAFCO impact assessment

IMPACT CATEGORY	UNITS	STAGE			
		A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Global warming (gwp_{100})	kg CO_2 equivalents	8.81E+03	2.25E+02	-	9.03E+03
Ozone depletion	kg CFC ^{11} equivalents	1.09E-02	4.35E-05	-	1.09E-02
Acidification of land and water	kg SO^2 equivalents	4.55E+01	5.75E-01	-	4.61E+01
Eutrophication	$PO_4{}^{3-}$ equivalents	1.57E+01	1.25E-01	-	1.58E+01
Photochemical ozone creation	C_2H_4 equivalents	2.51E+00	2.75E-02	-	2.54E+00
Depletion of abiotic resources (elements)	kg Sb equivalents	2.06E-01	4.22E-03	-	2.10E-01
Depletion of abiotic resources (fossil)	MJ net calorific value	1.30E+05	3.53E+03	-	1.33E+05

EPD of construction products may not be comparable if they do not comply with EN 15804 Environmental product declarations within the same product category from different programs may not be comparable

2.4. USE OF RESOURCES

Table 34 shows the use of renewable and nonrenewable material resources, renewable and non-renewable primary energy and water divided into the stages considered (A1 to A3).

Table 34. FAFCO use of resources

PARAMETER		UNITS	STAGE			
			A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Primary energy resources - Renewable	Use as energy carrier	MJ, net calorific value	1.06E+04	4.95E+01	-	1,07E+04
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	-	0,00E+00
	TOTAL	MJ, net calorific value	1.06E+04	4.95E+01	-	0,00E+00
Primary energy resources – Non-Renewable	Use as energy carrier	MJ, net calorific value	1.55E+05	3.82E+03	-	1,59E+05
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	-	0,00E+00
	TOTAL	MJ, net calorific value	1.55E+05	3.82E+03	-	1,59E+05
Secondary material		kg	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Net fresh water		m3	64,5	0.686	-	65.2

2.5. OTHER INDICATORS DESCRIBING WASTE CATERGORIES

Table 35. FAFCO other indicators

Parameter	Unit (expressed per functional unit or per declared unit)
Hazardous waste disposed	2.47E-01
Non-hazardous waste disposed	1.38E+03
Radioactive waste disposed	6.12E-01

2.6. RELEASE OF DANGEROUS SUBSTANCES DURING THE USE STAGE

Use stage is not include in the scope

3. ADDITIONAL ENVIRONMENTAL INFORMATION

N.A.

4. PROGRAMME RELATED INFORMATION AND MANDATORY STATEMENTS

4.1. DIFFERENCES VERSUS PREVIOUS VERSIONS OF THE EPD

No previous EPD has been published.

4.2. VERIFICATION AND REGISTRATION

Table 36.CEN standard EN 15804 served as the core PCR

PCR:	PCR 2012:01 Construction products and Construction services, Version 2.01, 2016-03-09 *<name and date of sub-oriented PCR, if applicable>*
PCR review was conducted by:	The Technical Committee of the International EPD® System. Chair: Massimo Marino. Contact via info@environdec.com
Independent verification of the declaration and data, according to ISO 14025:	□ EPD process certification (Internal) □ EPD verification (External)
Third party verifier:	*<Name and contact information>*
Accredited or approved by:	*<Name of the accreditation body. >* *For individual verifiers: "The International EPD® System"*

4.3. REFERENCES

- ISO14040:2006. Environmental management. Life cycle assessment. Principles and framework.
- ISO14044:2006. Environmental management. Life cycle assessment. Requirements and guidelines.
- ISO 14025:2006: Environmental labels and declarations. Type III environmental declarations. Principles and
- procedures.
- General Programme Instructions of the International EPD® System. Version 3.0.
- PCR - "Construction products and construction services. Product group classification: multiple un CPC codes 2012:01 version 2.01".
- EN 15804:2012+A1:2014. Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

4.6.6 HALTON

Environmental Product Declaration

"1 HIGH-EFFICIENCY CHILLED BEAM (HALTON REX 600)"

Version 1.0

PCR - "Construction products and construction services, version 2.01".

CPC 546

Halton
Address: 12, rue Saint Germain 60 80,0 Crépy-en-Valois
FRANCE
Phone: + 33(0)3 44 94 60 70
E-mail: contacts.fr@halton.com

Program: The International EPD System,
www.emvironde.com

Program operator: EPD International AB

Number registration: S-P-XXXXX

Issue date: dd/mm/year

Validity: dd/mm/year

H2020 Research and Innovation Actions (RIA)
723930_LowUP
"Low valued energy sources and industry uses"

European Commission | Horizon 2020 European Union funding for Research & Innovation

1. DECLARATION OF GENERAL INFORMATION

1.1. SPECIFICATION OF THE PRODUCT

Halton Rex 600 chilled beam offers combined cooling, heating, and supply air unit for flush installation within a suspended ceiling. The system is well suited for spaces with high cooling loads, low humidity load, and variable ventilation requirements. It is also the ideal solution for applications where high-quality environmental conditions, demand-based ventilation, and individual room control are appreciated.

This EPD complies with the product's relevant materials and substances. In addition, the gross weight of material declared in this EPD is more than 99%, as stated by the regulation.

The main raw materials that constitute the chilled beam are listed below see Table 37:

Table 37. FAFCO Component resume

COMPONENT	AMOUNT	UNITS
Steel.	81.34	% in mass
Aluminum	10.51	
Copper	7.29	
Polyacetal	0.59	
Polyethylene foam	0.27	

1.2. FUNCTIONAL OR DECLARED UNIT

The Declared Unit considered in this EPD is "1 high-efficiency chilled beam (model Halton Rex 600)"

1.3. CONTENT DECLARATION

N.A.

1.4. FLOW DIAGRAM

Figure 20 describes the scope of the inventory performed in the LCA. The EPD-type declared is a "Cradle-to gate" EPD

Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
Raw materials	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND
X: module is accounted in EPD; MND: module is not accounted in EPD																

Figure 20. International EPD® system Life Cycle stages

1.5. TECHNICAL INFORMATION

N.A.

2. ENVIRONMENTAL PERFORMANCE-RELATED INFORMATION

2.1. RULES FOR DECLARING INFORMATION PER MODULE DERIVED FROM LCA

The system boundaries considered in this work have been a “**Cradle-to-gate” EPD**. Thus, this study has evaluated the impact from the extraction of raw materials until the product leaves the factory, see Figure 21:

A1) Supply of raw materials:

- Extraction and processing of raw materials
- Extraction and processing of fuels.

A2) Transport to factory:

- External transportation of raw materials to the factory.

A3) Manufacturing: No data is available, thus, this stage has been not included in the assessment

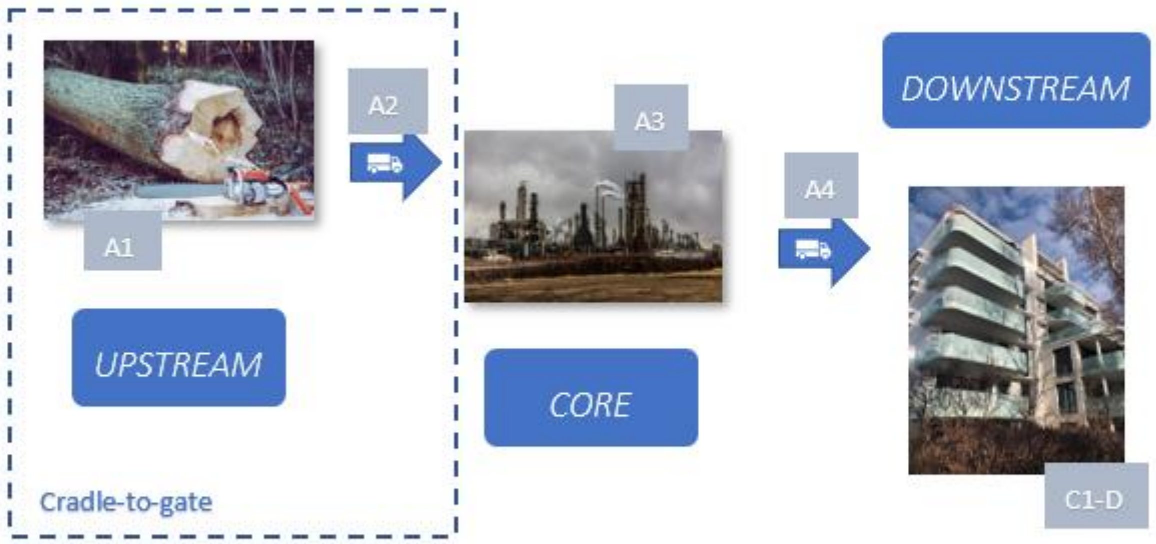


Figure 21. FAFCO EPD boundaries

The geographic scope of this EPD is Europe.

2.2. AGGREGATION OF INFORMATION MODULES

No aggregation of information modules has been done.

2.3. POTENTIAL ENVIRONMENTAL IMPACT

According to reference PCR document and considering the geographical scope of this EPD the methodology used for the assessment of the environmental burdens has been CML-IA.

The assumptions considered in the LCA are listed below:

- Due to the lack of information of some transports has been assume 100 km

Finally, Table 38 shows the environmental profile of declared unit of this EPD.

Table 38. FAFCO impact assessment

IMPACT CATEGORY	UNITS	STAGE			
		A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Global warming (gwp100)	kg CO2 equivalents	8.81E+03	2.25E+02	-	9.03E+03
Ozone depletion	kg CFC ^{11} equivalents	1.09E-02	4.35E-05	-	1.09E-02
Acidification of land and water	kg SO^2 equivalents	4.55E+01	5.75E-01	-	4.61E+01
Eutrophication	$PO4^{3-}$ equivalents	1.57E+01	1.25E-01	-	1.58E+01
Photochemical ozone creation	C2H4 equivalents	2.51E+00	2.75E-02	-	2.54E+00
Depletion of abiotic resources (elements)	kg Sb equivalents	2.06E-01	4.22E-03	-	2.10E-01
Depletion of abiotic resources (fossil)	MJ net calorific value	1.30E+05	3.53E+03	-	1.33E+05

EPD of construction products may not be comparable if they do not comply with EN 15804 Environmental product declarations within the same product category from different programs may not be comparable

2.4. USE OF RESOURCES

Table 39 shows the use of renewable and nonrenewable material resources, renewable and non-renewable primary energy and water divided into the stages considered (A1 to A3).

Table 39. FAFCO use of resources

PARAMETER		UNITS	STAGE			
			A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Primary energy resources - Renewable	Use as energy carrier	MJ, net calorific value	3.06E+03	6.93E+00	-	3,06E+03
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	-	0,00E+00
	TOTAL	MJ, net calorific value	3.06E+03	6.93E+00	-	3,06E+03
Primary energy resources – Non-Renewable	Use as energy carrier	MJ, net calorific value	9.64E+04	4.82E+02	-	9,69E+04
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	-	0,00E+00
	TOTAL	MJ, net calorific value	9.64E+04	4.82E+02	-	9,69E+04
Secondary material		kg	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Net fresh water		m3	161	0.043	-	161

2.5. OTHER INDICATORS DESCRIBING WASTE CATERGORIES

Table 40. FAFCO other indicators

Parameter	Unit (expressed per functional unit or per declared unit)
Hazardous waste disposed	1.01E+00
Non-hazardous waste disposed	3.49E+03
Radioactive waste disposed	1.73E-01

2.6. RELEASE OF DANGEROUS SUBSTANCES DURING THE USE STAGE

Use stage is not include in the scope

3. ADDITIONAL ENVIRONMENTAL INFORMATION

N.A.

4. PROGRAMME RELATED INFORMATION AND MANDATORY STATEMENTS

4.1. DIFFERENCES VERSUS PREVIOUS VERSIONS OF THE EPD

No previous EPD has been published.

4.2. VERIFICATION AND REGISTRATION

Table 41.CEN standard EN 15804 served as the core PCR

PCR:	PCR 2012:01 Construction products and Construction services, Version 2.01, 2016-03-09 *<name and date of sub-oriented PCR, if applicable>*
PCR review was conducted by:	The Technical Committee of the International EPD® System. Chair: Massimo Marino. Contact via info@environdec.com
Independent verification of the declaration and data, according to ISO 14025:	□ EPD process certification (Internal) □ EPD verification (External)
Third party verifier:	*<Name and contact information>*
Accredited or approved by:	*<Name of the accreditation body. >* *For individual verifiers: "The International EPD® System"*

4.3. REFERENCES

- ISO14040:2006. Environmental management. Life cycle assessment. Principles and framework.
- ISO14044:2006. Environmental management. Life cycle assessment. Requirements and guidelines.
- ISO 14025:2006: Environmental labels and declarations. Type III environmental declarations. Principles and
- procedures.
- General Programme Instructions of the International EPD® System. Version 3.0.
- PCR - "Construction products and construction services. Product group classification: multiple un CPC codes 2012:01 version 2.01".
- EN 15804:2012+A1:2014. Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

4.6.7 POZZI LEOPOLDO

Environmental Product Declaration

"1 ROTATING HEAT EXCHANGER"

Version 1.0

PCR - "Construction products and construction services, version 2.01".

CPC 546

Pozzi Leopoldo srl

Address: via Paganini 14 Barlassina 20825 (MB) Italy.

Phone: +39 0362 90811

Address: info@pozzi.it

Program: The International EPD System, www.emvironde.com

Program operator: EPD International AB

Number registration: S-P-XXXXX

Issue date: dd/mm/year

Validity: dd/mm/year

H2020 Research and Innovation Actions (RIA)

723930_LowUP

"Low valued energy sources and industry uses"

1. DECLARATION OF GENERAL INFORMATION

1.1. SPECIFICATION OF THE PRODUCT

Pozzi RHeX system is a non-conventional water to water heat exchanger especially designed to claim otherwise wasted energy out of polluted wastewater. Pozzi rotating exchangers are able to heat up fresh water and simultaneously cool down effluents, thus cutting down energy bills and meeting legal requirements on effluent temperatures. Its unique operating principle, based on a rotating exchanging shaft, makes the unit self-cleaning. Pozzi RHeX can be used in several industries such as textile care and finishing, dyeing, leather, paper and food.

This EPD complies with the product's relevant materials and substances. In addition, the gross weight of material declared in this EPD is more than 99%, as stated by the regulation.

The main raw materials that constitute the RHeX system are listed below, see Table 42:

Table 42. POZZI LEOPOLDO component resume

COMPONENT	AMOUNT	UNITS
Stainless steel for the structure.	78.07	% in mass
Composite flexible pipes.	1.08	
Bronze for safety valves.	4.60	
Electric and electronic components.	8.39	
Iron	7.85	
Rubber	0.01	

1.2. FUNCTIONAL OR DECLARED UNIT

The Declared Unit considered in this EPD is "1 rotating heat exchanger".

1.3. CONTENT DECLARATION

N.A.

1.4. FLOW DIAGRAM

Figure 22 describes the scope of the inventory performed in the LCA. The EPD-type declared is a “Cradle-to gate” EPD

Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
Raw materials	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND
X: module is accounted in EPD; MND: module is not accounted in EPD																

Figure 22. International EPD® system Life Cycle stages

1.5. TECHNICAL INFORMATION

N.A.

2. ENVIRONMENTAL PERFORMANCE-RELATED INFORMATION

2.1. RULES FOR DECLARING INFORMATION PER MODULE DERIVED FROM LCA

The system boundaries considered in this work have been a "**Cradle-to-gate" EPD**. Thus, this study has evaluated the impact from the extraction of raw materials until the product leaves the factory, see Figure 23:

A1) Supply of raw materials:

- Extraction and processing of raw materials
- Extraction and processing of fuels.

A2) Transport to factory:

- External transportation of raw materials to the factory.

A3) Manufacturing: No data is available, thus, this stage has been not included in the assessment

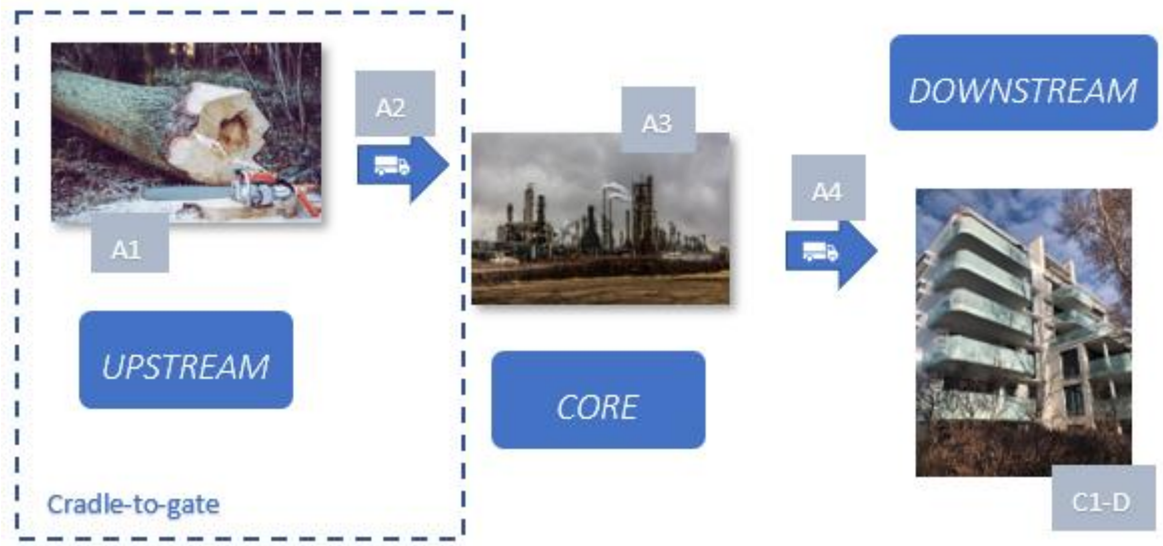


Figure 23. POZZI LEOPOLDO EPD boundaries

The geographic scope of this EPD is Europe.

2.2. AGGREGATION OF INFORMATION MODULES

No aggregation of information modules has been done.

2.3. POTENTIAL ENVIRONMENTAL IMPACT

According to reference PCR document and considering the geographical scope of this EPD the methodology used for the assessment of the environmental burdens has been CML-IA.

Finally, Table 43 shows the environmental profile of declared unit of this EPD.

Table 43. POZZI LEOPOLDO impact assessment

IMPACT CATEGORY	UNITS	STAGE			
		A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Global warming (gwp100)	kg CO2 equivalents	2.74E+03	4.62E+00	-	2.75E+03
Ozone depletion	kg CFC ^{11} equivalents	1.34E-04	8.45E-07	-	1.35E-04
Acidification of land and water	kg SO^2 equivalents	6.29E+01	1.09E-02	-	6.29E+01
Eutrophication	$PO4^{3-}$ equivalents	8.49E+00	2.41E-03	-	8.49E+00
Photochemical ozone creation	C2H4 equivalents	2.80E+00	5.58E-04	-	2.80E+00
Depletion of abiotic resources (elements)	kg Sb equivalents	3.35E-01	1.16E-04	-	3.35E-01
Depletion of abiotic resources (fossil)	MJ net calorific value	3.24E+04	6.85E+01	-	3.24E+04

EPD of construction products may not be comparable if they do not comply with EN 15804 Environmental product declarations within the same product category from different programs may not be comparable

2.4. USE OF RESOURCES

Table 44 shows the use of renewable and nonrenewable material resources, renewable and non-renewable primary energy and water divided into the stages considered (A1 to A3).

Table 44. POZZI LEOPOLDO use of resources

PARAMETER		UNITS	STAGE			
			A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Primary energy resources - Renewable	Use as energy carrier	MJ, net calorific value	4.00E+03	1.07E+00	-	4,00E+03
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	-	0,00E+00
	TOTAL	MJ, net calorific value	4.00E+03	1.07E+00	-	0,00E+00
Primary energy resources – Non-Renewable	Use as energy carrier	MJ, net calorific value	4.00E+04	7.44E+01	-	4,01E+04
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	-	0,00E+00
	TOTAL	MJ, net calorific value	4.00E+04	7.44E+01	-	4,01E+04
Secondary material		kg	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Net fresh water		m3	622	0.008	-	622

2.5. OTHER INDICATORS DESCRIBING WASTE CATERGORIES

Table 45. POZZI LEOPOLDO other indicators

Parameter	Unit (expressed per functional unit or per declared unit)
Hazardous waste disposed	4.77E+00
Non-hazardous waste disposed	6.24E+02
Radioactive waste disposed	6.92E-02

2.6. RELEASE OF DANGEROUS SUBSTANCES DURING THE USE STAGE

Use stage is not include in the scope

3. ADDITIONAL ENVIRONMENTAL INFORMATION

N.A.

4. PROGRAMME RELATED INFORMATION AND MANDATORY STATEMENTS

4.1. DIFFERENCES VERSUS PREVIOUS VERSIONS OF THE EPD

No previous EPD has been published.

4.2. VERIFICATION AND REGISTRATION

Table 46.CEN standard EN 15804 served as the core PCR

PCR:	PCR 2012:01 Construction products and Construction services, Version 2.01, 2016-03-09 *<name and date of sub-oriented PCR, if applicable>*
PCR review was conducted by:	The Technical Committee of the International EPD® System. Chair: Massimo Marino. Contact via info@environdec.com
Independent verification of the declaration and data, according to ISO 14025:	☐ EPD process certification (Internal) ☐ EPD verification (External)
Third party verifier:	*<Name and contact information>*
Accredited or approved by:	*<Name of the accreditation body. >* *For individual verifiers: “The International EPD® System”*

4.3. REFERENCES

- ISO14040:2006. Environmental management. Life cycle assessment. Principles and framework.
- ISO14044:2006. Environmental management. Life cycle assessment. Requirements and guidelines.
- ISO 14025:2006: Environmental labels and declarations. Type III environmental declarations. Principles and
- procedures.
- General Programme Instructions of the International EPD® System. Version 3.0.
- PCR - "Construction products and construction services. Product group classification: multiple un CPC codes 2012:01 version 2.01".
- EN 15804:2012+A1:2014. Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

4.6.8 GEA

Environmental Product Declaration

“1 HEAT PUMP”

Version 1.0

PCR - “Construction products and construction services, version 2.01".

CPC 546

ENDEF Solar Solutions

Address: Parallelweg 25, 'S-HERTOGENBOSCH, Netherlands

Phone: +31 73 620 3911

Program: The International EPD System, www.emvironde.com

Program operator: EPD International AB

Number registration: S-P-XXXXX

Issue date: dd/mm/year

Validity: dd/mm/year

H2020 Research and Innovation Actions (RIA)

723930_LowUP

“Low valued energy sources and industry uses”

European Commission | Horizon 2020 European Union funding for Research & Innovation

1. DECLARATION OF GENERAL INFORMATION

1.1. SPECIFICATION OF THE PRODUCT

GEA's compact heat pump for small to medium heat loads. Flexibly selected modules, depending on the output size, combine to form a space-saving and efficient system concept. Perfect for temperatures up to 70 °C, they are ideally suited to a wide range of heat pump applications.

This EPD complies with the product's relevant materials and substances. In addition, the gross weight of material declared in this EPD is more than 99%, as stated by the regulation.

The main raw materials that constitute the heat pump are listed below see Table 47:

Table 47. GEA component resume

COMPONENT	AMOUNT	UNITS
Carbon steel	64.64	% in mass
Stainless steel	32.32	
Rockwool	0.06	
Aluminum	0.13	
Copper	0.94	
Synthetic oil	0.26	
Ammonia	0.65	

1.2. FUNCTIONAL OR DECLARED UNIT

The Declared Unit considered in this EPD is "1 heat pump"

1.3. CONTENT DECLARATION

N.A.

1.4. FLOW DIAGRAM

Figure 24 describes the scope of the inventory performed in the LCA. The EPD-type declared is a “Cradle-to gate” EPD

Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
Raw materials	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND
X: module is accounted in EPD; MND: module is not accounted in EPD																

Figure 24. International EPD® system Life Cycle stages

1.5. TECHNICAL INFORMATION

N.A.

2. ENVIRONMENTAL PERFORMANCE-RELATED INFORMATION

2.1. RULES FOR DECLARING INFORMATION PER MODULE DERIVED FROM LCA

The system boundaries considered in this work have been a "**Cradle-to-gate" EPD**. Thus, this study has evaluated the impact from the extraction of raw materials until the product leaves the factory, see Figure 25:

A1) Supply of raw materials:

- Extraction and processing of raw materials
- Extraction and processing of fuels.

A2) Transport to factory:

- External transportation of raw materials to the factory.

A3) Manufacturing: No data is available, thus, this stage has been not included in the assessment

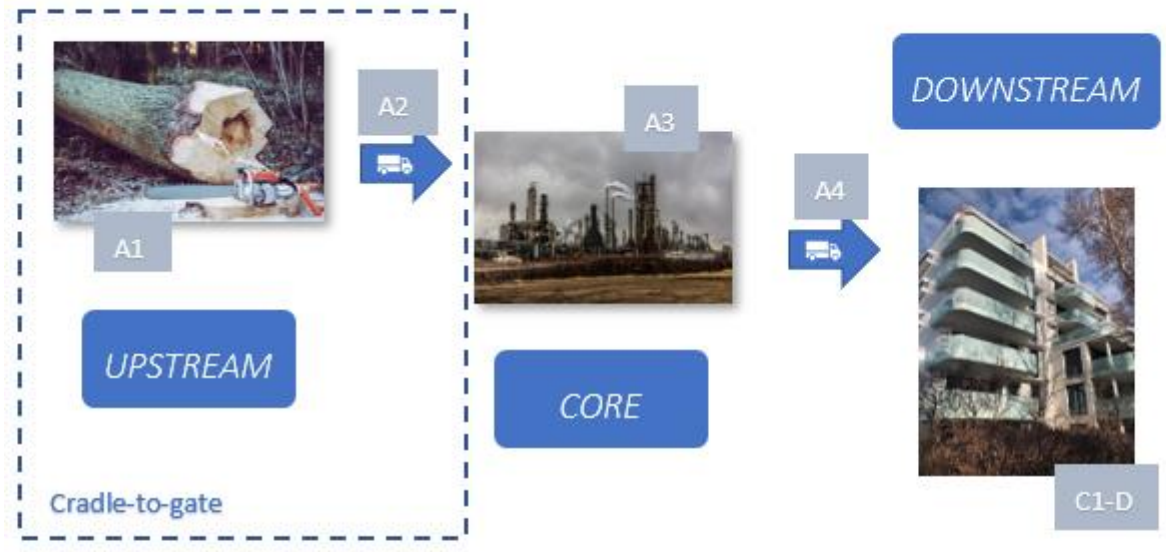


Figure 25. GEA EPD boundaries

The geographic scope of this EPD is Europe.

2.2. AGGREGATION OF INFORMATION MODULES

No aggregation of information modules has been done.

2.3. POTENTIAL ENVIRONMENTAL IMPACT

According to reference PCR document and considering the geographical scope of this EPD the methodology used for the assessment of the environmental burdens has been CML-IA.
The assumptions considered in the LCA are listed below:

- Due to the lack of information of some transports has been assume 100 km

Finally, Table 48 shows the environmental profile of declared unit of this EPD.

Table 48. GEA impact assessmentTable 48.

IMPACT CATEGORY	UNITS	STAGE			
		A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Global warming (gwp100)	kg CO2 equivalents	5.20E+04	2.52E+02	0.00E+00	5.22E+04
Ozone depletion	kg CFC ^{11} equivalents	2.50E-03	4.60E-05	0.00E+00	2.54E-03
Acidification of land and water	kg SO^2 equivalents	3.20E+02	5.96E-01	0.00E+00	3.20E+02
Eutrophication	$PO4^{3-}$ equivalents	1.18E+02	1.31E-01	0.00E+00	1.19E+02
Photochemical ozone creation	C2H4 equivalents	2.42E+01	3.04E-02	0.00E+00	2.43E+01
Depletion of abiotic resources (elements)	kg Sb equivalents	1.79E+00	6.33E-03	0.00E+00	1.79E+00
Depletion of abiotic resources (fossil)	MJ net calorific value	4.74E+05	3.73E+03	0.00E+00	4.78E+05

EPD of construction products may not be comparable if they do not comply with EN 15804 Environmental product declarations within the same product category from different programs may not be comparable

2.4. USE OF RESOURCES

Table 49 shows the use of renewable and nonrenewable material resources, renewable and non-renewable primary energy and water divided into the stages considered (A1 to A3).

Table 49. GEA use of resources

PARAMETER		UNITS	STAGE			
			A1 Raw Material	A2 Transport	A3 Manufacturing	TOTAL
Primary energy resources - Renewable	Use as energy carrier	MJ, net calorific value	9.79E+04	5.83E+01	-	9,80E+04
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	-	0,00E+00
	TOTAL	MJ, net calorific value	9.79E+04	5.83E+01	-	9,80E+04
Primary energy resources – Non-Renewable	Use as energy carrier	MJ, net calorific value	5.52E+05	4.05E+03	-	5,56E+05
	Use as raw material	MJ, net calorific value	0.00E+00	0.00E+00	-	0,00E+00
	TOTAL	MJ, net calorific value	5.52E+05	4.05E+03	-	5,56E+05
Secondary material		kg	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Non-renewable secondary fuels		MJ, net calorific value	0,00E+00	0.00E+00	0.00E+00	0.00E+00
Net fresh water		m3	1335	0.643	-	1336

2.5. OTHER INDICATORS DESCRIBING WASTE CATERGORIES

Table 50. GEA other indicators

Parameter	Unit (expressed per functional unit or per declared unit)
Hazardous waste disposed	7.12E+00
Non-hazardous waste disposed	4.27E+04
Radioactive waste disposed	1.82E+00

2.6. RELEASE OF DANGEROUS SUBSTANCES DURING THE USE STAGE

Use stage is not include in the scope

3. ADDITIONAL ENVIRONMENTAL INFORMATION

N.A.

4. PROGRAMME RELATED INFORMATION AND MANDATORY STATEMENTS

4.1. DIFFERENCES VERSUS PREVIOUS VERSIONS OF THE EPD

No previous EPD has been published.

4.2. VERIFICATION AND REGISTRATION

Table 51.CEN standard EN 15804 served as the core PCR

PCR:	PCR 2012:01 Construction products and Construction services, Version 2.01, 2016-03-09 *<name and date of sub-oriented PCR, if applicable>*
PCR review was conducted by:	The Technical Committee of the International EPD® System. Chair: Massimo Marino. Contact via info@environdec.com
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4.3. REFERENCES

- ISO14040:2006. Environmental management. Life cycle assessment. Principles and framework.
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- ISO 14025:2006: Environmental labels and declarations. Type III environmental declarations. Principles and
- procedures.
- General Programme Instructions of the International EPD® System. Version 3.0.
- PCR - “Construction products and construction services. Product group classification: multiple un CPC codes 2012:01 version 2.01".
- EN 15804:2012+A1:2014. Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

4.7 EPD verification

Then the EPD are developed it shall be independently verified in order to ensure the reliability of declaration contents. To be certified and published, the EPD must successfully have passed the verification procedure. Regarding LowUp project, this stage of the EPD® procedure has not been developed. However, in following paragraphs a brief description and the principles for EPD verification process have been developed.

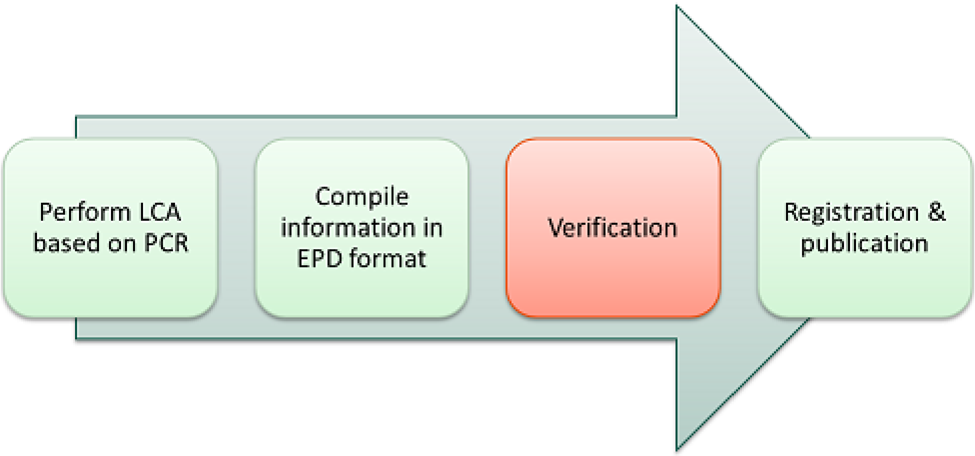


Figure 26. EPD flowchart [10]

According to the general programme instructions (GPI) for the International EPD® system, there are two types of verification procedures in the International EPD® System [8]:

- **EPD verification.** The verification process shall be carried out by an approved individual verifier or an accredited certification body with knowledge and experience of the types of products, the industry, and relevant standards of the product covered by the EPD and its geographical scope. The aim of this process is the verification of LCA-based data, additional environmental information and the information given in an
- **EPD process certification.** To simplify the process for organisations in collecting data, conducting LCAs, and developing EPDs on a large scale, the International EPD® System includes the possibility of "EPD process certification". This process aimed to develop EPDs according to the GPI and valid reference PCRs covered under the scope of certification. In contrast with EPD verification, with EPD process certification, the organisation may handle the management of EPD data involved in the verification procedure by themselves and issue EPDs without a third-party verifier being involved in each case.

In both cases, the verification procedure could be seen as being divided into two separate parts [8]:

- **Documental review**. This stage involves the documental review shall focus on the analysis of all documents that justify input data and information included in the EPD, both the underlying LCA study and documents describing other environmental information included in the EPD®. The objectives of the documental review are:
    - to assess compliance of the LCA and the EPD with the General Programme Instructions and the valid reference PCR.
    - to verify procedures established for updating the information in the LCA and EPD.

- to verify procedures established for an assessment of the conformity to all relevant process and product-related environmental laws (if appropriate).

- **Validation.** This phase shall focus on an assessment of the validity of data and information included in the LCA study and the EPD. This phase is conducted by sampling activities focusing, in particular, on those processes and activities having significant influence on results the overall environmental impact. The objectives of the validation phase are:

  - to assess the accuracy of the information contained in the LCA study and the EPD.
  - to assess the application of documented procedures established for updating the information in the LCA and EPD.
  - to assess the compliance with relevant process and product-related environmental laws (if relevant).

5 Environmental and economic assessment

The aim of this section is to compare a baseline scenario to the situation after the implementation of LowUp technologies, project scenario, through the application of LCA & LCC methodologies. In the following sections each scenario is described and evaluated. The role of each partner along the course of the project is shown in Table 52

Table 52.LowUP technologies and manufacturers

Low Up system and application		Data provider	LCA practitioner
Heating system	**Radiant surfaces**	RDZ	CARTIF
	Integrated PV recovery	EndeF	CARTIF
	Hybrid sewage water heat recovery	WASENCO	CARTIF
	Stratified heat storage	Entropy	CARTIF
Cooling system	**Chilled beams**	HALTON	CARTIF
	PCM cool storage	FAFCO	CARTIF
HP - Recovery system	**High efficiency heat recovery for industrial processes**	POZZI	CARTIF
	High temperature cost effective heat pump	GEA	CARTIF

5.1 Seville demonstration site – Office building

The demonstration site in Seville consists of a reworked warehouse that has been turned into a 150 m^2 office building. The goal of this demonstrator is to use solar energy to heat an office space, using hybrid thermal-PV solar collectors which also produce electricity for the system, with a heat pump as a back-up system for the moments of solar absence. The system is expected to achieve thermal indoor comfort with lower temperature respect to actual technology, storing excess of heat efficiently for low solar radiation periods, improving energetic consumption of the system and minimising the architectural impact.

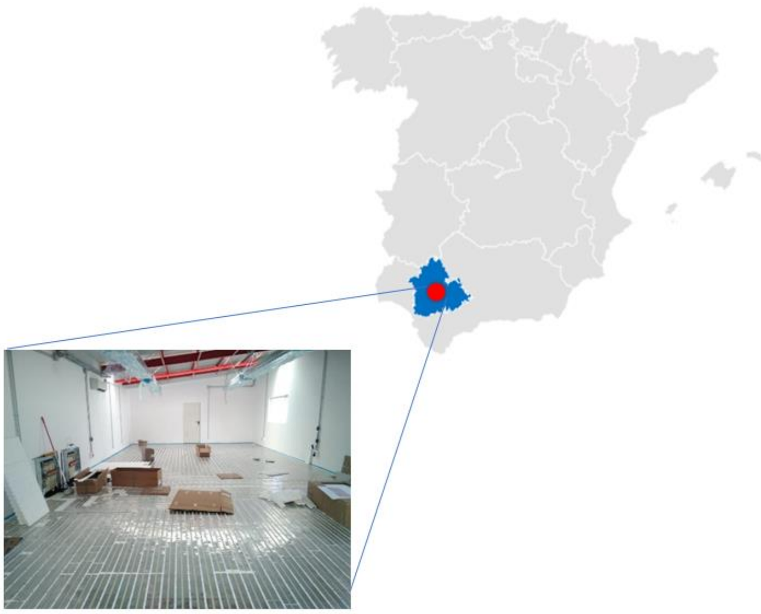


Figure 27. Office building location

5.1.1 *Environmental assessment (LCA)*

5.1.1.1 Goal and scope definition

The goal of this study is to evaluate the environmental impact of the implementation of LowUP solutions in the demo site of Seville (LowUP scenario) against a reference scenario (baseline scenario) using conventional technologies. The boundaries of the system include the extraction of the raw materials, the production of the different technologies, transportation and the operation stage (Figure 28). The system includes both Heat LowUp (combining RDZ, ENDEF, ENTROPY and WASENCO solutions) and Cool LowUp (FAFCO and HALTON) technologies as shown in Figure 29. The reference scenario consists of a conventional gas boiler combined with a benchmark radiant floor for heating, and an absorption chiller for cooling.

The cooling season goes from May to October, while the heating season spans from October to May. The functional unit considered in this study was “the energy required to meet the cooling and heating needs of the building for 25 years”.

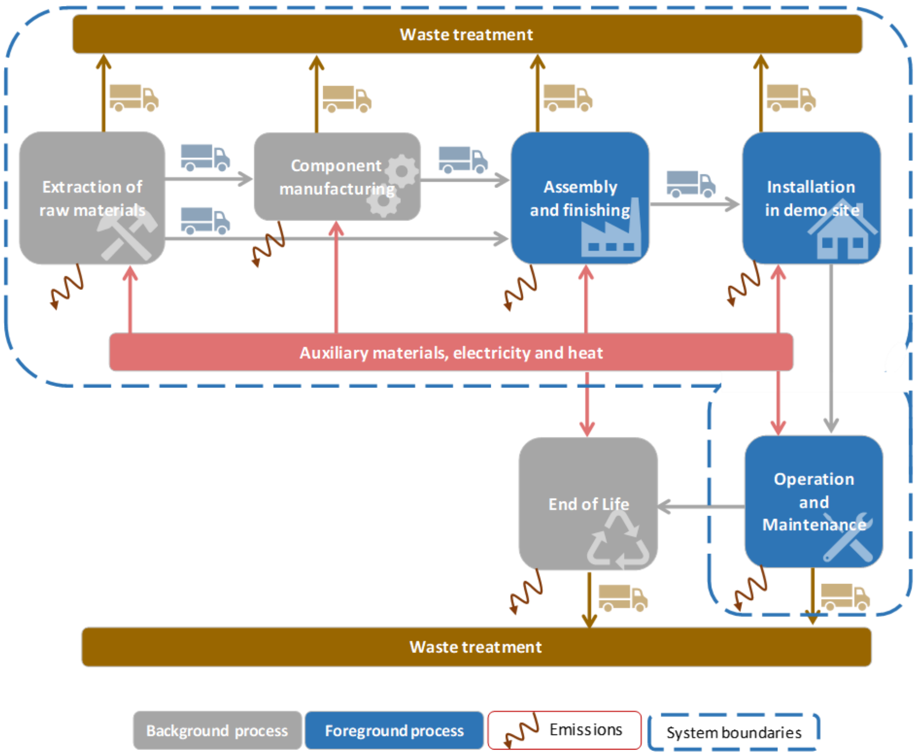


Figure 28. System boundaries for the assessment of the three demo sites.

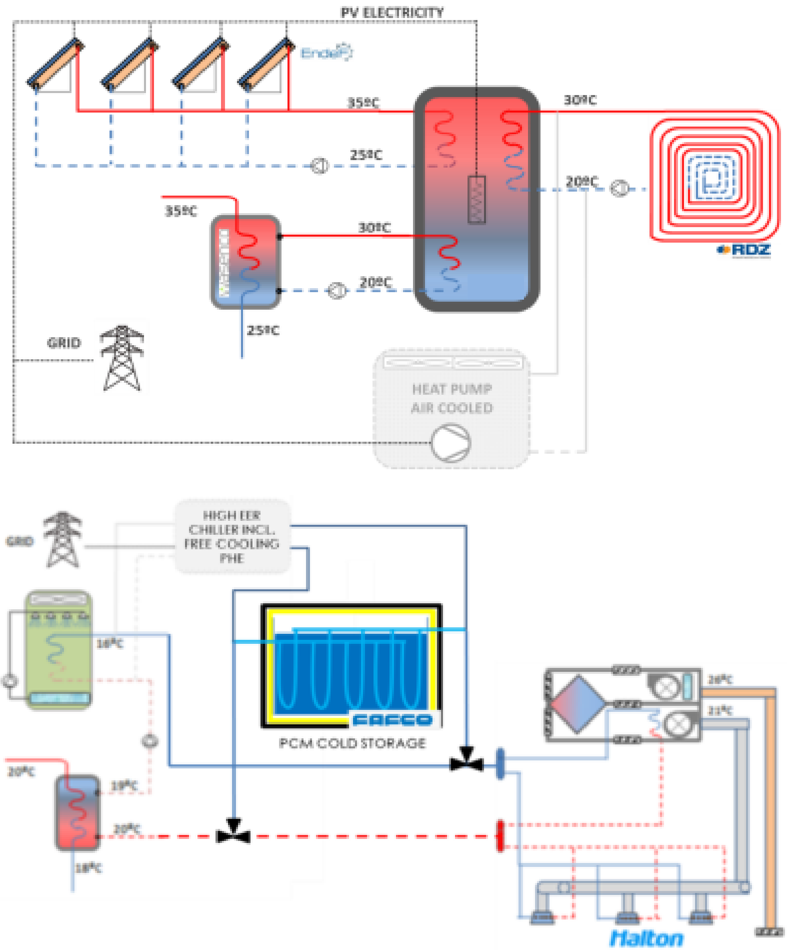


Figure 29. LowUP technologies for demo 1. Heat LowUP (Top) and Cool LowUP (Bottom)

5.1.1.2 Life cycle inventory

In order to assess the scenarios considered, a gathering data process has been developed in a previous step. As mentioned in previous section 4.3 the data gathered involves the construction and operation phases of the technologies considered.

Regarding the manufacturing phase, primary data provided by the product manufacturers has been used to assess the environmental impacts of the project scenario. On the other hand, Ecoinvent 3.0 databases has been the source for the baseline scenarios technology data.

As for the use stage, due to the lack of real field data during the elaboration of the present analyses, a robust detailed yearly transient energy simulations haves been developed run in order to know estimate the energy consumption produced during the use phases of all the technologies involved in the target scenarios evaluated.

Table 53 shows all the data considered in the environmental assessment of baseline and project scenario.

Table 53. Data sources

Scenario	Stage	Resource	Source
Baseline scenario	Manufacturing	Ecoinvent 3.0 date base	Secondary data
	Use stage	Simulation	Secondary data
Project scenario	Manufacturing	Primary data	Primary data from industrial partners.
	Use stage	Simulation	Secondary data

The use stage has been modelled based on simulations… the energy models developed in TRNSYS environment for the HEAT-LowUP and COOL-LowUP solutions (see D2.1, D2.2 and D2.10 for further details). They have been used to obtain reasoned estimations of the yearly energy demand and electricity consumptions.

The heating and cooling energy demands were calculated through dedicated simulations of the building energy model created for the LowUP demo building in Seville. The corresponding results allowed to identify actual durations of the heating and cooling seasons for simulation of HEAT- and COOL-LowUP solutions in accordance. Demand calculations also enabled the definition of reference cases and estimation of baseline energy uses:

- Reference solution for heating: Natural gas boiler with 0.9 seasonal efficiency
- Reference solution for cooling: Compression cooling system with 2.5 seasonal COP

Results for the inventory of the use stage referred to the functional unit for the baseline scenario and the LowUP scenario are displayed in Table 54 and Table 55, respectively.

Table 54. Baseline scenario: Seville demo site

Input	Unit	Heating	Cooling
Electricity from grid	MWh		31.2
Natural gas	MWh	140.8	-

Table 55. LowUP scenario: Seville demosite (HEAT- and COOL-LowUP)

Input	Unit	Heating	Cooling
Electricity from grid	MWh	20.2	25.85
Surplus electricity exported to the grid*	MWh	11.85	-

*Surplus electricity produced by the solar panels is exported to the grid.

5.1.1.3 Impact assessment

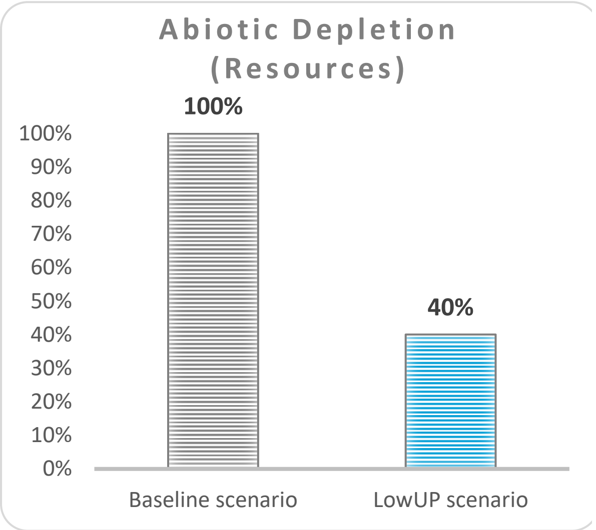
Life cycle impact assessment was conducted following the guidelines in ISO 14040/14044. The analysis considered only the mandatory steps: selection of impact categories, category indicators and characterization models, classification, and characterization.

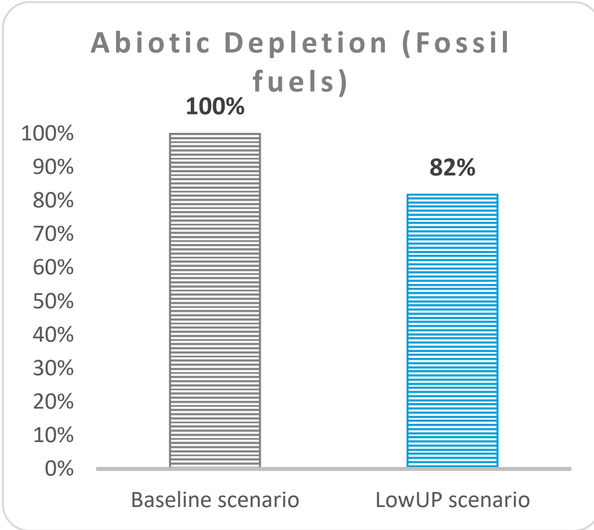
In this project, the CML-IA baseline method (version 4.2) was used. The selected impact categories included Abiotic depletion (both resources and fossil fuels), global warming, ozone layer depletion, photochemical oxidation, acidification and eutrophication. SimaPro (version 9) was used to perform the assessment.

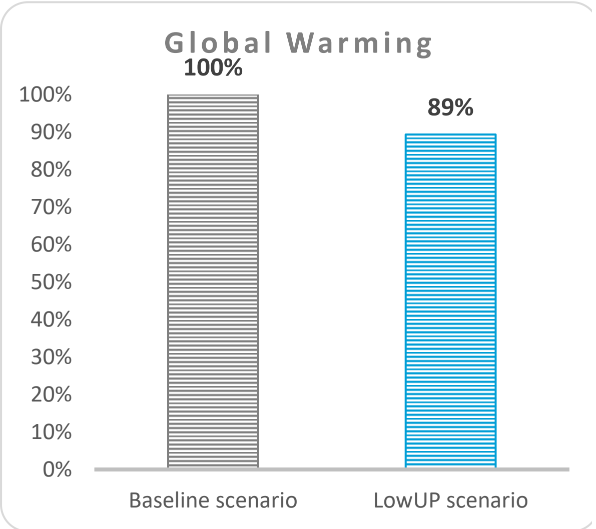
5.1.1.4 Interpretation

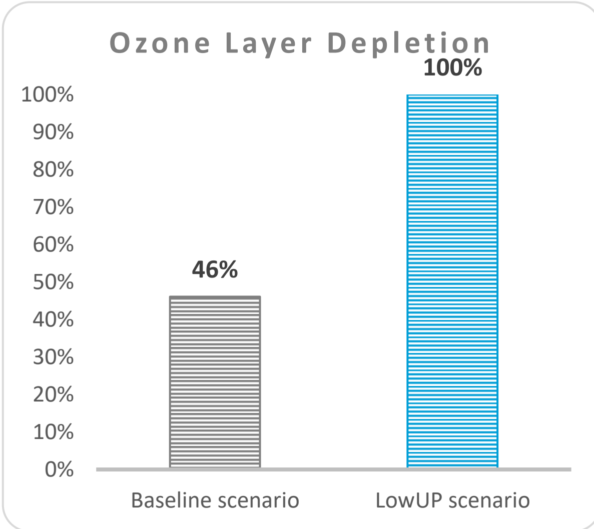
The results of the comparative assessment for the different categories included in the study are shown in Figure 30.. For this demo site, the implementation of LowUP's technologies for heating and cooling reduces the environmental impact for all the categories except for the ozone layer depletion. In this case, the impact is higher as a consequence of the use of polystyrene for insulation in FAFCO's technology. However, this is a small trade-off compared to the environmental benefits that are achieved for the rest of the categories, with reductions ranging from 5 % (photochemical oxidation) to 60 % (abiotic depletion of resources). This means that the implementation of the LowUP system considerably reduces the environmental impact linked to the operation of the office.

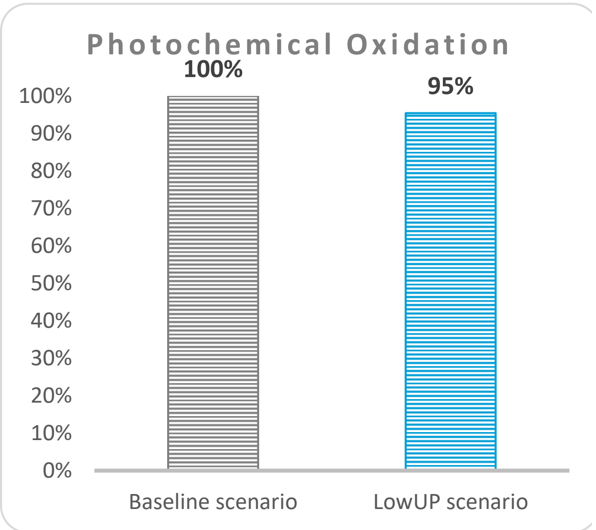
However, suitable strategies such as the extension of the service life of the equipment and proper end-of-life activities (repurposing, recycling) would increase the environmental benefits and reduce the burdens linked to the depletion of the ozone layer.

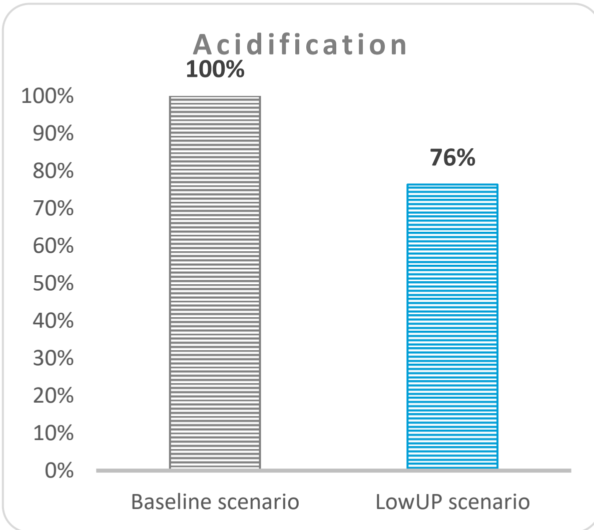

Abiotic Depletion (Resources)
100%
40%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Baseline scenario
LowUP scenario


Abiotic Depletion (Fossil fuels)
100%
82%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Baseline scenario
LowUP scenario


Global Warming
100%
89%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Baseline scenario
LowUP scenario


Ozone Layer Depletion
100%
46%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Baseline scenario
LowUP scenario


Photochemical Oxidation
100%
95%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Baseline scenario
LowUP scenario


Acidification
100%
76%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Baseline scenario
LowUP scenario

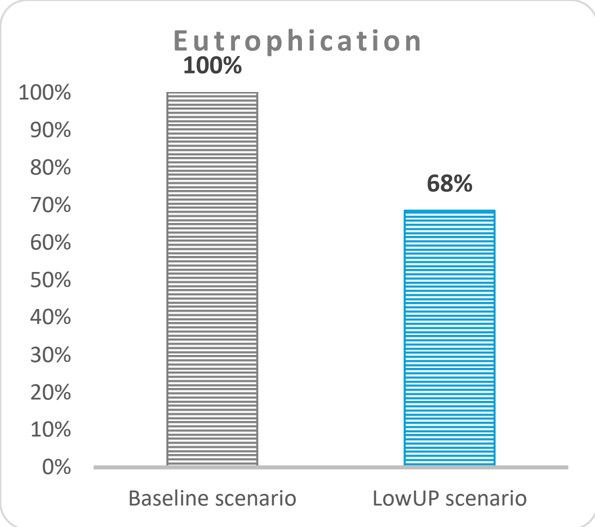


Figure 30. Environmental results

5.1.2 Economic evaluation (LCC)

In this section an economic evaluation has been developed considered the costs from the equipment acquisition and use phase in the demo site during the period life of 25 years. The economic data related to the different equipment have been provided by each manufacturer and the energy consumption for this time period, as we have explained previously, has been simulated. On the other hand, the electricity price considered in this assessment has been obtained from the Eurostat agency [11] for household consumers from the second half 2019, see Table 56.

Table 56. Energy prices

Location	Energy source	Unit	Value (VAT included*)
Spain	Natural gas	€/kWh	0.1021
	Electricity		0.2394

*A VAT of 21% has been considered

Accounting from the previous information on investment and energy costs during the use stage of the LowUP solutions' life cycle, the results obtained are shown in Figure 31. It can be observed that the share of total Life-Cycle Costs (LCC) associated to the equipment construction is very important, being the use stage almost negligible. Therefore, it is evident that in order to reduce the economic impact of the proposed building solutions from the LC perspective, there is still a wide room for improvement. However, it should be reminded that the involved technologies and equipment have evolved from the conceptual and design stage, through prototyping and up to a TRL5-6 validation in a relevant environment. For this reason, the focus should be put on manufacturing optimization and cost reduction within the expected individual and combined exploitation pathways; such kind of improvements will result on enhanced market competitiveness and lower overall LCC impact.

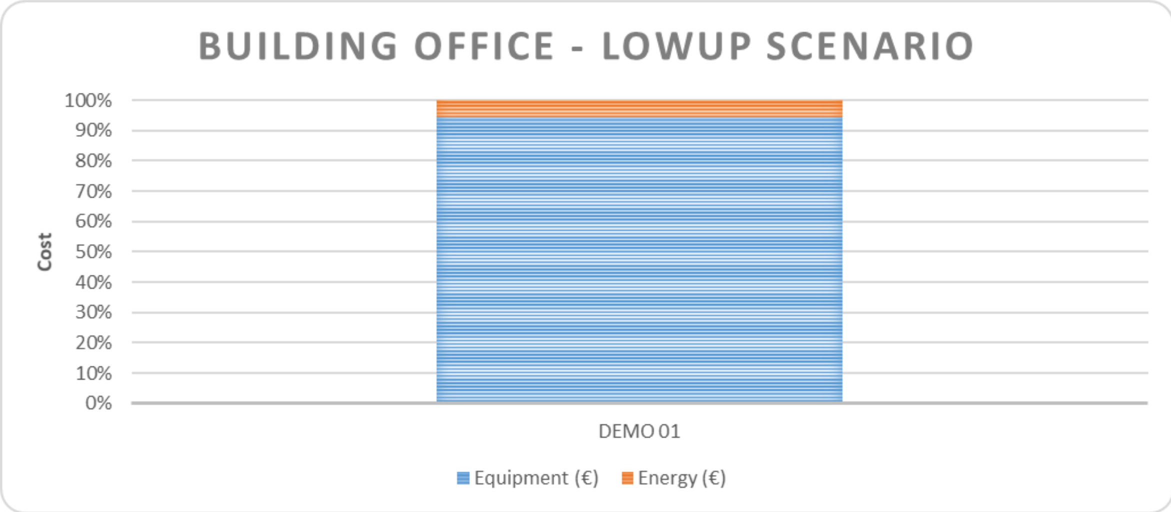


Figure 31. Economic results for office building

In order to know if the economical investment of the LowUP technologies is profitable for this demonstration site, in the period of 25 years, an economic assessment for a hypothetical baseline scenario and following comparison with LowUp scenario has been developed. For the baseline scenario, the equipment considered has been a natural gas boiler of 10 kW, an air-water chiller of 15-20kW and auxiliary elements (fan coils, pumps, pipe…). Thus, considering this assumption and the information shown in Table 57. the result obtained are shown, graphically, in Figure 38

Table 57. Economic results for office building

Category	Energy	Unit	Value
Energy prices	Electricity	€/kWh	0.1336
	Natural gas	€/kWh	0.0371
Equipment	Baseline scenario	Total equipment	13750
	LowUP scenario	POZZI LEOPOLDO and GEA technologies	153232
Energy consumption	Baseline scenario	MWh (Natural gas)	140.8
		MWh (Electricity)	31.2
	LowUP scenario	MWh (Electricity)	34.2
	Baseline scenario	€	21840
	LowUP scenario		8166
Total investment	Baseline scenario	€	35590
	LowUP scenario		161398

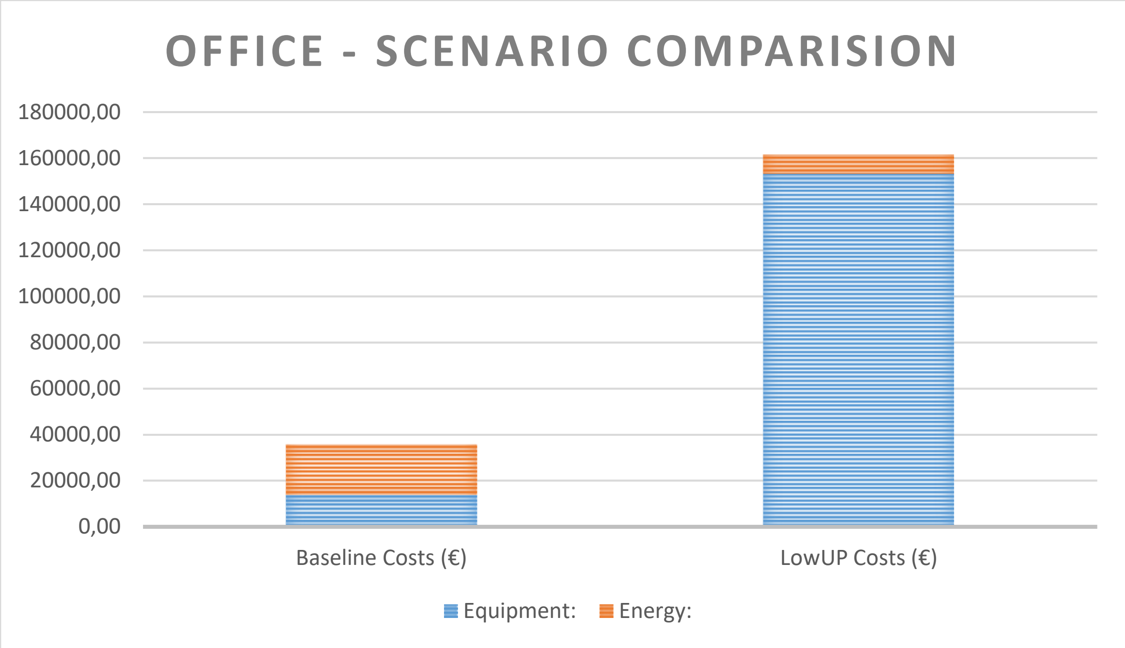


Figure 32. Scenarios comparison

Figure 32 shows the economical results for the evaluation of both scenarios. As it can be observed, the LowUP scenario is not able to compete yet with the solutions for the baseline scenario. This is because of the initial investment related to the equipment acquisition (and the LCC costs embedded in them). However, the simulation shows that the energy consumption in the project scenario for the period of 25 years, is more than 60% less than the baseline scenario which is quite promising. Optimization of systems sizing and manufacturing should contribute to reduce the gap between the LowUP and baseline scenario when approaching final TRLs (8-9), scalability and market roll out.

5.2 Madrid demonstration site – Wastewater treatment plant

The next demo site has been brought in as a collaboration with Canal de Isabel II and Acciona Aqua. “Arroyo Culebro Baja WWTP” manages part of the depuration of the residual water that comes from the city of Madrid, see Figure 33. The system is expected to efficiently recover an important quantity of energy from an effluent at low temperature. This heat recovered is afterwards re-injected it in the cycle to keep the temperature of the anaerobic digesters to reduce the global consumption of the plant.

Figure 33.Wastewater treatment plan location

5.2.1 Environmental assessment (LCA)

5.2.1.1 Goal and scope definition

The goal of this study is to evaluate the environmental impact of the implementation of LowUP solutions in the WWTP at the city of Pinto (Madrid) (LowUP scenario) against a reference scenario (baseline scenario) using conventional technologies. The boundaries of the system include the extraction of the raw materials, the production of the different technologies, transportation and the operation stage (See Figure 28 in section 5.1.1.1). The LowUP system is based on HP LowUP technologies as previously described (GEA and POZZI LEOPOLDO) and shown in Figure 34. The reference scenario consists of a conventional gas boiler to meet the energy needs of the digestors without energy recovery.

The assessment considered 5,000 yearly running hours for 25 years. For a more detailed description of the different scenarios, see section 5.2.1.2. The functional unit considered in this study was "the energy required to meet the heating needs of the anaerobic digesters for 25 years"

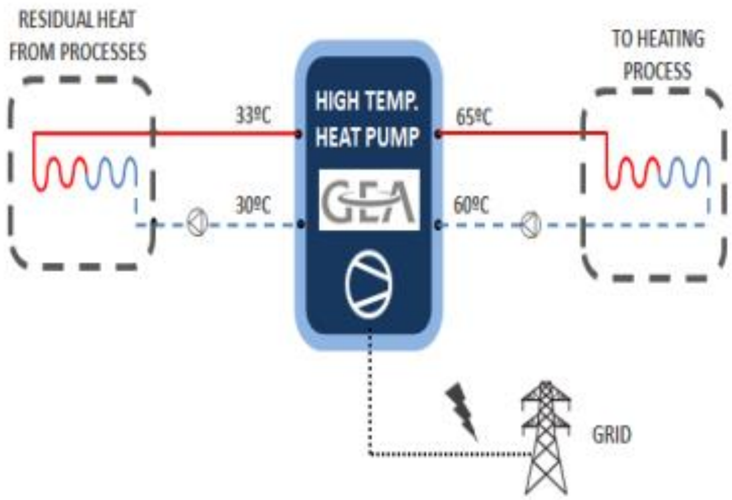
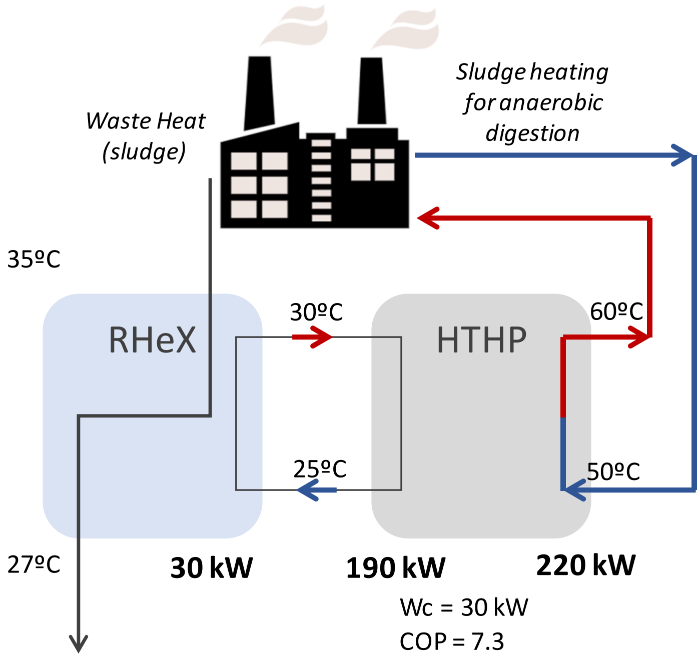


Figure 34. LowUP system for wastewater treatment plant

5.2.1.2 Life cycle inventory

In this case, the data for the construction stage was collected following the same methodology already developed in section 5.1.1.2. For a detailed listing of all the data used for the construction stage please refer to section 4.3 of this deliverable.

For the use stage, the lack of real data from the operation was overcome using a simulation of the system considering the most relevant parameters for the assessment. The model considered the combined used of the energy recovery system and the high-efficiency heat pump to upgrade the heat from the sludge and reduce the energy needs of the digesters (Figure 35).



Parameter	Value	Unit
RHeX output	30	kW
HTHP source input	190	kW
Scale factor	6.33	kW
COP	7.33	-
WC	30	kW
Yearly running hours	5,000	h

Figure 35. System simulation

The energy consumption for both scenarios, baseline and project scenario are shown in Table 58 and Table 59.

Table 58.Baseline scenario

Input	Unit	Value
Natural gas	GWh	30.6

Table 59. LowUP scenario

Input	Unit	Value
Electricity from grid	GWh	3.75

5.2.1.3 Impact assessment

Life cycle impact assessment was conducted following the guidelines in ISO 14040/14044. The analysis considered only the mandatory steps: selection of impact categories, category indicators and characterization models, classification, and characterization.

In this project, the CML-IA baseline method (version 4.2) was used. The selected impact categories included Abiotic depletion (both resources and fossil fuels), global warming, ozone layer depletion, photochemical oxidation, acidification and. SimaPro (version 9) was used to perform the assessment.

5.2.1.4 Interpretation

Figure 36. environmenta results for wastewater plant comparison

Figure 36 shows the results for the comparative assessment for this demo site. In this case, the LoWUP scenario results in higher impacts for Acidification, Eutrophication and abiotic depletion of resources. This is a consequence of the electricity consumed by the heat pump. However, the solution achieves a meaningful reduction in the emissions of greenhouse gases (84 % reduction), the consumption of fossil fuels (88 % reduction), the depletion of the ozone layer (82 % reduction) and the photochemical oxidation (17% reduction).

This reduction stems from the switch from natural gas to electricity from the Spanish national grid. The reduction in the consumption is the reason of this reduction of impacts, although switching to electricity increases the impact in Acidification and Eutrophication. This highlights the importance of the electricity mix and the need for renewable energies. Additionally, as in the previous demo site, suitable end-of-life activities to maximize the recovery of secondary raw materials is key to reduce the consumption of resources.

5.2.2 Economic evaluation (LCC)

In this section an economic evaluation has been developed considered the costs from the equipment acquisition and use phase in the demosite during the period life of 25 years. The data economic data for the equipments has been provided by each manufacturer and the energy consumption for this period time, as we have explained previously, has been simulated. On the other hand, regarding to the electricity price considered in this assessment has been obtained from the Eurostat agency [12] for non-household consumers from the second half 2019, see Table 60.

Table 60. Energy prices

Energy	Location	Unit	Value (included VAT*)
Electricity	Spain	€/kWh	0.1336
Natural gas	Spain	€/kWh	0.0371

*A VAT of 21% has been considered

The results obtained shows that during the period considered, 25 years, the energy contribution, to the total costs, are higher, 62% of the total investment, than the equipment contribution, see Figure 37.

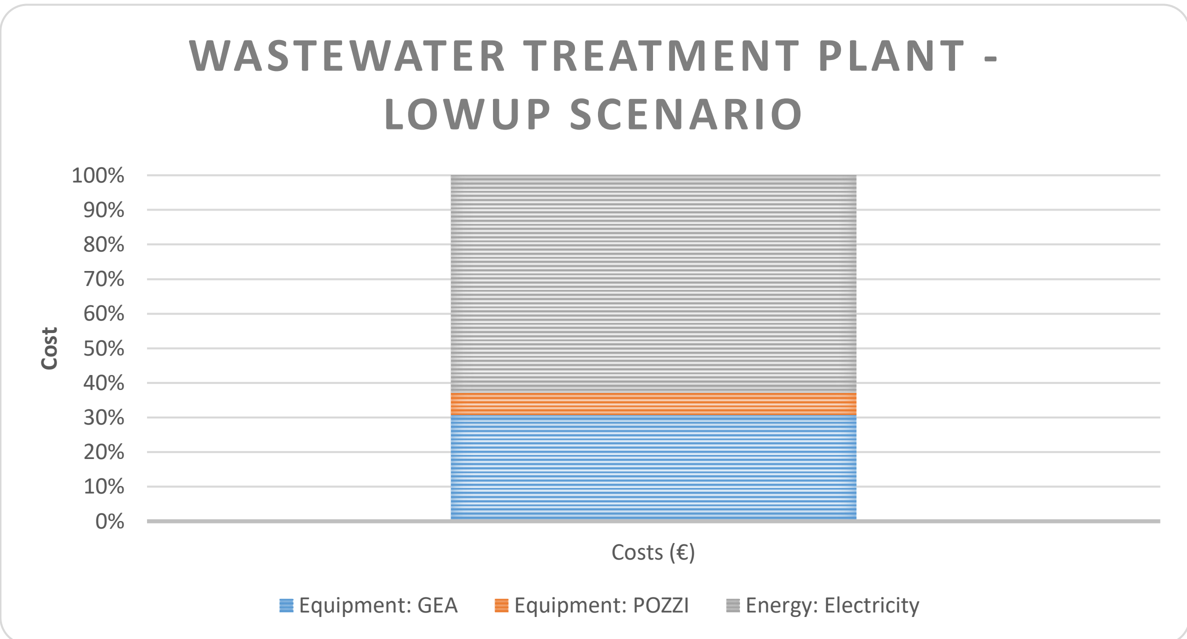


Figure 37.Economical results for LowUP scenario

Finally, in order to know if the economical investment of the LowUP technologies is profitable for this industry, in the period of 25 years, an economic assessment for a hypothetical baseline scenario and following comparison with LowUp scenario has been developed. For the baseline scenario, the equipment considered has been a natural gas industrial boiler of 250 kW. Thus, considering this assumption and the information shown in Table 61 the result obtained are shown, graphically, in Figure 38

Table 61. Results for scenarios comparison

Category	Energy	Unit	Value
Energy prices	Electricity	€/kWh	0.1336
	Natural gas	€/kWh	0.0371
Equipment	Baseline scenario	Total equipment	50000
	LowUP scenario	POZZI LEOPOLDO and GEA technologies	296282
Energy consumption	Baseline scenario	GWh (Natural gas)	30.6
	LowUP scenario	GWh (Electricity)	3.75
	Baseline scenario	€	1135047
	LowUP scenario		500940
Total investment	Baseline scenario	€	1185047
	LowUP scenario		797222

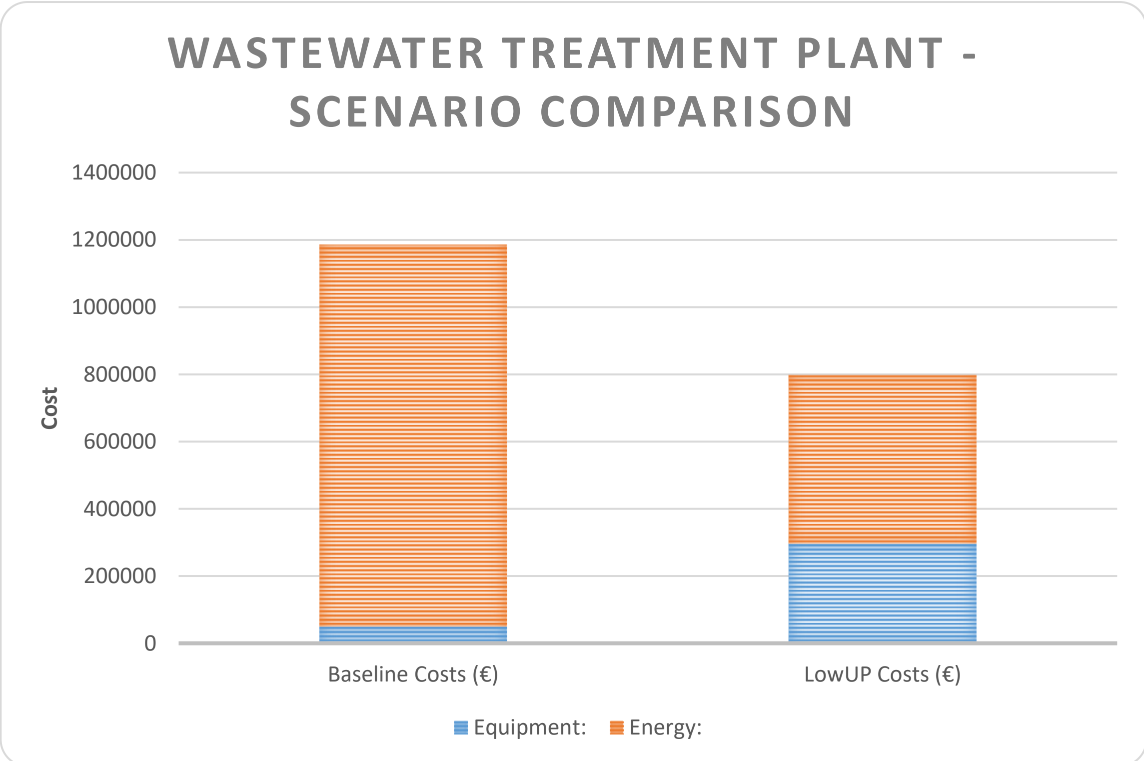


Figure 38. Scenarios comparison

The result obtained shows that the application of the LowUP technologies combination (GEA and LEOPOLDO POZZI) in this industry gets a profitable economic result. The application of LowUP technologies allowing a reduction of the energy consumption, more than 65%, during the period of time considered that gets to recover the initial investment related to the equipment adquisition.

5.3 Setubal demonstration site – Pulp & Paper production plant.

In collaboration with Navigator, this is LowUP's next demonstration site. The Setubal Industrial Complex is located on the Mitrena peninsula, near the city of Setubal (Portugal), see Figure 39. The system is expected to recover an important quantity of energy from an affluent with residual energy actually not used, in order to re-inject it in the cycle and reduce the global consumption of the plant.

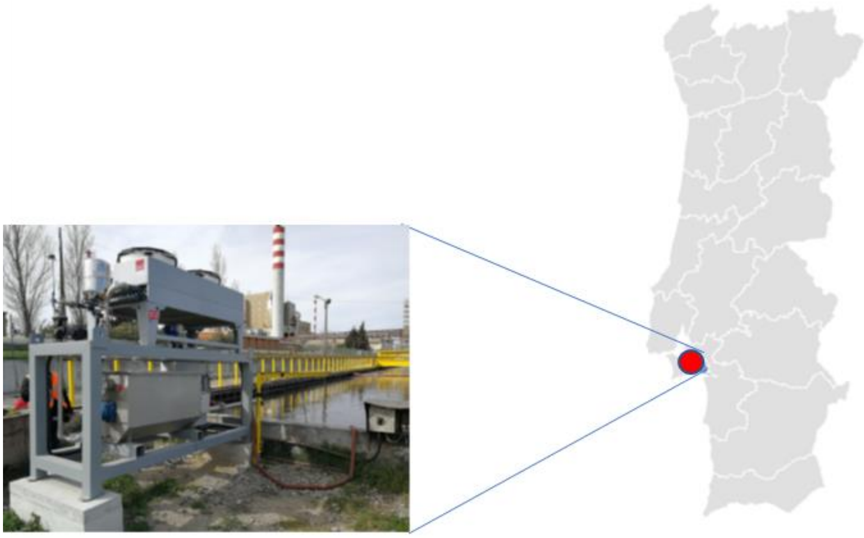


Figure 39. Location of Setubal demosite

5.3.1 Environmental assessment (LCA)

5.3.1.1 Goal and scope definition

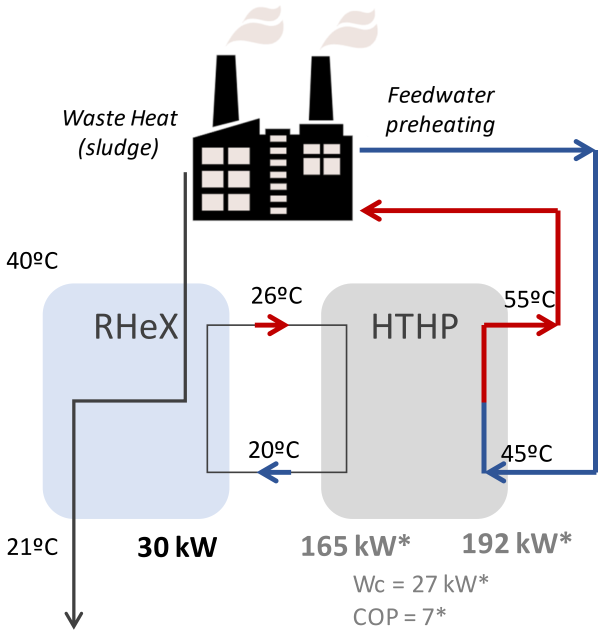
The goal of this study is to evaluate the environmental impact of the implementation of LowUP solutions in the pulp and paper plant at the city of Setubal (LowUP scenario) against a reference scenario (baseline scenario) using conventional technologies. The boundaries of the system include the extraction of the raw materials, the production of the different technologies, transportation and the operation stage (See Figure 28in section 5.1.1.1). The LowUP system is based on HP LowUP technologies as previously described (GEA and POZZI). The reference scenario consists of a conventional gas boiler to meet the energy needs of the digestors without energy recovery.

The assessment considered 5,000 yearly running hours for 25 years. For a more detailed description of the different scenarios, see section 5.2.1.2. The functional unit considered in this study was "the energy required to preheat the feed water for 25 years"

5.3.1.2 Life cycle inventory

In this case, the data for the construction stage was collected following the same methodology already developed in section 5.1.1.2. For a detailed listing of all the data used for the construction stage please refer to section 4.3 of this deliverable.

For the use stage, the lack of real data from the operation was overcome using a simulation of the system considering the most relevant parameters for the assessment. The model considered the combined used of the energy recovery system and the high-efficiency heat pump to upgrade the heat from the sludge and reduce the energy needs of the water preheating process (Figure 40).



Parameter	Value	Unit
RHeX output	30	kW
HTHP source input	165	kW
Scale factor	6.33	kW
COP	7,11	-
WC	27	kW
Yearly running hours	5,000	h

Figure 40. Simulation for Setubal demosite

The energy consumption for both scenarios, baseline and project scenario are shown in Table 62 and Table 63.

Table 62. Energy consumption for baseline scenario

Input	Unit	Value
Natural gas	GWh	26.7

Table 63. Energy consumption for project scenario

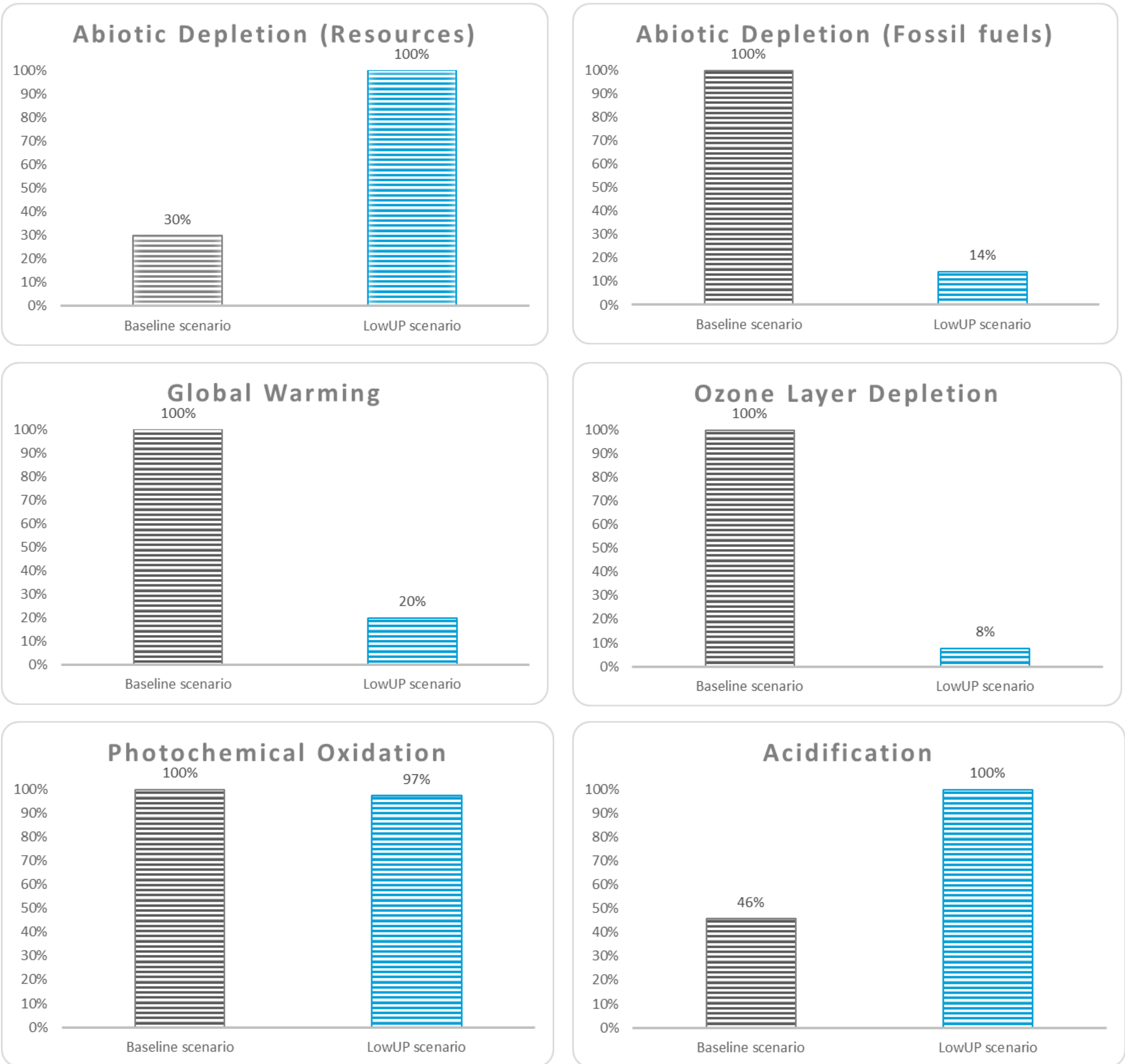
Input	Unit	Value
Electricity from grid	GWh	3.38

5.3.1.3 Impact assessment

Life cycle impact assessment was conducted following the guidelines in ISO 14040/14044. The analysis considered only the mandatory steps: selection of impact categories, category indicators and characterization models, classification, and characterization.

In this project, the CML-IA baseline method (version 4.2) was used. The selected impact categories included Abiotic depletion (both resources and fossil fuels), global warming, ozone layer depletion, photochemical oxidation, acidification and eutrophication. SimaPro (version 9) was used to perform the assessment.

5.3.1.4 Interpretation



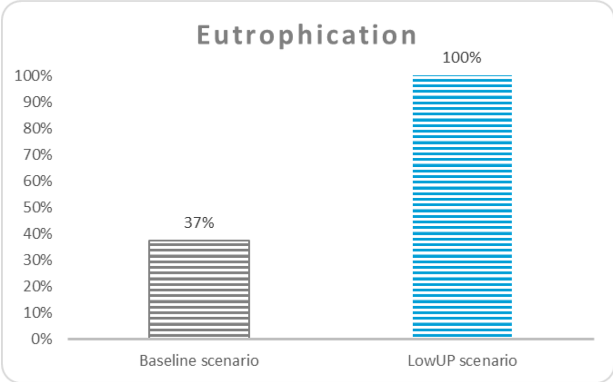


Figure 41. Environmenta results for Setubal demosite

The results of the comparative assessment for the different categories included in the study are shown in Figure 41. As this demo sites works with the same technology than the previous one, the results follow the same trend. The reduction in the energy consumption results in a significant reduction in the emission of greenhouse gases (80 % reduction), the consumption of fossil fuels (86 % reduction) and the ozone layer depletion (92 % reduction). The consumption of resources is higher as a consequence of the need for steel, copper and other non-ferrous metals for the production of the LowUP technologies. The use of electricity from the grid is responsible for the increase in the impacts in acidification and eutrophication. In this case, the impacts stem from the use of coal for electricity production in the Portuguese electricity mix. For the demo in Setubal, these impacts are higher since the share of coal is higher than for the Spanish electricity mix, which again highlights the importance of the use of renewable energies instead of energy from fossil fuels.

In the same way, suitable strategies such as the extension of the service life of the equipment and proper end-of-life activities (repurposing, recycling) would increase the environmental benefits and reduce the burdens linked to the depletion of the ozone layer and the consumption of resources, making LowUP solutions more environmentally friendly.

5.3.2 Economic evaluation (LCC)

In this section an economic evaluation has been developed considered the costs from the equipment acquisition and use phase in the demosite during the period life of 25 years. The data economic for the equipments has been provided by each manufacturer and the energy consumption for this period time, as we have explained previously, has been simulated, see Table 62 and Table 63. On the other hand, regarding to the electricity price considered in this assessment has been obtained from the Eurostat agency [11] for non-household consumers from the second half 2019, see Table 64.

Table 64.Energy prices

Energy	Location	Unit	Value (included VAT*)
Electricity	Portugal	€/kWh	0.1408
Natural gas	Portugal	€/kWh	0.0378

*A VAT of 23% has been considered

The results obtained shows that during the period considered, 25 years, the contribution, to the total costs, of the equipment (38%) and the energy consumption (62%) are very close, see Figure 42

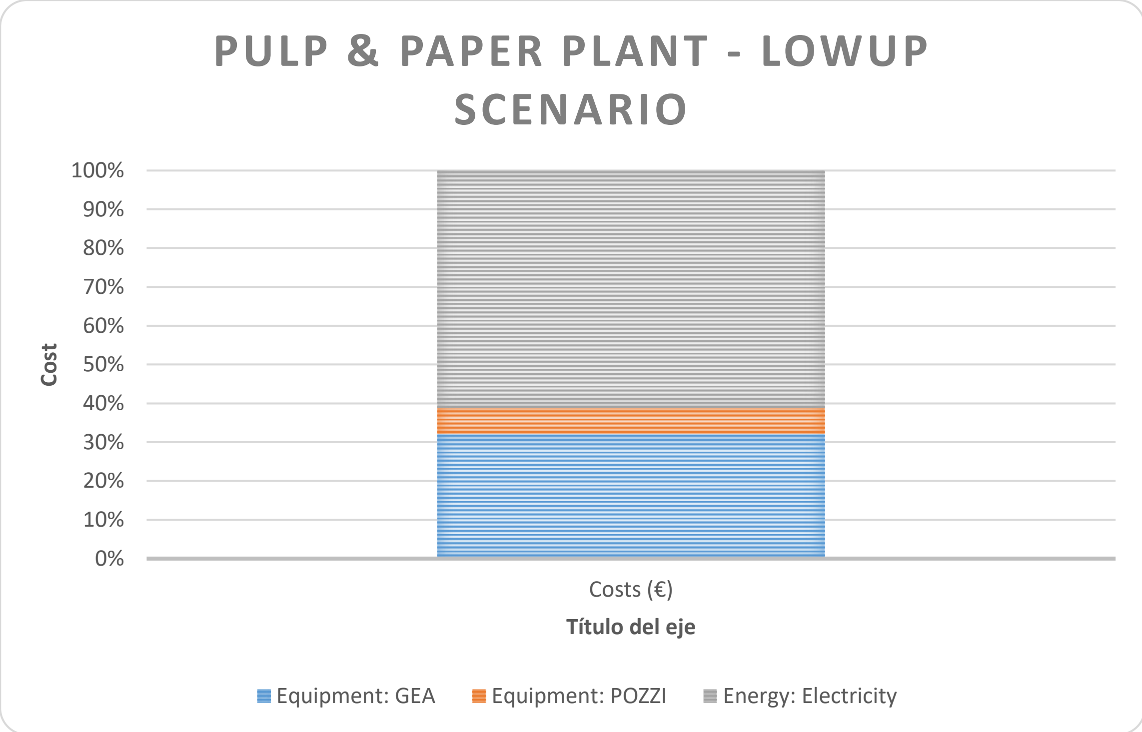


Figure 42.Economic results for Setubal demosite

Finally, in order to know if the economical investment of the LowUP technologies is profitable for this industry, in the period of 25 years, an economic assessment for a hypothetical baseline scenario and following comparison with LowUp scenario has been developed. For the baseline scenario, the equipment considered has been a natural gas industrial boiler of 250 kW. Thus, considering this assumption and the information shown in Table 65 the result obtained are shown, graphically, in Figure 43

Table 65. Economic results for Setubal demosite

Category	Energy	Unit	Value
Energy prices	Electricity	€/kWh	0.1408
	Natural gas	€/kWh	0.0378
Equipment	Baseline scenario	Total equipment	50000
	LowUP scenario	POZZI LEOPOLDO and GEA technologies	296282
Energy consumption	Baseline scenario	GWh (Natural gas)	26.7
	LowUP scenario	GWh (Electricity)	3.38
	Baseline scenario	€	1006720
	LowUP scenario		467589
Total investment	Baseline scenario	€	1056720
	LowUP scenario		763871

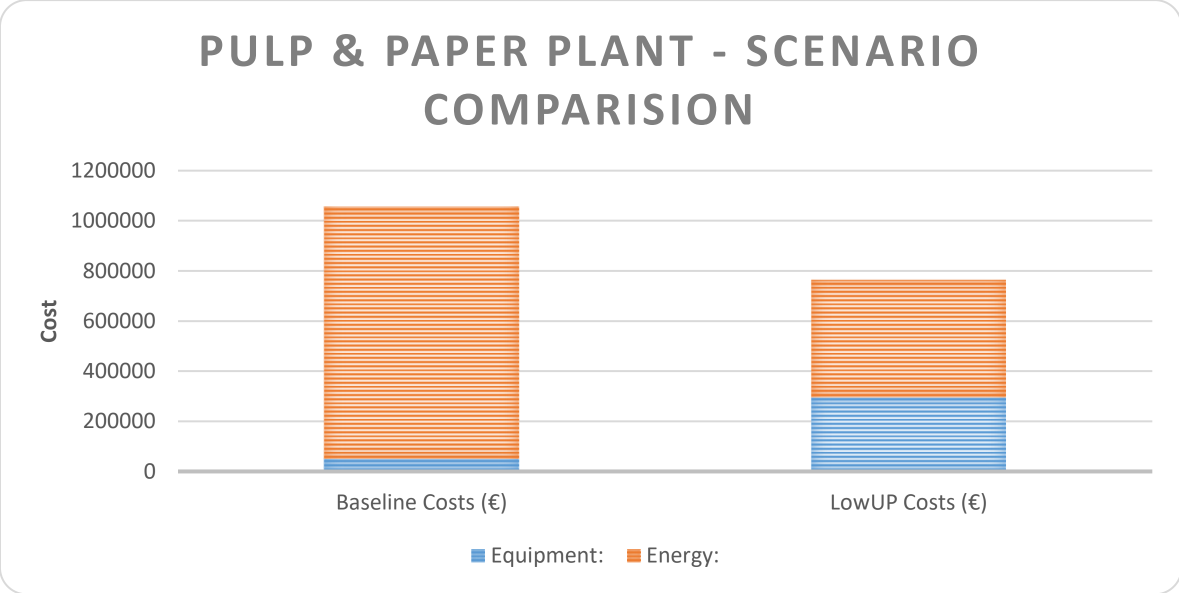


Figure 43. Economic results for Setubal demosite comparision

The result obtained shows that the application of the LowUP technologies combination (GEA and LEOPOLDO POZZI) in this industry gets a profitable economic result. The application of LowUP technologies allowing a reduction of the energy consumption, more than 50%, during the period of time considered that gets to recover the initial investment related to the equipment acquisition.

6 Guidelines for optimal environmental and economic performance of the Low Up systems

Finally, this report presents a set of good practices that could be used to optimise the environmental and economic impact of LowUP's technologies. These guidelines have been developed based on the results of the environmental and economic evaluation, which highlighted the hotspots and therefore allowed to take measures to potentially reduce the impacts. These good practices have been provided following the same life-cycle approach.

➢ Production stage

Efficient use of raw materials: special focus on critical RMs:

As it has been mentioned before, the main source of impact for the production stage is the consumption of raw materials. In particular, for the LowUP technologies, the consumption of ferrous and non-ferrous metals such as steel, aluminium, copper… represents a significant share of the impact. The use of plastics materials also has a significant impact because of its good technical properties. However, the use of fossil plastics should be progressively transitioned into the use of more environmentally-friendly materials. This means that the consumption of these raw materials should be carefully monitored, using appropriate design tools and processing technologies to optimize resource use and minimize waste generation. Additionally, potential internal recovery routes should be designed to introduce any by-products and wastes back in the process, reducing the need of primary raw materials yielding both environmental and economic profits.

Higher resource substitution: use of secondary raw materials

In line with the previous recommendation, and following the principles of Circular Economy, closing material loops will be an effective way of reducing the environmental impact of manufacturing processes. For the LowUp project, this means increasing the recycling rates, with higher % of recycling content in the products.

Lightweighting

Although transportation is not the main source of impact, the international value chains demonstrated in LowUP include long-distance transportations, and an effective way to reduce environmental and economic cost of this step is to reduce the weight of the different components of the technologies under assessment through the selection of the appropriate materials and the use of optimum design strategies.

Packaging use

Another aspect that shouldn't be overlooked despite its low share of the impact. Reducing or simplifying the packaging of the different components reduces the need for packaging materials and the subsequent management activities for waste packaging. Another alternative to optimize the environmental and economic performance of the is to set an effective system of reverse logistics to ensure the optimal management of all the packaging used in the product manufacture, installation and operation.

- Operation stage

Life extension

Extending the service life of a product reduces the overall environmental footprint of a product, as avoids the need of producing a new piece of equipment. As seen in this deliverable, the environmental and economic impact of the production stage is significant, so the longer the service life, the better performance, as long as the operation of the system is kept efficient. To this end, the appropriate measures should be taken from the very beginning at the design state. Additionally, a good maintenance is key to keep the product in shape and reduce the risk of breakdown and eventual failure.

Optimal integration and sizing

LowUP technologies and the corresponding integrated solutions have been demonstrated up to TRL5-6 in a relevant environment with specific building characteristics and climate conditions, as well as including some emulated behaviours. In this sense, there is still room for further improvements in terms of defining the optimal adaptations to different applications and weather conditions. The integrated designs and sizing should be optimized according to load characteristics and potential for maximized renewable production (e.g. solar component should be prioritized in Southern regions where cost-effective thermal production is easier, while maybe reduced in Northern regions; the sewage water waste heat recovery unit should be sized according to the actual waste energy of each specific application but can be even removed if no relevant recovery potential exists). Finally, the electrical output from the solar panels should be exploited at its maximum in order to reduce the energy costs during the operational stage.

Advanced predictive control for operational optimization

The cost and environmental impacts during the operation stage are mainly linked to the energy use during the life of the LowUP solutions. As previously described and conveniently reported in other deliverables (see D2.10) the optimal selection of control setpoints will be crucial to obtain clear benefits in comparison to conventional existing solutions. Implementing predictive control algorithms capable of defining variable optimal setpoints for the day ahead (or even for shorter periods) will enable improved reductions of the energy use. Moreover, in order to maximize local, renewable, 'free' energy generation (e.g. from the solar field, the waste heat recovery units or the ambient air as source for the cooling generation equipment) special attention should be paid to operating temperature levels, which, moreover, are at the core of the low-temperature / low-grade energy sources exploitation and upgrade promoted within the project.

End of life

Design for disassembly

To reduce the overall impact of the life cycle of the different products involved in LowUP, it is important to offset part of the impacts with appropriate end-of-life processing routes. It is important to recover as much secondary raw materials as possible for the EoL products.

A good way of ensuring high recycling rates is to apply design-for-disassembly at the beginning of the life cycle of the product: the design stage, ensuring that the product can be easily dismantled, that its components can be readily separated and that the materials have high recyclability potential.

Appropriate EoL management

Once all the equipment has reached the end of its useful life, the different alternatives for its management should be explored. In this situation, different options can be evaluated, such as refurbishment (restoring the product and bring it up-to-date), reuse for a different consumer if the product can still be used, remanufacture (using parts of the product in new pieces of equipment) and repurposing (transform the product or its parts in a new product with a different function).

When no one of these options is available, then recycling of the product should be addressed, achieving high recycling rates for all the components of the product.

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