ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

GRADO EN INGENIERÍA ELECTROMECÁNICA

ESPECIALIDAD ELÉCTRICA

LIFE CYCLE ASSESSMENT OF RENOVATION ACTIVITIES OF SINGLE FAMILY HOUSE IN SPAIN

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Madrid
10 de julio de 2018

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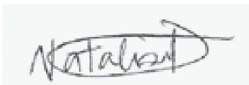

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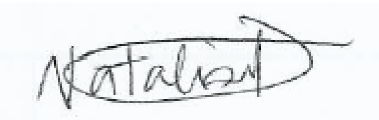

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Entidad Colaborativa: Technische Universität Wien

RESUMEN DEL PROYECTO

1. Introducción

   El sector de la construcción está creciendo con el paso del tiempo, y está actualizando nuevos tipos de edificación. Sin embargo, no todas estas renovaciones son beneficiosas para el medioambiente. Hoy en día, alrededor del 75% de los edificios en Europa son ineficientes desde el punto de vista energético. El sector de la construcción en la UE es el mayor consumidor individual de energía de Europa, siendo responsable del 40% del consumo de energía y del 36% de las emisiones de CO_2 en la UE. En la actualidad, alrededor del 35% de los edificios de la UE tienen más de 50 años. Al mejorar la eficiencia energética de los edificios, podríamos reducir el consumo total de energía de la UE entre un 5 % y un 6 % y reducir las emisiones de CO_2 en un 5 % aproximadamente.

   El vicepresidente responsable de la Unión de la Energía, Maroš Šefčovič, ha declarado: "La lucha contra el cambio climático comienza 'en casa', ya que más de un tercio de las emisiones de la UE son producidas por los edificios. Al renovarlos y hacerlos inteligentes, estamos capturando varios pájaros de un tiro: las facturas de energía, la salud de la gente y el medio ambiente. Y como la tecnología ha desdibujado la distinción entre sectores, también estamos estableciendo un vínculo entre los edificios y la infraestructura de movilidad electrónica, y ayudando a estabilizar la red eléctrica. Mantengámonos en marcha"

   Es fundamental mejorar el rendimiento energético de los edificios europeos, no sólo para alcanzar los objetivos de la UE 2020, sino también para alcanzar estos objetivos a más largo plazo de nuestra estrategia climática, tal como se establece en la estrategia de 2050 con bajas emisiones de carbono. El parque de edificios existente tiene la capacidad de reducir su consumo de energía en un 61% para el año 2030. Un hecho importante en el sector de la construcción es que el 75% del parque construido en la UE es residencial.

   Para 2020, la UE se propone reducir sus emisiones de gases de efecto invernadero al menos un 20 % con respecto a los niveles de 1990, aumentar la cuota de energía renovable hasta al menos el 20 % del consumo y lograr un ahorro energético del 20 % o más. Todos los países de la UE también deben alcanzar una cuota del 10 % de energías renovables en su sector del transporte.

2. Estado de la cuestión

El ciclo de vida de un edificio comienza con la extracción de la materia prima, la producción de materiales, la fabricación y utilización del edificio y, finalmente, el final de la vida útil donde el material se elimina o se recicla para nuevos materiales. En Europa existe un instrumento legislativo para mejorar la eficiencia energética llamado Directiva sobre la Eficiencia Energética de los Edificios 'DEEE'. Su objetivo para conseguir los objetivos de 2020 es implementar la construcción de Edificios de Energía Casi Cero 'NZEBs'.

El ACV se aplicará para analizar una vivienda unifamiliar en Madrid (España). La vivienda será de una planta de 160 m^2 compuesta por un salón-comedor, cocina y lavadero, tres habitaciones y dos baños.

3. Objetivos del proyecto

El objetivo de este proyecto es estudiar el análisis del ciclo de vida de una vivienda unifamiliar en España. En primer lugar, se realizará una pequeña maqueta de la vivienda para proceder al análisis. A continuación, se calcularán las emisiones de CO_2 y la energía incorporada para las fases consideradas de ACV, construcción y uso.

El objetivo principal de la tesis es comparar dos casos diferentes cambiando los sistemas de energía de refrigeración y calefacción y analizar su efecto sobre las emisiones de CO_2 y la energía incorporada. La tipología A tiene una caldera eléctrica, energía solar y suelo radiante, y la tipología B tiene una caldera de biomasa y radiadores.

4. Metodología

Se analizarán los impactos ambientales en dos de las tres fases del edificio: construcción y uso. La fase de construcción incluye la fabricación y el transporte de materiales de construcción. La fase de uso incluye la calefacción, ventilación y aire acondicionado, ACS (Agua Caliente Sanitaria) e iluminación.

LCA se basa en las directrices de la norma UNE-EN ISO 14040 y 14044. El ACV es una metodología para evaluar los impactos ambientales a través de un sistema. El proceso consta de cuatro fases:

1) Definición de objetivos y Alcance: Definir y describir el producto, proceso o actividad. Establecer el contexto en el que se realizará la evaluación e identificar los límites y los efectos ambientales que se revisarán para la evaluación.

2) Análisis de Inventario: Identificar y cuantificar el uso de energía, agua y materiales y las liberaciones ambientales (por ejemplo, emisiones atmosféricas, eliminación de desechos sólidos, descargas de aguas residuales).

3) Evaluación de impacto: Evaluar los posibles efectos humanos y ecológicos del uso de energía, agua y materiales y las liberaciones ambientales identificadas en el análisis del inventario.

4) Interpretación: Evaluar los resultados del análisis de inventario y la evaluación de impacto para seleccionar el producto, proceso o servicio preferido con un claro entendimiento de la incertidumbre y los supuestos utilizados para generar los resultados.

5. Softwares aplicados en el estudio

   Para los cálculos se utilizarán dos programas informáticos. Primero, CYPE, se usará la versión del estudiante. CYPE es un software desarrollado por ingenieros. El programa calcula los costos económicos, las necesidades energéticas y los impactos ecológicos, una vez que el proyecto está definido con todos los datos de localización geográfica, especificación de urbanización, infraestructura y unidades de construcción.

   El segundo conjunto de software es proporcionado por el gobierno español y está compuesto por dos programas complementarios, LIDER (Limitación de Demanda Energética) y CALENER VYP (Calificación Energética para Vivienda y Pequeños Edificios Terciarios). Siendo ambos los métodos oficiales aprobados por la Administración española para el cálculo de la demanda y consumo energético de los edificios, respectivamente.

   Una vez que el edificio y la envolvente están bien definidos por CYPE, la demanda energética se calcula con LIDER, y después de dimensionar y diseñar los sistemas de climatización y ACS, se calculan las emisiones y la clasificación final con CALENER VYP.

6. Conclusiones

   En este estudio se muestran dos casos diferentes comparando su consumo energético, emisiones de CO_2 y costes económicos. Después de todos los datos, está claro que el uso de la tipología B es más eficiente y económico que la tipología A.

   Hay muchas maneras de mejorar la eficiencia del edificio. La más importante es mejorar el aislamiento. Sin embargo, cambiar el sistema de calefacción y refrigeración a uno más eficiente también es un factor influyente.

   Cabe mencionar que el uso de paneles solares no siempre es la mejor solución para que el edificio sea eficiente. En este caso, es más eficiente disponer de una caldera de biomasa.

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PROJECT ABSTRACT

1. Introduction

   The building sector is growing as the time pass, and is updating new types of construction. However, not all these renovations are beneficial for the environment. Nowadays, about the 75% of buildings in Europe are energy inefficient. The building sector in the EU is the largest single energy consumer in Europe, building is responsible for 40% of energy consumption and 36% of CO_2 emissions in the EU. Currently, about 35% of the EU's buildings are over 50 years old. By improving the energy efficiency of buildings, we could reduce total EU energy consumption by 5-6% and lower CO_2 emissions by about 5%.

   Vice-President responsible for the Energy Union Maroš Šefčovič said: "The fight against climate change starts 'at home', given that over a third of EU's emissions is produced by buildings. By renovating and making them smart, we are catching several birds with one stone – the energy bills, people's health, and the environment. And as technology has blurred the distinction between sectors, we are also establishing a link between buildings and e-mobility infrastructure, and helping stabilize the electricity grid. Let's stay on high gear."

   It is fundamental to improve the energy performance of Europe's building stock, not only to achieve the EU 2020 targets, but also to reach these longer terms objectives of our climate strategy as laid down in the low carbon economy roadmap 2050. The existing building stock has the capability to reduce its energy consumption by 61% by 2030. An important fact in the building sector, is that the 75% of EU built stock is residential.

   By 2020, the EU aims to reduce its greenhouse gas emissions by at least 20% lower than 1990 levels, increase the share of renewable energy to at least 20% of consumption, and achieve energy savings of 20% or more. All EU countries must also achieve a 10% share of renewable energy in their transport sector.

2. State of the question

   The life cycle of a building starts with the raw material extraction, the material production, manufacturing and utilization of the building, and finally, the end of life where the material is eliminated or is recycle for new materials.

   In Europe exists a legislative instrument for improving the energy efficiency called Energy Performance of Buildings Directive 'EPBD'. It's objective to obtain 2020

targets is to implement the construction of Nearly Zero-Energy Buildings 'NZEBs'.

The LCA will be applied to analyse a single-family house in Madrid (Spain). The house will be a one floor dwelling of 160 m^2 composed with a living/dining room, a kitchen, three rooms and two bathrooms.

3. Objectives of the project

The aim of this project is to study the life cycle analysis of a single-family house in Spain. First, a small model of the dwelling will be set up in order to proceed with the analysis. Then, the CO_2 emissions and embedded energy will be calculated for the considered LCA phase's, construction and production, and use.

The main objective of the thesis, is to compare two different cases changing the cooling and heating energy systems (HVAC system) and analyse its effect on the CO_2 and embedded energy. The typology A have an electric boiler, solar energy and radiant floor heating, and the typology B have a biomass boiler and radiators.

4. Methodology

Environmental impacts will be analysed for two of the three building phases: construction and use. The construction phase includes the manufacturing and transportation of building materials. The use phase includes de HVAC (Heating, Ventilation and Air Conditioning), DHW (Domestic Hot Water), lightning.

LCA is based in the guidelines of UNE-EN ISO 14040 and 14044. The LCA is a methodology to evaluate environmental impacts throughout a system. The process consists of four phases:

1) Goal Definition and Scoping: - Define and describe the product, process or activity. Establish the context in which the assessment is to be made and identify the boundaries and environmental effects to be reviewed for the assessment.
2) Inventory Analysis: Identify and quantify energy, water and materials usage and environmental releases (e.g., air emissions, solid waste disposal, waste water discharges).
3) Impact Assessment: Assess the potential human and ecological effects of energy, water, and material usage and the environmental releases identified in the inventory analysis.
4) Interpretation: Evaluate the results of the inventory analysis and impact assessment to select the preferred product, process or service with a clear understanding of the uncertainty and the assumptions used to generate the results.

5. Software applied in the analysis

Two software's will be used for the calculations. First, CYPE, the student's version will be used. CYPE is a software developed by engineers. The program calculates economic costs, energy needs and ecological impacts, once the project is defined with all the data of geographical localization, specification of urbanization, infrastructure and building units.

The second set of software is provided by the Spanish government and composed of two complementary programs, LIDER (Limitación de Demanda Energética, Energy Demand Limitation) and CALENER VYP (Calificación Energética para Vivienda y Pequeños Edificios Terciarios, Energy Rating for Housing and Small Tertiary Buildings). Being both the official methods approved by the Spanish Administration to calculate energy demand and energy consumption of buildings, respectively.

Once the building and the envelope are well defined by CYPE, the energy demand is calculated with LIDER, and after the HVAC and DHW systems are dimensioned and designed, the emissions and final classification are calculated with CALENER VYP.

6. Conclusions

In this study, two different cases are shown comparing their energy consumption, CO_2 emissions and economic costs. It is cleared, after all the data, that the use of the typology B is more efficient and economical than typology A.

There are many ways to improve the efficiency of the building. The most important is to improve the insulation. However, changing the HVAC to a more efficient is also an influential factor.

It is worth mentioning that the use of solar panels is not always the best solution to make the building efficient. In this case, is more efficient to have a biomass boiler.

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LIST OF ABREVIATIONS

CDW	Construction and demolition waste
CO_2	Carbon dioxide
CTE	Technical Building Code
DB	Basic Document
DHW	Domestic Hot Water
EPA	Environmental Protection Agency
ETS	Emissions Trading System
EU	European Union
GHG	Green-House Gases
HULC	Unified Tool LIDER-CALENER
HVAC	Heating, Ventilating and Air Conditioning
IDAE	Institute for Energy Diversification and Saving
ISO	International Standards Organization
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCIA	Life Cycle Impact Assessment
LCI	Life Cycle Inventory
LER	European Waste List
MJ	Megajoule

1. INTRODUCTION

Global Warming and climate change are two of the biggest challenges for our future, they are a threat for the environment. It may be a result of human activity (anthropogenic changes in the composition of the atmosphere or in land use) or due to natural variability (internal processes or external forcing's). However, one of the biggest factor are the Green-House Gases (GHG) emissions. These gases trap heat in the atmosphere, and are composed mainly with Carbon dioxide (CO_2), Nitrous oxide (N_2O), Methane (CH_4) and Fluorinated gases. In Figure 1 can be observed the distributions of GHG Emissions worldwide in 2015.

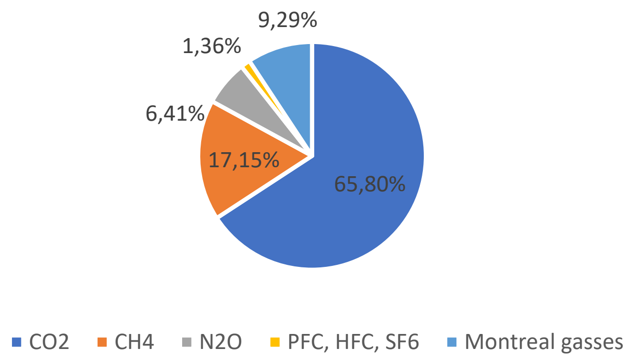


Figure 1. GHG Emissions in 2015.

Carbon Dioxide present the highest percentage of GHG Emissions worldwide. Its evolution in the past 75 years, divided by countries, can be observed in Figure 2. To begin to reduce atmospheric CO_2 concentrations, our emissions need to not only stabilise but also decrease significantly.

The European Union has set some targets to reduce Climate Change. The targets were set by EU leaders in 2007 and enacted in legislation in 2009. They are also headline targets of the Europe 2020 strategy for smart, sustainable and inclusive growth. These targets are: reduce a 20% greenhouse gas emission (from 1990 levels), increase a 20% EU energy use from renewables and an improvement of 20% in energy efficiency. [EURO__]

The world population is growing rapidly. It has increase from 1.6 billion to 7.6 billion only in 117 years (Source: World Population Review). To be able to meet the needs for the present and future generations, changes should be done considering resource use and emissions.

Buildings are responsible for approximately 40% of energy consumption and 36% of CO_2 emissions in the European Union. Currently, about 35% of the EU's buildings are over 50 years old. By improving the energy efficiency of buildings, we could reduce total EU energy consumption by 5-6% and lower CO_2 emissions by about

5%. It is essential to achieve sustainable development. The building sector is the largest cost-effective GHG mitigation potential.

It is fundamental to improve the energy performance of Europe's building stock, not only to achieve the EU 2020 targets, but also to reach these longer terms objectives of our climate strategy as laid down in the low carbon economy roadmap 2050. The existing building stock has the capability to reduce its energy consumption by 61% by 2030. An important fact in the building sector, is that the 75% of EU built stock is residential. [EUROBU]

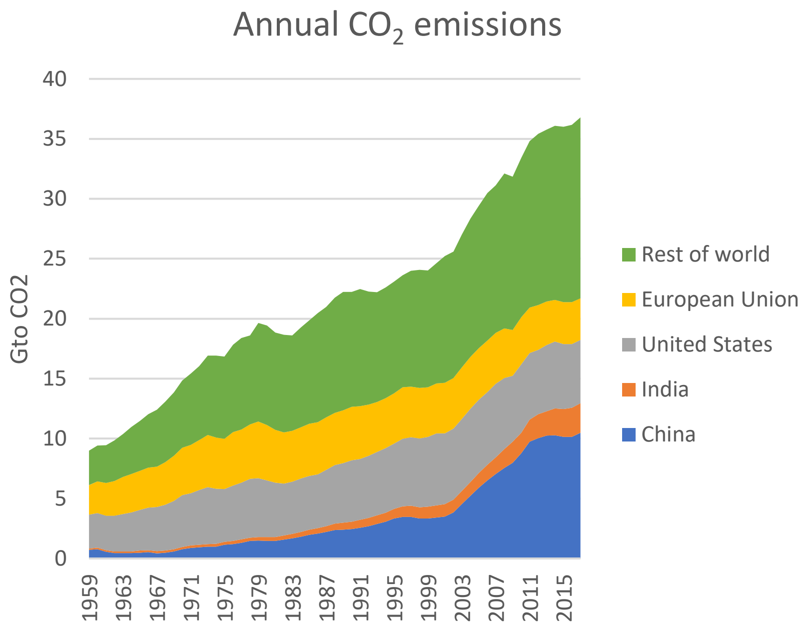


Figure 2. Annual CO2 Emissions.

2. BASIC CONCEPTS OF LIFE CYCLE ASSESSMENT (LCA)

Life Cycle Assessment (LCA) is a tool that studies and evaluates the environmental impact of a product or service during all stages of its existence, establishing an environmental balance in order to achieve sustainable development.

2.1 HISTORICAL BACKGROUND

At the end of the 1960s, Life Cycle Analysis began to be used in the United States as a tool for quantifying the energy consumption associated with production processes, preferably in the chemical industry sector.

At the beginning of the following decade, and because of the oil crisis, studies were carried out aimed at optimising energy resources, including the consumption of raw materials and the generation of waste due to their direct link with energy expenditure, developing the first analytical tools and LCA methodologies, being pioneers United States, United Kingdom and Sweden.

Once the oil crisis was assimilated, there was a certain loss of interest in LCA-related issues. LCA, reborn again at the beginning of the 1980s as a consequence of a greater awareness of the population for the environment. Motivating the different administrations to enact regulations or establish criteria to quantify the environmental burden of processes and products, and the industry companies to design and manufacture with a lower environmental impact, in order to promote their green products to increase their sales.

In this context, the SETAC foundation (Society for Environmental Toxicology and Chemistry), a leader in its field, emerged in 1979 with the aim of developing the methodology and criteria on which the Life Cycle Analysis (LCA) of processes and products is based.

The LCA took a new impulse at the beginning of the 90s, arousing the interest of the technicians, as it provides them with a tool that facilitates the elaboration of studies aimed at preventing pollution and reducing the impact on the environment.

In order to promote and standardise the use of LCA, the SPOLD (Society for the Promotion of LCA Development) was created in 1992, made up of 20 large European companies. Afterwards, in 1993, the Technical Committee 207 (ISO/TC 207) was created in ISO (International Standards Organization), with the objective of developing international standards for environmental management, being in charge of Subcommittee SC 5 the elaboration of the norms to regulate the Life Cycle Analysis, among which it is possible to highlight:

- ISO 14040. Environmental management. Life cycle assessment. Principles and framework

- ISO 14044. Environmental management. Life cycle assessment. Requirements and guidelines

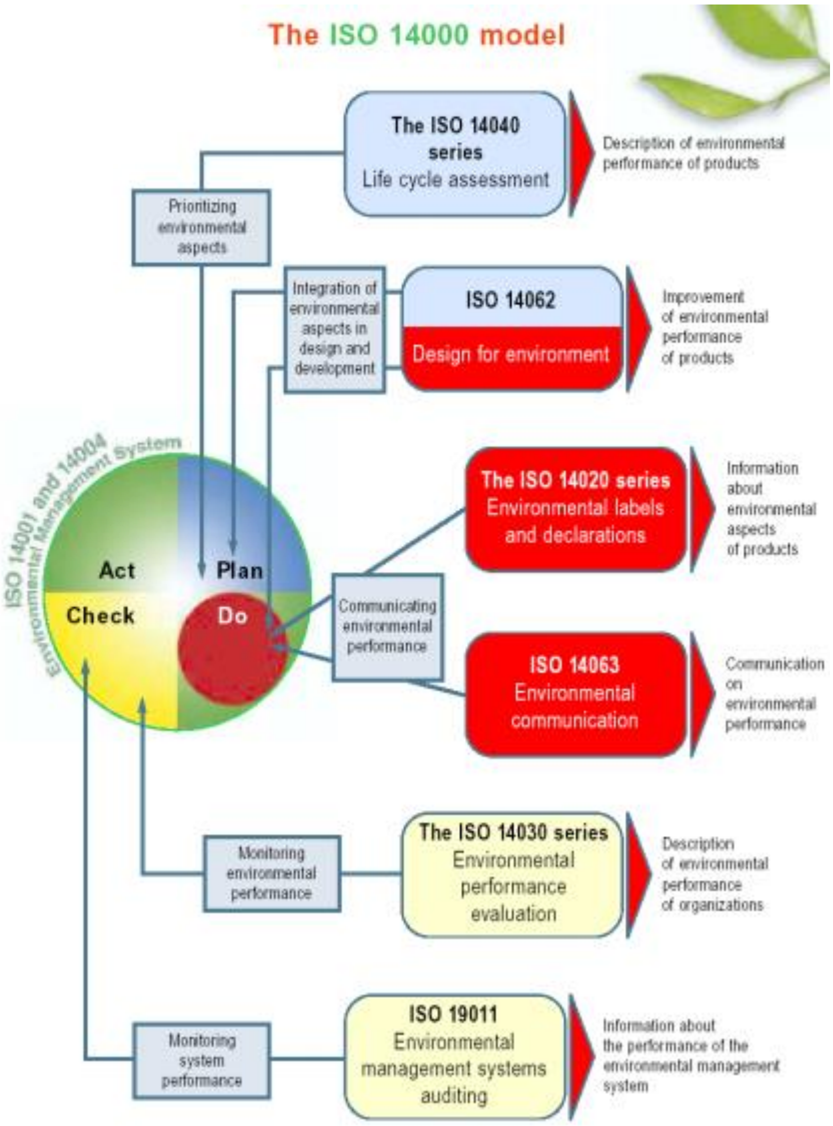


Figure 3. The ISO 14000 model.

At the end of the 20th century, there is a growing need to establish universal indicators that objectively assess industrial processes and projects, in order to preserve the environment in an appropriate way.

Following the Conference on Environment and Development in Rio de Janeiro, Brazil, in June 1992, the ISO committed itself to the development of international environmental standards. To this end, Technical Committee 207 (1993) was created, responsible for the development of the standards on Environmental Management

Systems (EMS) known as ISO 14000, whose objective is to standardize production and service provision methods in order to protect the environment and increase its quality and competitiveness.

The purpose of ISO standards is to encourage and promote more effective environmental management by providing useful tools for collecting, interpreting and transmitting evidence-based and objective information to improve environmental interventions. Providing three groups of environmental tools: Life Cycle Assessment (LCA), the Environmental Performance Assessment (EDA) and the Ecological Labelling System.

2.2 INTRODUCTION

The strong development suffered by the construction sector during the last two decades has been accompanied and influenced by the growing interest and awareness that society has experienced in the aspects related to the environmental impact that the different industrial processes, which inevitably include the building sector, have on the environment.

These factors, together with technological and scientific advances in the field, have led to the development of various regulations whose aim is to reduce the impact of this sector on the environment, without reducing the performance of its final product.

In essence, regulatory development has been geared towards reducing the energy consumed by buildings as a result of their daily operation (i.e. reducing the energy consumed in heating, cooling, domestic hot water production services, etc.), introducing new and higher technical requirements for the materials and equipment that make up the building.

Many methods are available to assess the environmental impacts. Although, the most widely used is the Life Cycle Assessment. The use of this methodology helps decision-makers select the products or process that have a less impact to the environment. It is defined and described by the International Organization for Standardization (ISO) in ISO 14040 and 14044.

Life Cycle Assessment is one of the methods used to estimate the environmental effects associated to the life cycle of products, which refers to the life-span of the product. Every product has a life cycle, starting with its production, use, disposal and recycling. In this way, it is possible to analyse and evaluate with accuracy, not just the certain environmental impacts arising from the element in question throughout their life cycle, but the variations suffered, one by one or globally, on the make modifications in any of the phases that compose it.

The life cycle of a building starts with the raw material extraction, the material production, manufacturing and utilization of the building, and finally, the end of life where the material is eliminated or is recycle for new materials. Each phase has an environmental impact. Buildings consume energy in all phases of their life cycle, from cradle to grave.

After many literature reviews, the conclusios is that the phase which has a higher environmental impact is the use phase. However, all phases are considered in this thesis to find new improvements for this case or for future ones. The Spanish normative framework, CTE (Technical Building Code, Código Técnico de Edificación) is going to be used for all the phases, since this thesis is focused on a dwelling in Spain. As there will be limitation in the different stages of the work.

Considering all the above points as a main priority, the decrease of the environmental impact in buildings requires the use of complex methods of evaluation of impacts.

The following figure (Figure 4) describes the general stages of the life cycle of any product:

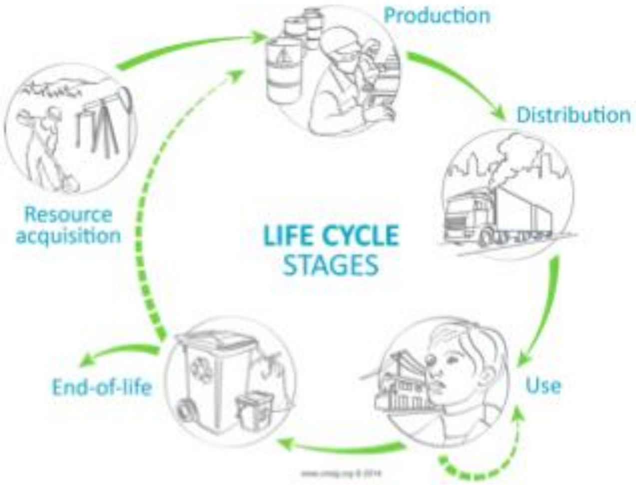


Figure 4. Life Cycle Stages.

The application of the LCA for the analysis of building constructions is recent, compared with the use for industrial products. Hence, a mayor effort is needed to adapt the methodology.

Precisely, the LCA compiles an inventory of relevant energy and material inputs and environmental releases, evaluates the potential environment impacts associated with identified inputs and releases and interpreter the results to help decision-makers make a more informed decision.

2.3 LCA SOFTWARE'S

The analysis is significantly complex, as it measures many environmental impacts. It is this complexity that makes necessary extra help to carry out the LCA.

Nowadays, due to the great capacity to solve problems, these software tools make the analysis work easier when it comes to making calculations, using extensive and useful databases, following a strict methodology, etc.

Below some software tools will be mention with a short description.

SOFTWARE TOOL	DESCRIPTION
SimaPro (Netherlands)	Compare and analyse complex products splitting into their materials and processes
Eco-it (Netherlands)	Specially useful for product designers. This tool uses the Ecoindicator 99 and is very easy to use
GaBi (Germany)	Comparing this tool with older ones, it also provides an economic analysis
TEAM (France)	It is a very complete tool with more than 500 modules of different sectors.
UMBERTO (Germany)	This tool makes eco-balances and prepares the LCA
ECOEFFECT (Sweden)	This tool evaluates the external and internal impacts of the building
ECO-SOFT (Austria)	It not only calculates the necessity of material, transport and energy but also emissions and waste.

Table 1. LCA tools

However, none of these tools will be used in this study. I will use different software's. The software's used are explain in Chapter 7.

2.4 PHASES OF A LCA

According to the classification and nomenclature included in the ISO 14040 and ISO 14044 standards, four phases are established in the life cycle of a construction:

- o Production: A1-A3
  1. Raw Materials supply
  2. Transportation
  3. Manufacturing
- o Building Process: A4-A5
  4. Products Transportation
  5. Installation and Construction Process
- o Use of the Product: B1-B7
  1. Use
  2. Maintenance
  3. Repair
  4. Replacement
  5. Refurbishment
  6. Operational energy use
  7. Operational water use
- o End of Life: C1-C4
  1. Deconstruction and Demolition
  2. Transportation
  3. Waste processing
  4. Final Disposal

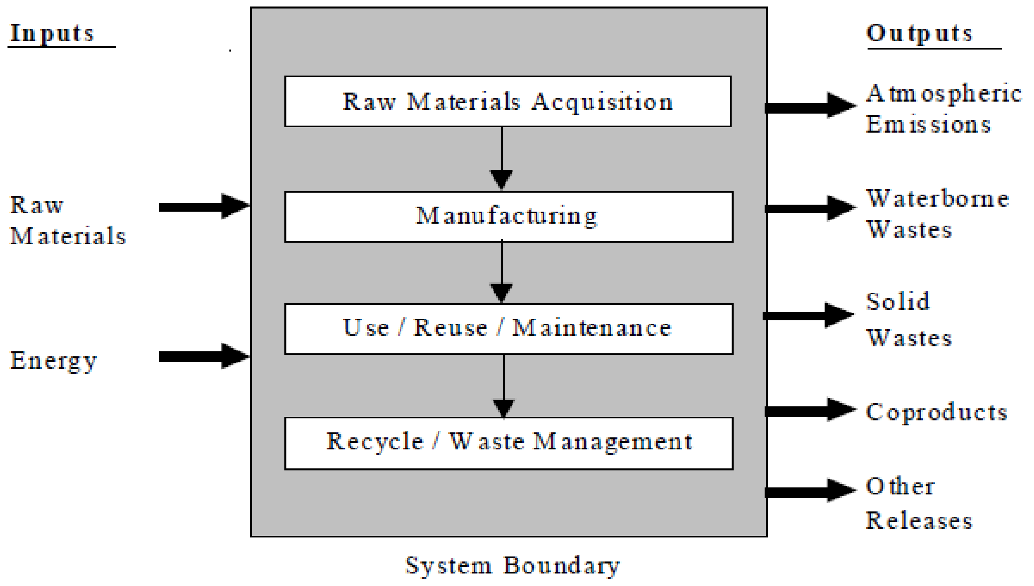


Figure 5. LCA stages.

There are different manners to focus the LCA according to the phases which are selected to realize it (see Figure 6).

2.4.1 Cradle to grave

It is the full LCA from the resource extraction phase to the disposal phase, being the use phase in between.

2.4.2 Cradle to gate

It a partial product life cycle from the resource extraction / manufacture phase to the factory gate, before it is transported to the consumer. For buildings, this variant would only cover the manufacturing phase.

2.4.3 Cradle to cradle

It is a cradle to grave assessment, where the disposal phase is a recycling process. This method is used to minimize environmental impacts with sustainable production, operation and disposal practices.

2.4.4 Gate to gate

This variant focus only one value-added process in the entire production chain. This module is sometimes linked in their appropriate production chain to form a complete cradle to gate evaluation.

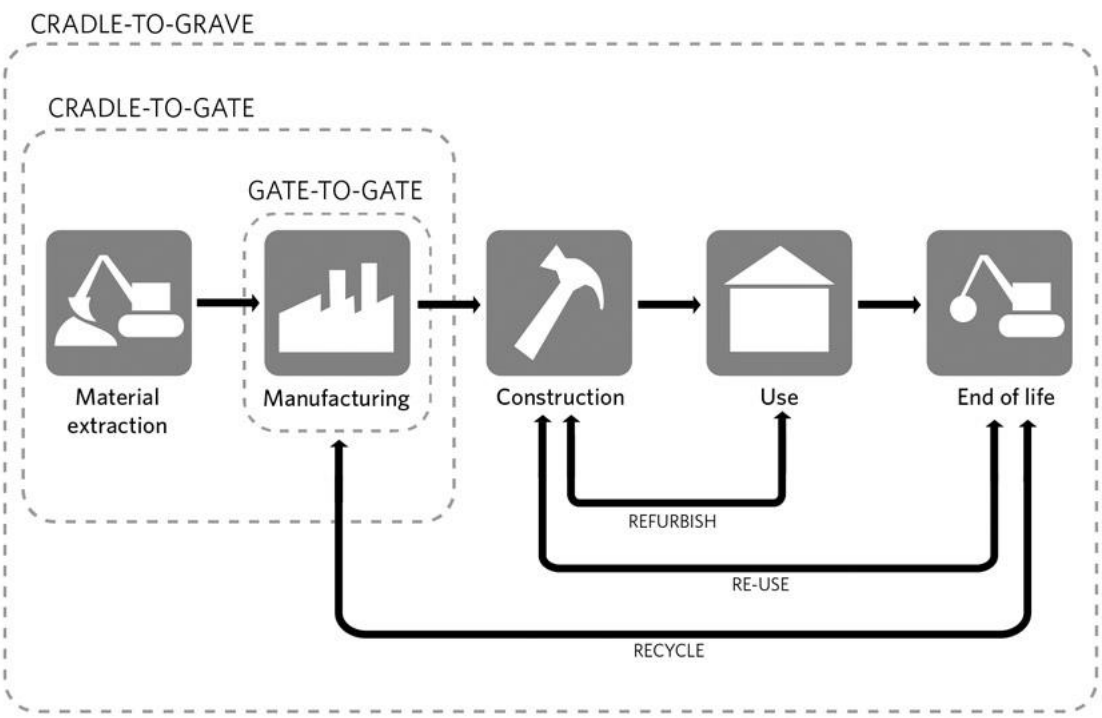


Figure 6. LCA Variants

2.5 COMPONENTS OF A LCA

To realize the LCA process properly, four components (Figure 7) must be considered:

1. Goal Definition and Scoping: in the first phase the purpose, objectives, functional units and system boundaries should be defined.
2. Inventory Analysis: Identify and quantify all data regarding inputs, processes, emissions, etc. of the entire life cycle.
3. Impact Assessment: quantifies the potential human and ecological effects.

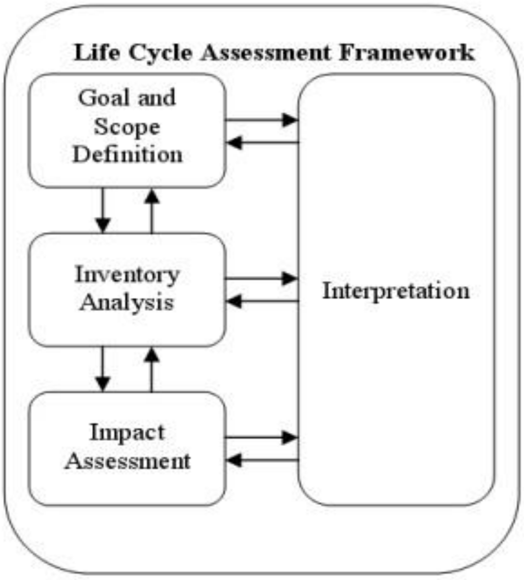


Figure 7. Phases of a LCA.

4. Interpretation: the last phase is the interpretation of the results of the life cycle analysis.

2.5.1 Goal and scope definition

It is at this stage that the time and resource requirements will be defined for the realization of the study.

It includes the exhaustive definition of the product, process or service to be analysed, its main characteristics, the causes that give rise to the analysis, the expected expectations and objectives for the application of the results obtained, etc.

Must be clearly and concisely specified all the premises and limitations to be considered in the study, the different approximation techniques to be used to obtain certain results, the quality requirements that will be demanded of the data to be analysed, the accuracy of the results to be achieved, etc.

From all the above explained, it is clear that any decision taken at this stage of the study will have some impact on the other stages of the process, and therefore a high degree of definition is recommended in the aspects mentioned above.

2.5.2 Life Cycle Inventory (LCI)

This phase consists of quantifying the inputs and outputs of the system under study, which may include all or some of the following: resource use (raw materials and energy), emissions to air, soil and water, waste generation, etc.

According to the EPA's 2006 document, "Life Cycle Assessment: Principles and Practice", the key aspects that should guide the inventory process are as follows:

1. Develop a flow diagram of the processes being evaluated: It allows to visualize in a fast and simple way, the main flows of matter, energy or any other resource or emission generated in the process
2. Develop a data collection plan: to ensure that expectations of the quality and accuracy of the data collected are met
3. Collect data: in order to minimize the time invested in the construction of the inventory, the use of some type of specialized software can be productive.
4. Evaluate and report results: the presentation of the data in the form of tables
5. and graphics is often particularly intuitive and concise.

2.5.3 Life Cycle Impact Assessment (LCIA)

It is at this stage where the potential environmental and human impact of the results obtained on the life cycle inventory is allocated.

This phase is the main difference between life cycle analysis and other environmental analysis techniques, as it does not aim to quantify a given current process/product related impact, but rather to establish a relationship between this system and its potential environmental impacts, considered globally.

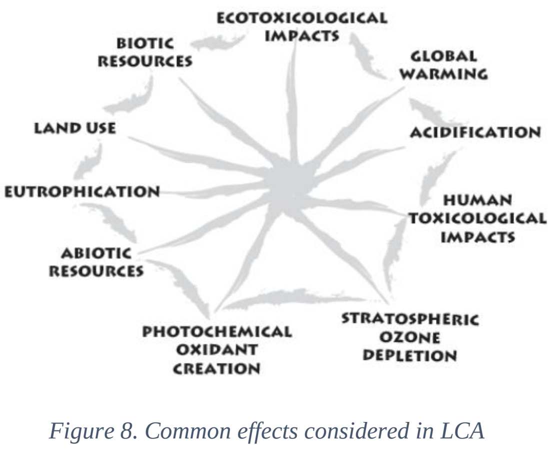


Figure 8. Common effects considered in LCA

This introduces the concept of impact categories, defined as the consequence on human health or the environment that could result from the inputs and outputs of a given system (Figure 8).

2.5.4 Interpretation

Interpretation is a systematic evaluation of the results obtained in the previous phases of the analysis. ISO has defined the following two objectives of life cycle interpretation:

1. Analyse results, reach conclusions, explain limitations and provide recommendations based on the findings of the preceding phases of the LCA, and to report the results of the life cycle interpretation in a transparent manner.
2. Provide a readily understandable, complete and consistent presentation of the results of an LCA study, in accordance with the goal and scope of the study.

2.6 APPLICATION OF LCA IN BUILDING CONSTRUCTION

The concern of using LCA for whole buildings assessment started to rise in the 1990s, and today, a few building LCA tools are under development in various countries for use by specific users and to fill analytical needs.

A building can be defined in one of three ways: a product, a process or a place to live.

1. Product: or an assembly of products manufactured, used and disposed of. The product must be maintained during its use and some parts replaced.
2. Process: provide services to the users during the utilisation phase, also appropriate conditions for living, studying, working, leisure activities… involving input and output flows to make this process function. These inputs are water, energy and various resources, and the outputs, emissions, waste water…
3. A place to live: the buildings impact on the comfort and health of users is extremely important in this case.

Most of the European Union countries final energy consumption in the residential sector is covered by six different sources (Figure 9), the majority depend on natural gas or electricity. The same happens in Spain. However, in 2015 there is no energy consumption for the heat.

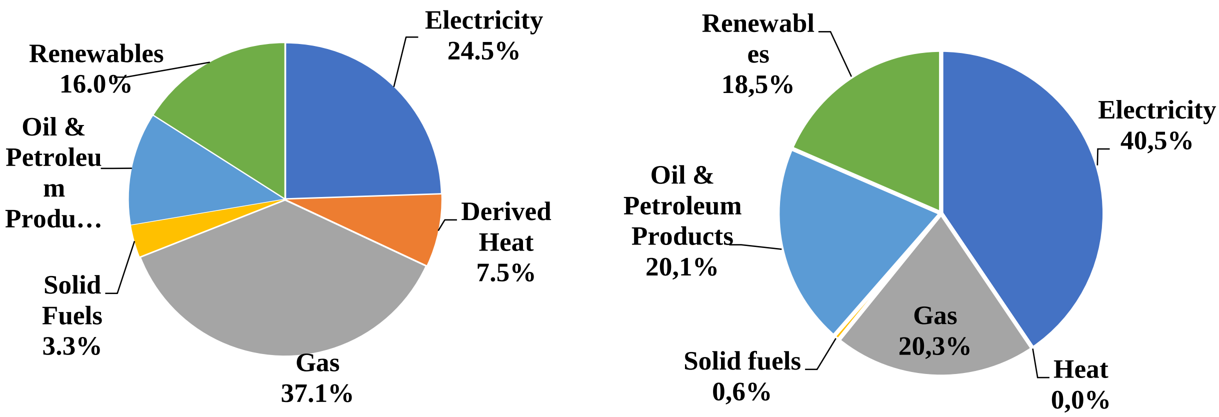


Figure 9. Energy Consumption in households 2015.
Left: World. Right: Spain

In the future, building's will become a part of the energy generation system with the use of solar panels, shared heat pumps and the sharing of heat between buildings, can contribute to build a more distributed and efficient system. And LCA tools will have to reflect this integration.

The use of LCA approach in buildings gives endless chances to the construction industry as it settles on much simple the basic decision-making for the construction companies and different associations of a similar segment in a wide range of parts of the strategy arranging of eco-efficiency in edification, for example:

- Recognition of the chances to perceive the environmental impacts created by the construction industry mulling over the entire dynamic existence of buildings.
- Foundation of the needs for the ecologic design or eco-rehabilitation of buildings.
- Proper election of providers for the construction materials and energy equipment.
- Examination between various choices for the design and for the choice of particular products or materials.
- Foundation of systems and fiscal approaches in order to deal with the residuals and the transports of the materials.
- Elaboration of programs of Research and Development (R&D) and eco-efficiency regulations.
- Implementation of aid policies in construction and rehabilitation.

2.6.1 Tools for applying LCA in the building industry

LCA can be realised using different software tools to make it easier to apply it. Many software tools have been developed in the las two decades.

The calculations should be realised when all the material quantities are identified and the data for the material and processes are available. The use of software tools makes the calculations much easier.

A critical perspective when utilizing this kind of tools, is that they should contain a precise database, which will help while doing the Life Cycle Inventory. Data used can be taken from various database relying upon the prerequisites for the LCA that is being analysed. In this study, the database used in included in the software's.

2.7 UNCERTAINTIES AND PROBLEMS IN LCA

LCA is not a perfect tool, it still needs some improvements. Multiple problems occur in each of the four LCA's phases and reduce the accuracy of this tool. In the first two phases, functional unit definition, boundary selection, and allocation are critical problems. These categories will be discussed in the next chapters.

It is essential to do a boundary selection in LCA, as it determines the activities and processes included. The risk of the incorrect selection of boundaries is that LCA results may not reflect reality and lead to incorrect interpretations of the results or provide a perception to the decision-maker that does not reflect the reality and lower his confidence in making decisions.

The ISO 14040 standard recommend that the boundary selection be based on the goal and scope of the study, the application and audience, assumptions, constrains and some cut-off criteria. It suggests selecting an initial system boundary and some refinements be made via sensitive analysis. However, a boundary selection cut off introduces a truncation error.

Phase	Problem
Goal and scope definition	Functional unit definition, boundary selection, social and economic impacts, alternative scenario considerations
Life Cycle Inventory Analysis	Allocation, negligible contribution criteria, local technical uniqueness
Life Cycle Impact Assessment	Impact category and methodology selection, spatial variation, local environment uniqueness, dynamics of the environment and time horizons
Life Cycle Interpretation	Weighting and valuation, uncertainty in the decision process

All	Data availability and quality

Table 2. LCA problems by phase

In the traditional LCA only environmental impacts are considered. Therefore, social and economic impacts are not considered. Many researches have tried to integrate the LCA with elements and methodologies for social impact assessment a life cycle costing (LCC).

The allocation problem is one of the most controversial issues of LCA and one of the classical methodological problems. Arbitrary allocation may lead to incorrect LCA results.

According to the ISO 14044, allocation means "partitioning the input or output flows of a process or other product system to the product system under study". The international standard ISO 14044 requires the following stepwise procedure for dealing with allocation problems:

1. Allocation should be avoided, wherever possible, either a) through division of the multifunction process into sub-processes, and collection of separate data for each sub process, or b) through expansion of the system investigated to include the additional functions related to the co-products.
2. Where allocation cannot be avoided, the allocation should reflect the physical relationships between the environmental burdens and the functions, i.e., how the burdens are changed by quantitative changes in the products delivered by the system.
3. Where such physical causal relationships alone cannot be used as the basis for allocation, the allocation should reflect other relationships between the environmental burdens and the functions, for example in proportion to the economic value of the products.

Normally, uncertainties are not considered in LCA, even if they can be very high. That is why, a specific analysis of these uncertainties should be carry out when doing a LCA, as it might make easier the interpretation of the results.

The main uncertainty sources are data, choices and relations. The data quality uncertainty is a main problem. There are a lot of existing databases, however, the data is not always accurate. The second source, choices, must be considered, as many hypotheses are made during the whole LCA and contain a high level of uncertainty. And the last one, relations, many assumptions are made in the process. Many other types of uncertainties exist.

Some examples of uncertainties types related to these sources are: data may be incomplete, contain error, miss-specified, choices may not be consistent, relation may be incorrect, incomplete…

The complexion of the impact model's selection could reduce the limitations of the accuracy of the assessment. These limitations have to be documented and included in the LCIA methodology comprehensive description.

2.8 CRITICAL REVIEW

This concept appears as a requirement in the ISO 14040 standard, especially in studies with a comparative objective.

The main objectives pursued at this stage are the verification of the following aspects:

1. The methodology used in the analysis is consistent with the methodology developed by the above-mentioned standard.
2. The methods used are technically and scientifically valid.
3. The data used are reasonable and in accordance with the purpose of the study.
4. Interpretations reflect the limitations identified and the objective of the study.
5. The report is clear and consistent.

The regulation also specifies three possible varieties of revision, characterized by the person in charge assigned to their realization and whose selection depends on the of the purpose of the analysis performed:

1. Internal expert review.
2. External expert review.
3. Review by interested parties.

3. SUSTAINABILITY

3.1 DEFINITIONS

The term sustainability, or sustainable development, is a concept used in various fields of the human activity. The Brundtland Commission in 1987 proposed a definition for sustainable development, which is the most often used.

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Sustainability is applied to socio-economic development and was first formalized in the document known as the Brundtland Report (1987), resulting from the work of the United Nations World Commission on Environment and Development, created at the in 1983.

Sustainable development is defined by its objective: “The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations”. This definition is the Principle 3 of the Rio Declaration (1992).

In a nutshell, we can conclude that it is a matter of `satisfying the needs of the present without putting in risk the resources of the future'.

3.2 OBJECTIVES

The primary objective of sustainable development is the development of viable projects that reconcile and harmonize the economic, social and environmental aspects, which are considered the three basic pillars of the human activity.

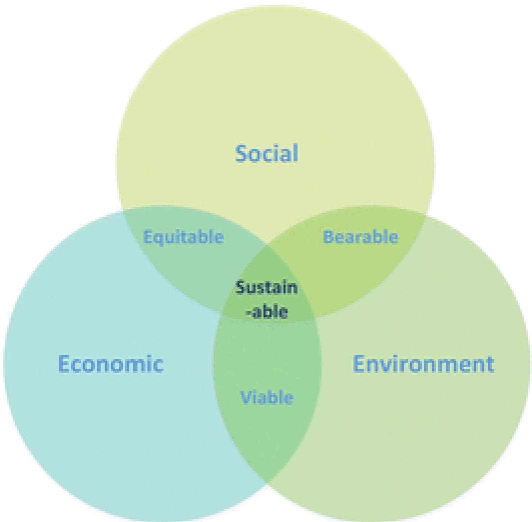


Figure 10. The three pillars of sustainability.

Sustainable development requires economically viable environmental conditions and bearable by a society in the long term, within an equitable socio-economic framework, understanding:

- Environmental: environment that affects living beings and conditions the way of life of people and their social organization.
- Economic: the organisation of production, distribution and consumption for the benefit of a society.
- Social: process of evolution and improvement in the welfare levels of a society, through an equitable and fair distribution of wealth

3.3 BASIC PRINCIPLES

In the field of sustainability, three basic principles are accepted:

- Life cycle analysis as a tool for studying and evaluating environmental impact.
- The promotion and development of the use of raw materials and renewable energies, understood as those that are obtained from virtually inexhaustible natural sources, some because of the immense amount of energy that they contain, and others because they are able to regenerate by natural means.
- The reduction of the quantities of materials and energy used in the extraction of natural resources, their exploitation and the destruction or recycling of waste.

4. SUSTAINABLE CONSTRUCTION

Sustainable construction it is a conception of the design of construction in a sustainable way, seeking the use of natural resources in order to minimize its impact on the environment and its inhabitants improving the energy performance.

Sustainable construction is based on the correct use, management and reuse of natural resources and available energy during the construction process and subsequent use of the building, applying Life Cycle Assessment (LCA) as an environmental tool.

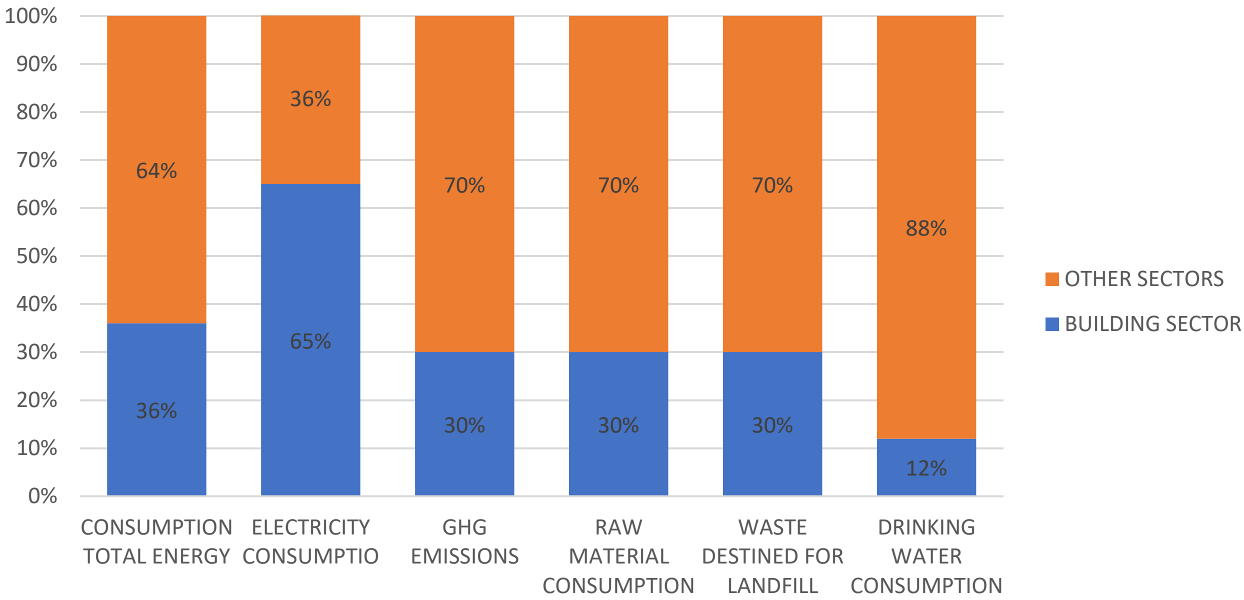


Table 3. Environmental impact of the construction sector.

4.1 PRINCIPLES OF SUSTAINABLE CONSTRUCTION

Sustainable construction is based on principles accepted by most of the actors involved in the construction process, summarised in the following points:

- The consideration from the initial stages of the project of the environmental conditions to obtain the maximum performance with the least environmental impact, highlighting the following conditions:
    - Climatic
    - Hydrographical
    - Topographical
    - Geological
    - Ecosystems of the environment
- Efficiency and moderation in the use of construction materials, with priority given to low energetic content materials.

- The reduction of energy consumption for heating, cooling, lighting, transport and other equipment, covering the rest of the demand with renewable energy sources.
- The minimization of the overall energy balance of the building, covering all phases of the construction process and the building's life stages:
  - Design
  - Construction
  - Use, repair and maintenance
  - End of life: Demolition and Recycling
- Consideration of basic requirements and compliance with regulations in relation to:
  - Safety
  - Habitability
  - Thermic comfort
  - Healthiness
  - Illumination

4.2 BENEFITS FOR BUILDINGS

Sustainable design and construction can provide economic, environmental and social benefits as a result of the responsible use of resources and of considering how the building will affect the environment.

- Economic benefits.
  There is a belief that building in an eco-smart way is more expensive than not doing so. Depending on several factors, many green buildings cost the same or even less than a traditional building due to more efficient resource management strategies that reduce electrical, mechanical and structural systems. The key to achieving this is the application of integrated design. Incorporating green strategies in the first steps of the project is key to the success of any green building.
  The cost of energy consumption is perhaps the most immediate economic benefit of applying sustainable design to a building due to the implementation of eco-efficient strategies. These energy savings come mainly from energy efficiency.

- Social benefits.
  Humans spend about 85% of their time indoors, which is why the good quality of this indoor environment is of great importance. Consequently, sustainable buildings have better acoustics, thermal and hydrothermal quality.
  Sustainable buildings have a lower demand for water and produce less wastewater than conventional buildings.

- Environmental benefits.
  The environmental benefits of sustainable building are significant. Sustainable buildings are designed to promote and protect ecosystems and biodiversity, improve air and water quality, reduce solid waste and conserve natural resources.

4.3 SUSTAINABLE CITY

A sustainable city is composed of multiple sustainable buildings. To build this city three different parties are involved for the construction of the buildings.

	Sustainable City Design		
Agents	Urban Planner	Architect	User
Document	Urban plan	Building Project	User's manual
Actions	Planning	Building	Operation
Processes	Infrastructure	Construction	Maintenance
Methods	Design and calculation		Regulation and control
Energy Consumption	Construction process		Operation energy use
Assessment parameters	Production/transportations/construction embodied energy		Energy consumption
	CO_2 emissions		
Assessment tools	Life cycle assessment		
		Energy efficiency and emissions impact labelling	
Results	Sustainability		Efficiency

Table 4. General overview of the creation of a Sustainable City

5. BUILDING SECTOR IN THE SPANISH ENERGY SECTOR

5.1 INTRODUCTION

The energy sector has undergone a discontinuous and irregular transformation., but very deep in the last twenty years, where new markets and competition into the once regulated hydrocarbon, electricity and gas monopolies had been introduced. However, this transformation is still far from complete. The development of competition is still incomplete and there are major weaknesses in regulation, including a lack of stability and predictability over time, which need to be corrected.

The Spanish government must face several problems if it wants to achieve a competitive, secure and sustainable energy sector, as the EU advises.

The building sector has been one of the main pillars on which the strong economic growth experienced by Spanish society throughout the first decade of the 21st century has been based.

This growth has led to a clear upward trend in the country's energy consumption, as well as an increase in the share of the building sector in its overall consumption.

On the other hand, and with a view to the future evaluation of the measures and incentives currently implemented in order to improve efficiency in the building sector, it is necessary to know the overall framework in which this sector is located.

In this sense, the sections that make up this chapter present the most relevant aspects of the national energy context, focusing its analysis on the repercussion that the building sector is responsible.

5.2 EVOLUTION OF THE ENERGY SECTOR

The following are some fundamental data that characterize the structure and evolution of the national energy sector during the last 20 years.

Spanish energy demand has been experiencing an upward trend since the country's entry into the European Union. In Spain, in the year 2015, the primary energy demand was $121.418 \cdot 10^3$ tep (tones equivalent of petroleum) and the final energy demand was $80.461 \cdot 10^3$ tep.

This moment marked a clear turning point in the quality of life of its inhabitants, generating a progressive increase in their purchasing power which was reflected in an increase in car and domestic equipment, as well as in a strong development of the real estate sector, factors that were decisive in the upward trend of Spanish energy consumption.

As far as the sector's performance is concerned, it remains practically unchanged the first 5 years of the last decade, with a steady increase in the downward trend in the last few years of the same years. This trend is based on the introduction of sustainability and efficiency criteria in many industrial sectors and has been strengthened, since 2008, by the impact of the international financial crisis.

The final energy consumption is mainly consumed mainly five sectors: industry, transport, agriculture, service and residential.

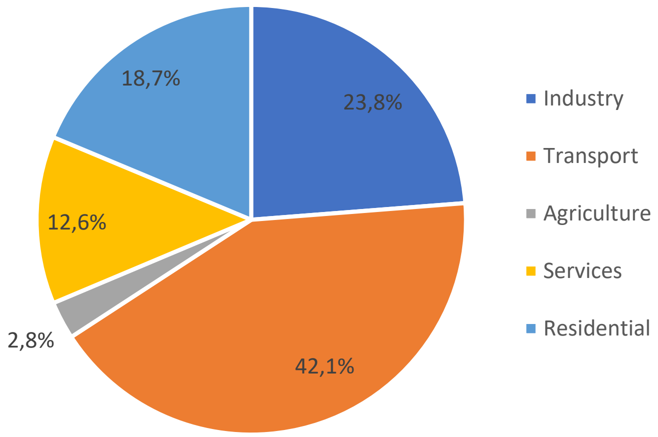


Figure 11. Final Energy Consumption by sectors

5.3 ENERGY CONSUMPTION IN CONSTRUCTION

Final energy consumption in the building sector (including consumption derived from services such as thermal installations, lighting, equipment, etc.) represents 42.1% of total energy consumption in Spain. From this number, 60% corresponds to buildings whose main use is for residential purposes, while the remaining 40% corresponds to service buildings. If we consider the segregation of the final consumption of the sector according to the uses for which it is intended, thermal and electrical, clear differences can be observed in the behaviour patterns of domestic buildings (buildings in which most of the consumption is destined for thermal uses) as opposed to buildings destined for the service sector (buildings in which most of the is intended for electrical use).

If we consider the segregation of the final consumption of the sector according to the uses to which it is use, electrical and thermal, it has been found that most of the consumption of residential buildings corresponds to the thermal, being especially relevant due to the heating consumption. (Source: IDAE)

5.4 CONSUMPTION EVOLUTION IN THE RESIDENTIRAL SECTOR

If we compare the energy intensity of the Spanish residential sector with other countries, of the European Union, it can be seen that the value recorded in Spain is lower than the European average.

It can be observed, additionally, there is a downward trend in energy consumption of households, at least partially due to the implementation of the programs of energy saving and energy efficiency measures mentioned in previous points. These differences may be due to the evolution of the building stock in Spain to efficient buildings.

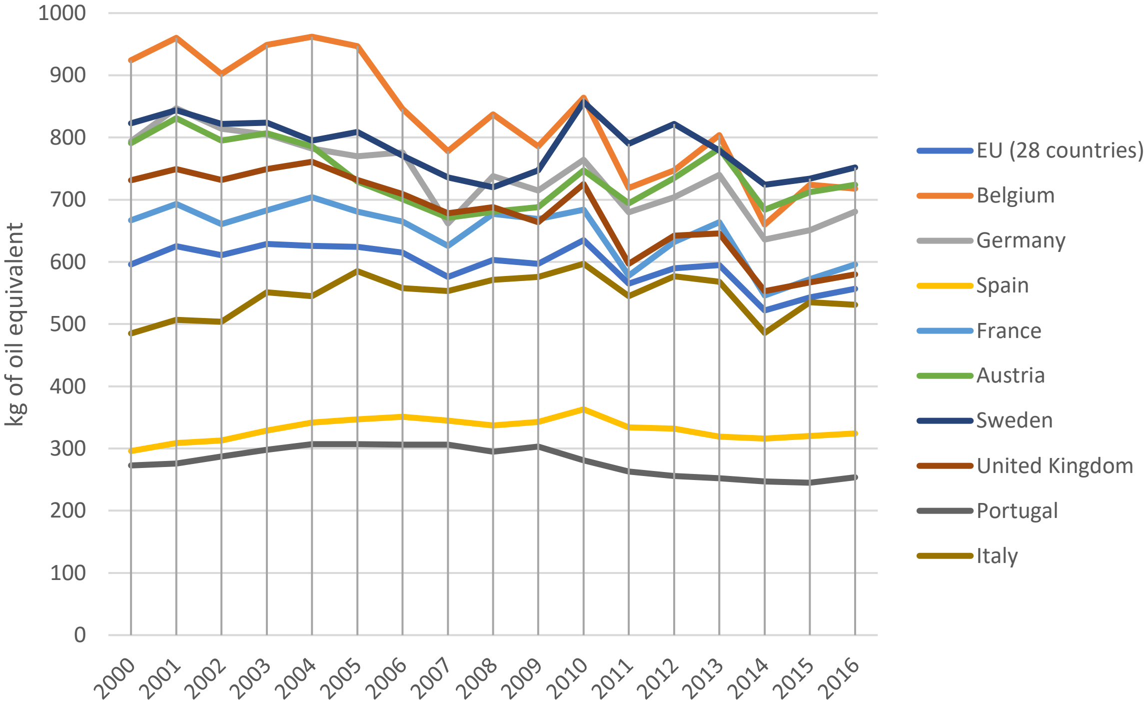


Figure 12. Final energy consumption in households per capita. Source: EU Open Data

6. RENOVATION OF RESIDENTIAL BUILDINGS IN SPAIN

European Directives on energy efficiency stablished a common framework of measures for the promotion of energy efficiency in order to achieve the EU 2020 20% target on energy efficiency and to give introduction for future energy efficiency improvements. The Directive 2012/27EU of the European Parliament and the Council of the European Union, has all these measures.

Among the Directive's provisions included in specific articles are:

- Concerning Efficiency in Energy Use
  1. Energy efficiency targets
  2. Building renovation
  3. The exemplary role of public buildings
  4. Energy efficiency obligation schemes
  5. Energy audits and energy management systems
  6. Metering and Billing information and access to these
  7. Consumer information and empowerment
- Concerning Efficiency in Energy Supply
  1. Promotion of efficiency in heating and cooling
  2. Energy transformation, transmission and distribution
- Concerning Horizontal Provisions
  1. Availability of qualification, accreditation and certification schemes
  2. Information and training
  3. Energy services
  4. Other measures to promote energy efficiency
  5. Energy Efficiency National Fund, Financing and Technical Support

Another objective of this directive is to eliminate the barriers in the energy market and overcome market failures that were an obstacle for the efficiency in the supply and use of energy.

The Article 4 from the Directive 27/2012/EU is a framework off the strategy for energy renovation in the building sector.

"The Commission Communication of 10 November 2010 on Energy 2020 places energy efficiency at the core of the Union energy strategy for 2020 and outlines the need for a new energy efficiency strategy that will enable all Member States to decouple energy use from economic growth."

The Article 4 compel all EU Member States to create a long-term strategy to reach the 2020 targets by investing in the renovation of residential and commercial buildings[1] by improving their energy performance. Consequently, cost-effective deep

[1] In this case, only residential buildings are considered

renovations reduce the delivered and the final energy consumption of a building compared with the pre-renovation levels.

The Spanish residential stock can be segmented into clusters depending on some conditions that will be explained bellow.

Three kinds of issues must be labelled by renovation and should act as a key for dividing the building stock:

1. Conservation defects in the building's construction systems and installations.
2. Problems of physical accessibility to the dwelling.
3. Voluntary improvements in the energy efficiency of the building.

The three problems are independent and can emerge one by one. Additionally, these problems require distinct solutions.

6.1 HISTORY OF TECHNICAL BUILDING CODE IN SPAIN

Since 1957, the technical standards governing the building sector, known as the MV Standards, have been the responsibility of the Ministry of Housing. These regulations were developed by the General Directorate of Architecture of the Ministry of the Interior, an institution that was created in 1937.

These rules became the Basic Building Regulations (NBE) in 1977, when the Government decided to create a unified framework for all building related regulations. Its application was mandatory for the agents of the sector. In addition to the NBE, the Building Technology Standards (NTE) were added to complete the regulatory framework. These specifications were not mandatory and served as the operational development of the NBE

Afterward, in 1999 the Law 38/1999 of 5 November on Building Planning (LOE), whose main objective is to regulate the building sector in Spain. With regard to regulations, it was necessary to update a regulation that had become deeply obsolete, and the law therefore urged and authorised the government to approve a Technical Building Code by means of a Royal Decree establishing the requirements that buildings must meet in relation to basic safety and habitability requirements.

The legislator also drafted the LOE with the aim of responding to the demands of Spanish society, which is increasingly concerned about the quality of buildings, safety, well-being, energy and environmental protection. The Technical Building Code (CTE) translates the objectives of the LOE into specifications and translates these aspirations into technical language. The CTE was finally published by Royal Decree 314/2006 of 17 March, from which date various updates have been taking place.

In terms of energy efficiency, the CTE has a document named Basic Document DB HE. This Basic Document (DB) aims to establish rules and procedures to meet the basic requirement of energy saving. The sections of this DB correspond to the basic requirements HE 1 to HE 5, and the HE 0 section that relates to several of the above. The correct application of each section implies the fulfilment of the corresponding basic requirement. The correct application of the whole DB implies that the basic requirement 'Energy saving' is met. This document is separated in six sections and each one set out some requirements:

- HE 0: Limitation of energy consumption
- HE 1: Limitation of energy demand
- HE 3: Energy efficiency in illumination installations
- HE 4: Minimum solar contribution for domestic hot water
- HE 5: Minimum photovoltaic contribution for electricity.

6.2 SEGMENTATION OF RESIDENTIAL STOCK INTO CLUSTERS

The document *Long-Term Strategy for Energy Renovation in the Building Sector in Spain Pursuant to Article 4 Of Directive 2012/27/UE* divide the residential stock into clusters based on the data from the INE database that holds the information from the 2011 census. The following data was checked:

- The province where the dwelling is located in order to locate it to its corresponding climatic zone (Appendix A).
- The municipality size, to relate the dwelling to a rural or urban area and the energy types to which it may have access.
- The year of the construction (from 1940 to 2008) which are vital due to technical and regulatory changes
- The classification into single- or multi-family buildings to estimate the renovation management.
- The number of floors and the presence of a lift.
- The state of conservation of the building, to know the requirement and extent of the actions on the building’s construction system and installations.
- The heating system of the building, to identify if it is shared or individual system.
- Finally, main, secondary and empty dwellings, though only main dwelling will be considered in the clusters definition, as they are the most widely used and need further improvement.

With all this data, the dwellings are separated into 10 clusters, from A to J. Clusters A to D include main single-family houses with less than three floors detached or terraced, while clusters E to J include the multi-family buildings. The division of the clusters can be seen on Table 4.

Year	Single family	Multi-family	
		1-3 floors	≥4
<1940	A	-	G
1941-1960	B	-	H
1961-1980	C	E	I
1981-2007	D	F	J

Table 5. Division into clusters

The Table shows a division by years, because the technical characteristics were different. The clusters belong to different periods between 1940 to 2007. The dwelling built after 2007 are not considered as they were constructed based on the last technical building code (CTE).

Dwellings built before the 1960 (clusters A, B, G and H), were built with traditional building envelope, with a predominance of solid masonry walls, whose thickness guarantees structural strength and permeability. In addition, providing thermal resistance and inertia. The standardised roof of this period was a tiled roof over a ventilated attic and the floor built directly onto compacted earth.

Buildings built after 1960 and before 1980 (clusters C, E and J) were constructed with double leaf brick walls with an intermediate air gap as envelope wall and a pitched tiled roof without ventilated loft. The frames were made from wood or metal profiles and the floor built directly onto compacted earth or with gravel sub-base.

And, the last period, dwelling built between 1981 and 2007, before the application of the CTE, are assumed to have thermal insulation in the walls and the roof. The frames made of aluminium start to dominate with thicker and double glazing with a gap. And the floors being suspended with an air space separating the floor from the ground.

6.3 ENERGY CONSUMPTION IN THE RESIDENTIAL SECTOR

To provide energy renovations interventions, the energy consumption must be analysed. The energy consumption for heating present higher percentage (Figure 14), so is considered the key for establishing energy consumption in climate control, as the energy consumption for cooling is almost negligible (0.96%). Moreover, heating consumption depends on the occupant's comfort levels.

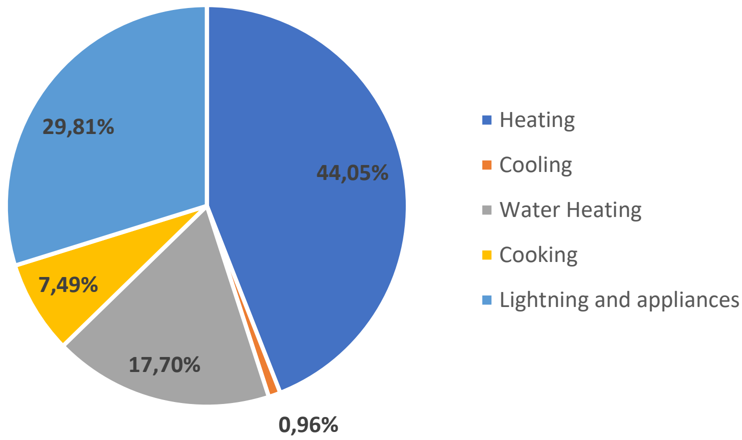


Figure 13. Households final energy consumption

6.4 MEASURES APPROVED RECENTLY OR IN PROGRESS

Some laws and decrees will be exposed, but not all existing are explained.

6.4.1 Law 8/2013 on Urban Renovation, Regeneration and Renewal

The purpose of the Law 8/2013 on Urban Renovation, Regeneration and Renewal is to ensure sustainable, competitive and efficient development of the urban environment, focusing on:

- Regulation to improve the state of conservation of buildings.
- Regulation to ensure universal accessibility and non-discrimination against persons with disabilities.
- Regulation to improve the energy efficiency of existing buildings.
- Legislative amendments to remove obstacles and make the current arrangements more flexible. Basically, by amending the Land Law, Horizontal Property Law and Building Planning Law + Technical Building Code
- New mechanisms for funding and public-private partnership.

These measures can be summarized:

a. Occupy space to do thermal insulation work, install solar collector on the roof and centralise energy installations. Also, to close terraces and balconies to have energy savings about 30%.
b. Create fund works for public subsidies and owner contributions. So, building renovation actions and urban regeneration and renewables can be cost-effective. Also, construction companies and energy services companies can enter these operations.
c. Promote public-private partnership between public administrations and owners or companies.

6.4.2 Royal Decree 235/2013

The Royal Decree stablish the necessity to realize an energy efficiency certificate for the building to provide it to the buyers or users, including information about the energy efficiency of a building. This certificate must follow some calculating methods considering the factor that impact on energy consumption.

6.4.3 Royal Decree 238/2013 of 5 April

This law sets out requirements related to general energy efficiency, correct installation and sizing. Also, establishes the periodically inspections of the climate control installations.

6.4.4 Order FOM/1635/2013 of 10 September

This order updates the Basic Document concerning energy saving and partially transposes into the Spanish legal system Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010.

In this update, the requirements set out in form the first phase of moving towards the objective of getting buildings with nearly zero energy consumption before 31 December 2020, also, it speaks to an impressive advance as far as the prerequisites with respect to vitality energy efficiency of buildings that were in constrain up to that point.

6.4.5 Royal Decree 233/2013 of 5 April

This Decree regulates the State Plan to promote rental housing, building renovation and urban regeneration and renewal. Contains incentive measures on the new rental and building renovation, urban regeneration and renewal policies.

6.5 TARGETS FOR THE ENERGY EFFIENCY AND RENOVATION

6.5.1 European Climate Strategies and Targets

Three different documents were created to define the EU targets for reducing its greenhouse gases emissions gradually up to 2050. These documents are:

- 2020 climate and energy package
- 2030 climate and energy framework
- 2050 low-carbon roadmap

The 2020 climate and energy package targets were set in 2007 and enacted in legislation in 2009. They are also targets for the Europe 2020 strategy for smart, sustainable and inclusive growth.

As it is said in the beginning, the 2020 targets are:

- 20% cut in greenhouse gas emissions (from 1990 levels)
- 20% of EU energy from renewables
- 20% improvement in energy efficiency

The 2020 climate and energy package includes four pieces of complementary legislation:

a. The EU Emissions Trading System (EU ETS): key tool for cutting GHG emissions form large-scale facilities (aviation, industry and power).
b. National targets for non-EU ETS emissions: this covers the housing, agriculture, waste and transport (excluding aviation) sectors.
c. National renewable energy targets: will help the EU to reach the 20% target for 2020 and a 10% use of renewables in the transport sector
d. Carbon Capture and Storage (CCS): the goal is to prevent CO_2 from reaching the atmosphere by storing it in suitable underground geological formations.

The 2030 climate and energy framework was adopted in October 2014 and is built on the 2020 climate and energy package.

This framework sets three key targets for the year 2030:

- 40% cuts in greenhouse gas emissions (from 1990 levels)
- 27% share for renewable energy
- 27% improvement in energy efficiency

It is additionally in accordance with the 2050 low-carbon roadmap.

To achieve the first target of the 2030 framework, the EU ETS sector should cut their emissions by 43% (compared to 2005) and the non-ETS sectors should cut their emissions by 30% (compared to 2005).

The EU aspire to make the European economy climate-friendly and less energy-consuming in a cost-effective manner. Hence, the 2050 low-carbon economy roadmap was created. It suggests:

- Reduction of GHG emissions by 80% (below 1990 levels) by 2050
- To achieve this, the GHG emissions should be reduced 40% by 2030 and 60% by 2040
- All sectors need to contribute, ETS and non-ETS (power generation, industry, transport, buildings, construction and agriculture)
- The low-carbon transition is feasible & affordable.

6.5.2 Spanish Climate Strategies and Targets

The targets set out by the EU vary depending on the Member State. Each Member State sets a national energy efficiency target based on their primary or final energy consumption, primary or final energy savings, or energy intensity.

In the report on the National Energy Efficiency Target, ten measures related to building and the equipment energy efficiency were included:

1. Energy renovation of the thermal envelope of existing buildings
2. Improving the energy efficiency of heating installations in existing buildings
3. Improving the energy efficiency of interior lighting installations in existing buildings
4. Construction of new buildings and renovation of existing buildings with a high energy rating
5. Improving the energy efficiency of commercial and industrial cooling installations
6. Improving the energy efficiency of existing lift installations in buildings
7. Improving energy efficiency in existing data centres
8. Improving the energy efficiency of electrical household appliances
9. Improving energy efficiency through home automation and smart management systems
10. Improving energy efficiency through district heating and cooling networks.

6.6 STRATEGY

The idea of the economic cost-effectiveness of renovation is the key to reach all targets. It is essential to invest public and private resources in renovation.

This investment has two main advantages. It can generate a significant volume of employments (18 jobs created per 1 million euros invested). And, also generates returns for the public coffers that are equivalent to the public investment.

The objective is to create an appropriate action for the design for building renovation and, also, for urban regeneration and renewal. And, construction companies and energy services companies could enter these operations providing own capital in exchange of opportunities.

The main renovation measures in the building stock in Spain is:

- Reduction of heating energy between 60% and 90%
- Use of solar energy for domestic hot water (DHW)

The household energy consumption is distributed between DHW, climate control, lighting and household appliances. The lighting and household appliances generate a consumption directly proportional with the hours they are used, and, to their efficiency. At the moment of the replacement of equipment with a more efficient one, two points should be taken into consideration, the amortisation of the investment produce compared to the energy savings generated by the new equipment, and, the pending amortisation[2] from the investment of the actual equipment. These investments can be amortised with the savings on energy bills for the future energy prices.

The agents that established the consumption of energy by climate control in a building are the use and management of the elements of a building, energy demand, efficiency of the climate installations and the energy source. To achieve the target of the reduction of heating energy between 60% and 90%, all these agents should be considered. By improving the use and management of a buildings, energy demand, climate installations and energy source, it will be much easier to reach the target.

Some potential actions that influence the consumption of a building are listed and explained bellow.

6.6.1 Use and management

These factors are crucial for the reduction of energy consumption as they control the energy demand. Use and management does not influence the constructive elements or installations of the building, as they are not specific technical applications.

It is necessary to define the use of a building refers not only to the set of activities that are developed in it, but also to the use of the systems and equipment that consume energy that it uses to carry out these activities. Some additional factors associated to the use, referring to the administration of the energetic resources, is associated to the management of the building.

All the actions aimed at optimising use and management can have a great impact on final energy consumption, with an additional attraction, which is the

[2] Normally, the amortisation is about 10 years

minimum investment required, with respect to actions related to the systems that meet the building's demand.

One example is the use of natural ventilation when is possible for adaptive comfort, which has a great impact on the cooling demand during warmer months.

6.6.2 Thermal insulation

Reducing the energy demand by changing the building skin is the second factor considered. The energy demand refers to the energy requirements for heating or cooling. It depends on the orientation, relation between area and volume of the dwelling, the location (climate) and the building envelopes. The last aspect is used for the action, since is the one that can be change, improving the thermal insulation.

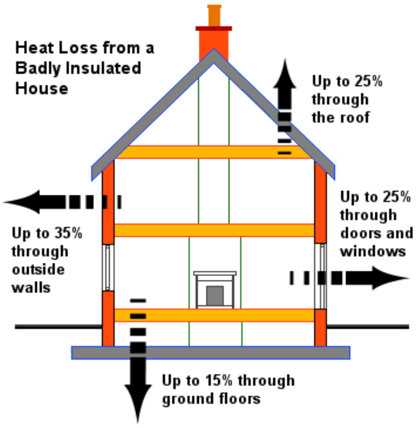


Figure 14. Heat Loss due to a badly insulated house. Source: Low Energy House

There are four different areas where the thermal insulation can be improved, shown in Figure 15:

a. External Walls.
Most of the heat in the building is lost through the external walls. There are two ways to improve the thermal insulation of the external walls. Applying insulation on the inside or the outside of the wall.
The insulation on the inside maintains the external appearance of the front of the house. It can be done filling the air gap cavity with an insulating material or attaching an internal lining system and an internal finish to attach the insulated layer to it.
The insulation on the outside changes the external appearance of the house to put insulation and, also, waterproof insulation and a finish layer with mortar.
The insulation on the outside, compare to the inside insulation, makes it easily to improve thermal bridging.

b. Windows

   In windows, not only the thermal insulation is improved, but also the tightness against leakage and the solar protection of the apertures.

   To improve the three parts, the windows in the aperture can be replaced with a frame with double glazing with thermal break or adding a new window with double glazing and thermal break to the apertures of the existing window. The second option is preferred, since it increases considerably the thermal resistance of the aperture.

   Moreover, it should be considered the application of a solar shading system (awning, blind, shutter…).

c. Roofs

   The difference between the roof with walls and windows, is that the thermal insulation is applied up to the maximum possible efficiency. Two different roof types exist, so different applications of insulation are made.

   Pitched roofs with no ventilated chamber under the waterproofing, the waterproofing is replaced, thermal insulation is attached and a new upper layer of waterproofing.

   Pitched roofs with an accessible ventilated chamber, thermal insulation is added between the ventilated chamber and the habitable space.

   In flat roofs, a thermal insulation layer and a trafficable upper protection are added.

d. Floors

   In floor, where the thermal insulation is increased up to maximum efficiency levels by attaching thermal insulation to the slabs and a new light weighting flooring layer with a thickness less than 7cm. In suspended floors is added a thermal insulation in the gap.

6.6.3 Ventilation control

Ventilation is a key factor in the energy demand once the previous two factors, use and management, and action in the building skin, have been achieved. The goal of the ventilation control is to control the temperature differences between the exterior and the interior of the building. Additionally, the ventilation control acts when the indoor CO2 concentration reaches certain levels, so when the building is not occupied it does not ventilate.

6.6.4 Heating installations

The last measured is applied after the sum of the above ones which limited the energy demand significantly. This last step is the improving the efficiency of heating installations to reduce consumption and the use of renewable energies. There exist many combinations of heating and cooling systems with renewable or non-renewable energies, but is only considered the most reasonable, viable economically and with a better environmental improvement.

The next improvements are proposed for dwellings:

- With natural gas heating installations: replacing boilers with high efficiency boilers.
- Using electricity for heating via plates or radiators: installing natural gas or biomass heating depending on whether they are in a rural or urban environment.
- Using fuel oil for heating: replacement with high efficiency gas boilers where there is a natural gas grid.
- Using liquefied petroleum gas stoves for heating: installing gas central heating with high efficiency boiler.
- If biomass is not an energy source, 50% of DHW should be covered with solar thermal panels.

7. LIFE CYCLE ASSESSMENT OF SINGLE-FAMILY HOUSE IN SPAIN

7.1 INTRODUCTION

In this chapter a LCA study is performed of a single-family house in Spain. First, a description of the building is realized to make easier the comprehension of the following steps. Afterwards, each step of the LCA will be described, and at the end, the results from the software tools will be analysed.

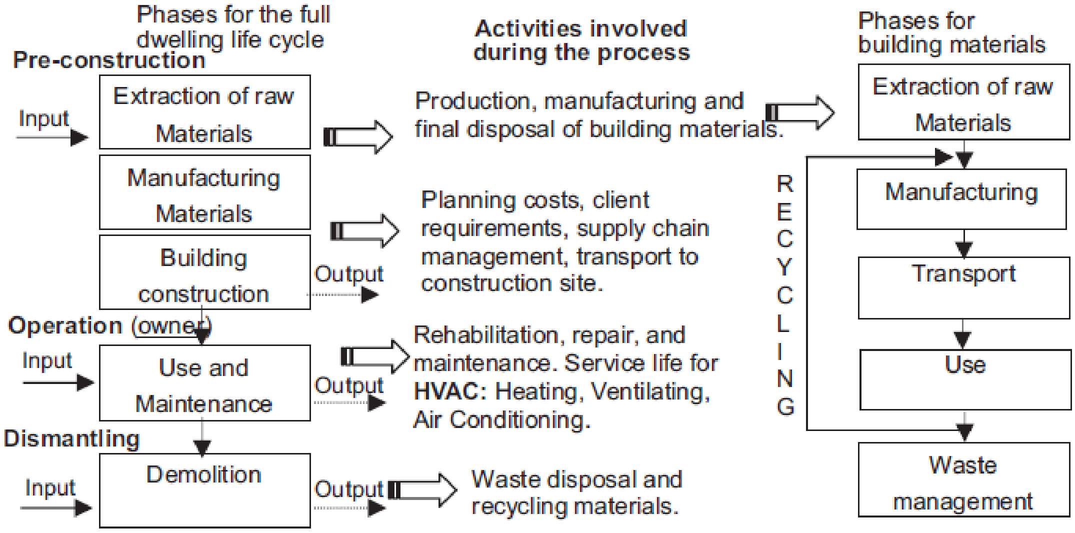


Figure 15. Representation of a building life cycle.

The different life cycles phases will be considered in the study, as it is a 'cradle-to-grave' analysis. These phases are described below.

7.2 DESCRIPTION OF THE BUILDING

The building that is going to be analysed is located in Madrid (Spain). This is not a real building, it is an example of the LCA of a building. Therefore, all the construction details and the materials used have been chosen based on the typical material used in the Spanish houses.

The dwelling is isolated (explained later) and is situated in a residential area in the north of Madrid (Alcobendas).

The Community of Madrid is divided into 179 municipalities, being the municipality of Madrid in the center of the community. Alcobendas corresponds to the red zone of the map (Figure 17).

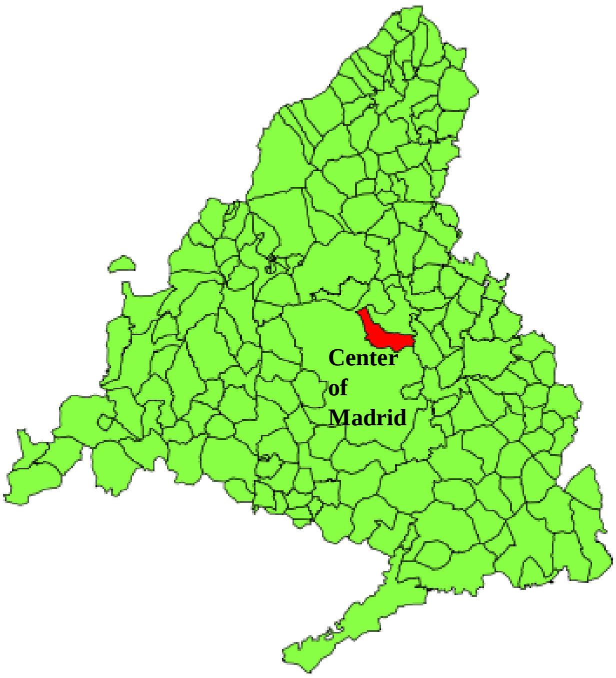


Figure 16. Map of Madrid

7.3 SOFTWARES

Two software's are used in this study: CYPE and HULC.

7.4.1 CYPE

CYPE is a technical software for Architecture, Engineering and Construction professionals. The software uses an extensive and constantly updated proprietary database.

Figure 17. Cype's logo

This software is divided into six different programs: structures, mep, cypetherm, management, documentation and infrastructure.

- **STRUCTURE**
  The CYPE Structure programmes include national and international standards that are applied to the calculation, sizing and testing of concrete, rolled steel, reinforced steel, formed steel, mixed steel, aluminium and wood structures, subject to gravity, wind, earthquake and snow actions.

- **MEP, CYPETHERM and INFRAESTRUCTURE**
  CYPE's Installation programmes include standards that are used to calculate and dimension building installations (water supply, water evacuation, air conditioning, solar capture for A.C.S. production, lightning protection, lighting, gas, electricity and telecommunications) and to test their thermal and acoustic insulation, energy certification and fire safety.
  The regulations contained in the CYPE software include current regulations and, in addition, repealed regulations that continue to be used, either to verify and revise structures that were sized when they were applicable, or because they continue to be applicable in countries other than their country of origin.
  Depending on the country from which the licensee acquires the license (or the country expressly chosen by the licensee), only the regulations implemented in each program are activated to work in that country, regardless of the language selected in the installation.
  In this case, the Spanish regulations are used.

- **MANAGEMENT and DOCUMENTATION**
  CYPE's project Management and Documentation programmes include a classification of regulations, both by work units and by geographical area of application, to facilitate the drafting of projects and project management.

In this study, installations (MEP and CYPETHERM) and management (ARQUIMEDES AND JOB CONTROL) programmes will be used, as explained bellow.

a. MEP
   This is the first programme used for the LCA, which calculates, checks and sizes the installations. It is composed of 19 different programmes.
   Specifically, the CYPECAD MEP subprogramme has been used. Which is a software for the design and sizing of the building envelope, distribution and installations on a 3D model integrated with the different elements of the building.
   At the beginning, all the general data from the building is introduced: type of building (single or multiple-family house, commercial, public, office…), type of projects (thermic, acoustic, gas, illumination, electricity, heating and cooling, solar heating…), location (select the province to choose the database), the area of the building, usage units (how many rooms, bathroom…), the floors, general data (choose the regulation, altitude and latitude…) and thermic parameters.
   Once all this data is introduced, the study can be started with the election of all the building materials and installations that are going to be used.

b. CYPETHERM

   These programmes are in charge for the thermal and energy analysis of buildings. It is composed of 8 programmes. Specifically, CYPETHERM HE has been used. Which is a regulatory justification of CTE DB HE 0 and HE 1 (revision 2013) by means of the calculation of the energy demand for heating and cooling, based on the simplified hourly method of UNE-EN ISO 13790, for buildings of any use; and the calculation of the energy consumption of heating, cooling and DHW in buildings of private or similar residential use.

   The project develop with CYPECAD MEP is imported to CYPETHERM HE to realise this analysis. This program uses some meteorological data exposed in the Appendix B.

c. MANAGEMENT

   Measurements, Budgets, Certifications, Specifications, Building Book (including Use and Maintenance Manual) and Budgetary Job Control are possible to obtain with these blocks of programmes which is composed of 8 programmes.

   The programme which is going to be use is ARQUIMEDES AND JOB CONTROL.

   Importing the project from CYPECAD MEP, many documents can be obtained which are very practical for this case study.

7.4.2 HULC

HULC (Unified Tool LIDER-CALENER, Herramienta Unificada LIDER-CALENER) is a tool that unifies two different software's, LIDER and CALENER, which were two different programmes years ago.

Figure 18. HULC logo

LIDER (Limitation of Energy Demand, Limitación de Demanda Energética) is used to validate the fulfilment of the CTE part on energy saving (HE) and CALENER (Energy Qualification, Calificación Energética) is used to qualify the building with a letter based on its environmental impact.

The Lider-Calener Unified Tool includes the unification in a single platform of the previous official general programmes used for the assessment of energy demand and consumption and of the General Procedures for the Energy Certification of Buildings (LIDER-CALENER), as well as the changes necessary for the convergence of energy certification with the Basic Energy Saving Document (DB-HE) of the Technical Building Code (CTE) and the Regulation on Thermal Installations of Buildings (RITE), both updated in 2013.

It is a tool promoted by the Ministry of Industry, Tourism and Trade (Ministerio de Industria, Turismo y Comercio), through the IDAE, and by the Ministry of Housing

(Ministerio de Vivienda), which makes it possible to determine the level of energy efficiency corresponding to a building.

The project done with the software CYPE is easily imported to this program, HULC, to evaluate the energy efficiency and the energy consumption and demand

To calculate the energetic rating that corresponds to the building, the software follows some steps:

- Calculation of the building demand under the standard conditions required by the energy certification by calling the calculation engine of the LIDER program. The demand for a reference building is generated and calculated for comparison.
- Then, a simulation of the behaviour of the object building's conditioning system is realized.
- And, at the end, the calculation of the energy rate is done and the results are exposed.

The results are shown on the official scale, including the CO_2 emission indicators for every square metre of living space in the target building and the reference building. And the boundaries between the different energy classes are indicated.

The partial ratings of the heating, cooling and DHW systems of both buildings are shown, expressing the results in both kWh/m^2 and kWh/year.

The heating and cooling requirements, in kWh/m^2 and in kWh/year, are also indicated for the target and reference buildings.

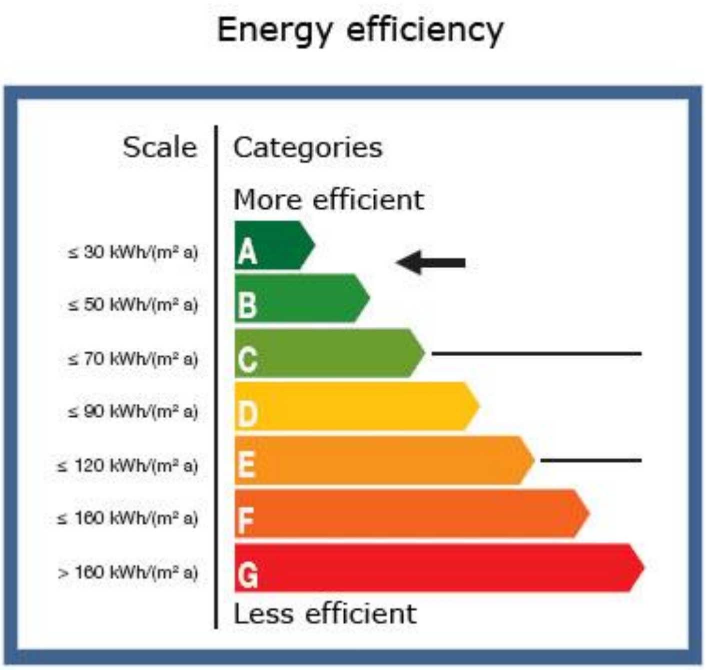


Figure 19. Energetic certification

7.4 GOAL AND SCOPE DEFINITION

The Goal and Scope definition is the first phase of the LCA, following the ISO 14044. Both parts shall be defined and be consistent with the intended application.

The goal definition will define the next points:

- The expected application
- The reasons for carrying out the study
- The target of the study

And the scope definition, the next points:

- The product system to be studied
- The functions of the product system or systems
- The functional unit
- The system boundaries
- Allocation procedures
- LCIA methodology and types of impacts
- Data quality requirements
- Assumptions
- Limitations

7.4.1 Goal of the Study

The goal definition is the first phase of any LCA, independently whether the study is limited to the development of a single unit process data set or it is a complete study of a comparative process.

A clear, initial goal definition is hence essential for a correct later interpretation of the results.

The expected application

The aim of this project is to study the LCA of a single-family house located in Madrid, during its whole life cycle. The CO2 emissions and the embodied and operating energy will be calculated, with the support of software tools, for each LCA phase.

The embodied energy is the energy used during the production and construction phase of the building, and, the operating energy is the energy utilized for the second phase, use phase, for maintaining comfort conditions and the maintenance of the building.

It is essential to consider the importance of doing a LCA for a building construction given that the construction industry speaks to a high level of the CO_2 emissions on the planet.

Another objective of the thesis is to compare different cases changing the cooling and heating energy systems. Hence, different cases will be compared obtaining diverse results.

The reasons for carrying out the study

The study of the environmental impacts due to human activities is a theme discussed in many occasions, as a result of the concern on the health of the planet.

The building and construction industry is very influential, with a high environmental footprint.

To assess the impacts, as it has been said before, the LCA is one of the best methodologies, as it takes into consideration all life cycle phases of the buildings. Moreover, the results are more detailed and reliable than other methodologies.

The target of the study

The LCA methodology is completely described, as the audience may not have all the knowledge of the LCA approach.

Also, as this is a bachelor thesis done in the university, the targets of this study are Technische Universität Wien (TU Wien) and the Comillas Pontifical University (ICAI School of Engineering).

7.4.2 Scope of the Study

In the scope definition phase, the object of the study is identified and defined in detail. This shall be done in line with the goal definition.

The product system to be studied

The system to be studied is the single-family house in Madrid, Spain, as it has been defined above. The next figure, Figure 21, show the house plan with the different rooms.

All measurements have been made separately for each different scenario to realize the study correctly.

The functions of the product system and functional unit

The function of the building is mainly residential. The model house for the project is a single-story dwelling with a total surface of 160.00m^2, and 3.00 m high. The dwelling consists of one double bedroom, two single bedrooms, two bathrooms, a living/dining room and a kitchen/laundry room. The garage is not considered. (See Figure 21)

The definition for *functional unit* in ISO 14040 is defined as: quantified performance of a product system for use as a reference unit.

The functional unit of the study is defined as the m^2 of living space in a residential building with a projected 30-year life span and four people living in the house. It is often to choose the functional of living area per year for the study for buildings.

The system boundary

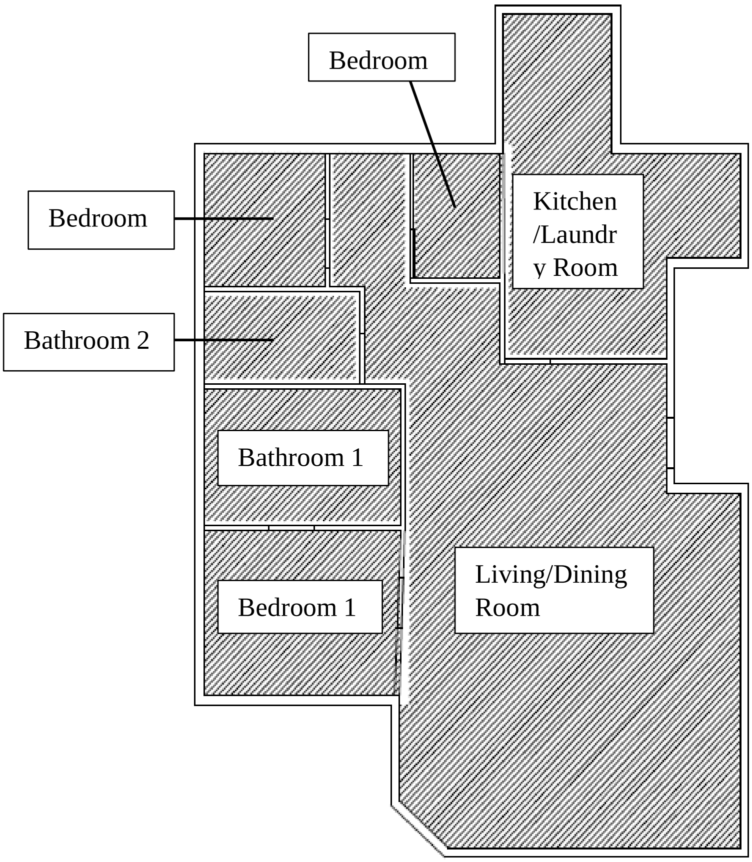


Figure 20. House plan

The system boundary determines which unit processes are included in the LCA.

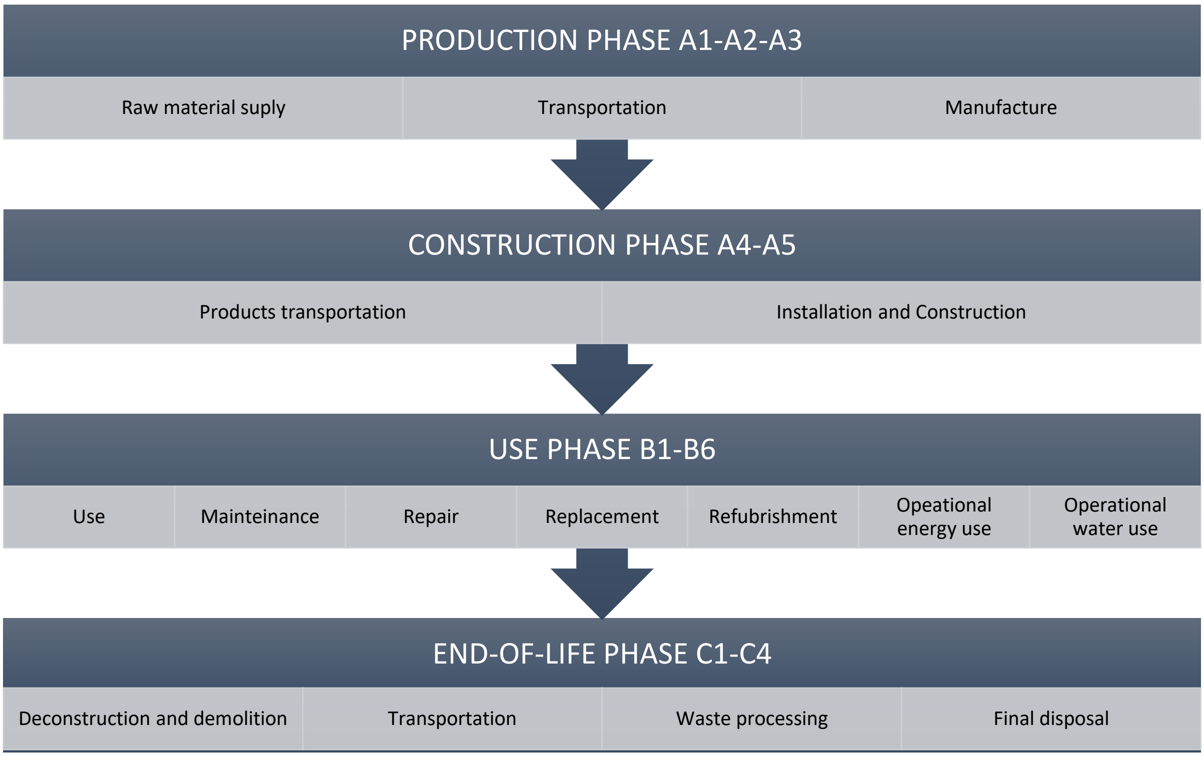


Figure 21. LCA phases and phases considered in the study

The environmental impacts that will be assess in the LCA are the CO_2 emissions and the embodied energy for the different LCA phases.

1. Production and Construction.
   As its name suggests, this stage refers to the different processes associated with the erection of the building. These are included in the manufacture and transport, to the place of performance, of the products, equipment and facilities that will form part of the building once it is completed conclude this stage, as well as the different construction processes necessary for the execution of the same (excavation of the ground, spillage of concrete, pile boring, etc.).
   Some environmental impacts are produce during these stages, for example, the use of natural resources, consumption of energy and water, waste generation, GHG emissions… Consequently, if there are some changes during these stages, the environmental impacts may change.

2. Use.
   Included in this stage are considered to be the set of processes derived from the daily use of the analysed product. In the case of the building, these processes usually include the energy consumption associated with the certain thermal conditions, the consumption of energy, the water, the production of waste, the

electricity demand associated with existing equipment and installations (household appliances, lighting, etc).

It is usual to consider at this stage those processes that are derived from the maintenance requirements of the building, such as the wall painting, replacement of finishes, etc

3. End of life

   It is the last stage of the building's life cycle, and includes the demolition work, debris removal to landfill sites and recycling plants, etc. This stage is not usually significant due to the lack of data, also, because in the use phase most of the environmental impacts are produced. That is why, this phase is not considered in the study.

The elimination of life cycle stages, processes, inputs or outputs is only allowed if this does not significantly change the overall conclusions of the study.

In this study, the phases that are not considered are shown in Figure 22 in red colour.

Allocation procedures

The term allocation is defined in the ISO 14044:2006 as "partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems". For example, the recycling in the end-of-life phase, each recycled component has determined emissions that is unknown due to the lack of data.

The inputs and outputs shall be allocated to the different products according to clearly stated procedures that shall be documented and explained together with the allocation procedure.

The ISO 14044:2006 divided the allocation procedure in three steps:

- Step 1: Wherever possible, allocation should be avoided by dividing the unit process into two or more sub-processes and collect the data from these sub-processes and by expanding the product system to include the additional functions of the co-products.
- Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them; i.e. they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.
- Step 3: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and

functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products.

Allocation procedures in this thesis are prevented when possible. Allocation procedures are avoided for the materials used in the first phase, production, as the calculations are made for all the materials.

Notwithstanding, referring to the consumption of energy and other equipment use in the place where the object of the study is located, the total consumption of energy is calculated for the entire construction period, so the energy must be allocated in proportion to the components weight.

If there are allocations applied, they should be described in their respective parts of the study.

LCIA methodology and types of impacts

The Life Cycle Impact Assessment is the third phase of the LCA methodology. However, the environmental impact categories that are covered during the LCA, should be determined before the Life Cycle Inventory (LCI) phase. This ensured that the data is collected for the right processes in the system.

The impact categories selection should be coherent with the goals of the LCA study. Plus, the selection must cover all relevant environmental impacts related to the analysed system. There are any environmental impact categories that where presented in the beginning of the document (Figure 8).

The choice of the impact categories is chosen by the LCA practitioner making the decision taking into account the main objectives of the study.

The following environmental impact indicators are considered in this project:

- Embodied/ Operating energy (kWh or MJ [1MJ=0.2778kWh): estimating the amount of energy consumed in the phases of the Life Cycle corresponding to the manufacturing process of the products and their installation or commissioning.
- CO_2 equivalent emissions (ton or kg [1ton=1000kg]): is a unit of measurement used to indicate the potential for global warming of each of the greenhouse gases involved in the process of the manufacture of the products, their transport and installation or putting into service, compared with the carbon dioxide.

Data quality requirements

This point is the most time-consuming stages, as the collection of data and the calculations for the construction of the data inventory
According to the ISO 14044:2006, the data quality requirements should address the following:

a. time-related coverage: age of data and the minimum length of time over which data should be collected;

b. geographical coverage: geographical area from which data for unit processes should be collected to satisfy the goal of the study;

c. technology coverage: specific technology or technology mix;

d. precision: measure of the variability of the data values for each data expressed (e.g. variance);

e. completeness: percentage of flow that is measured or estimated;

f. representativeness: qualitative assessment of the degree to which the data set reflects the true population of interest (i.e. geographical coverage, time period and technology coverage);

g. consistency: qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis;

h. reproducibility: qualitative assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the results reported in the study;

i. sources of the data;

j. uncertainty of the information (e.g. data, models and assumptions).

The missing data should be documented precisely.

The data used in this case study is mainly included in the software's that are used, that will be explained in the next chapters. The data that was not included in those software's, is taken mainly from the Eurostat Database.

Assumptions and Limitations

The assumptions and limitations are key for the assessment of the study, so the study is reliable and accurate.

For this study, the work done before the star of the construction (documentation, administrative, consultancy…) is not considered, as it is negligible. Also, the study deals only with environment impacts, not taking into account the economic and social aspects, being an environmental assessment.

The assumptions and limitation done during the study will be described in their respective phases.

Once all these points are defined and explained, the first phase of the LCA is completed with all the characteristics that have been defined. The next phase, Life Cycle Inventory (LCI) is going to be developed with all the necessary data to realize the LCI phase, and to continue with the next ones.

7.5 LIFE CYCLE INVENTORY

The initial plan of the Life Cycle Inventory phase can be conducted by the definition of the goal and scope of a study. The ISO 14044:2006 outlined the operational steps to execute the plan for the LCI analysis (Figure 23).

In this phase, the data collection and modelling of the system is to be done, in line with the first LCA phase, goal and scope.

Life cycle inventory (LCI) analysis is a data-driven technical process to quantify energy and materials consumed, and emissions to air and water, solid waste and any other discharge into the environment during the entire life cycle of a product, process, material or activity. In a broad sense, the inventory begins with the raw materials and ends with the deposition of the product residues.

The LCI of construction in more complicated compare to the LCI of industrial products. Each building construction is independent from the other, as the building depends on many factors. Furthermore, the quantification of flows is highly inaccurate, especially in the production and construction phase.

As explained in previous chapters, in this study, the data base used is integrated into the programmes that are used for the evaluation of the study.

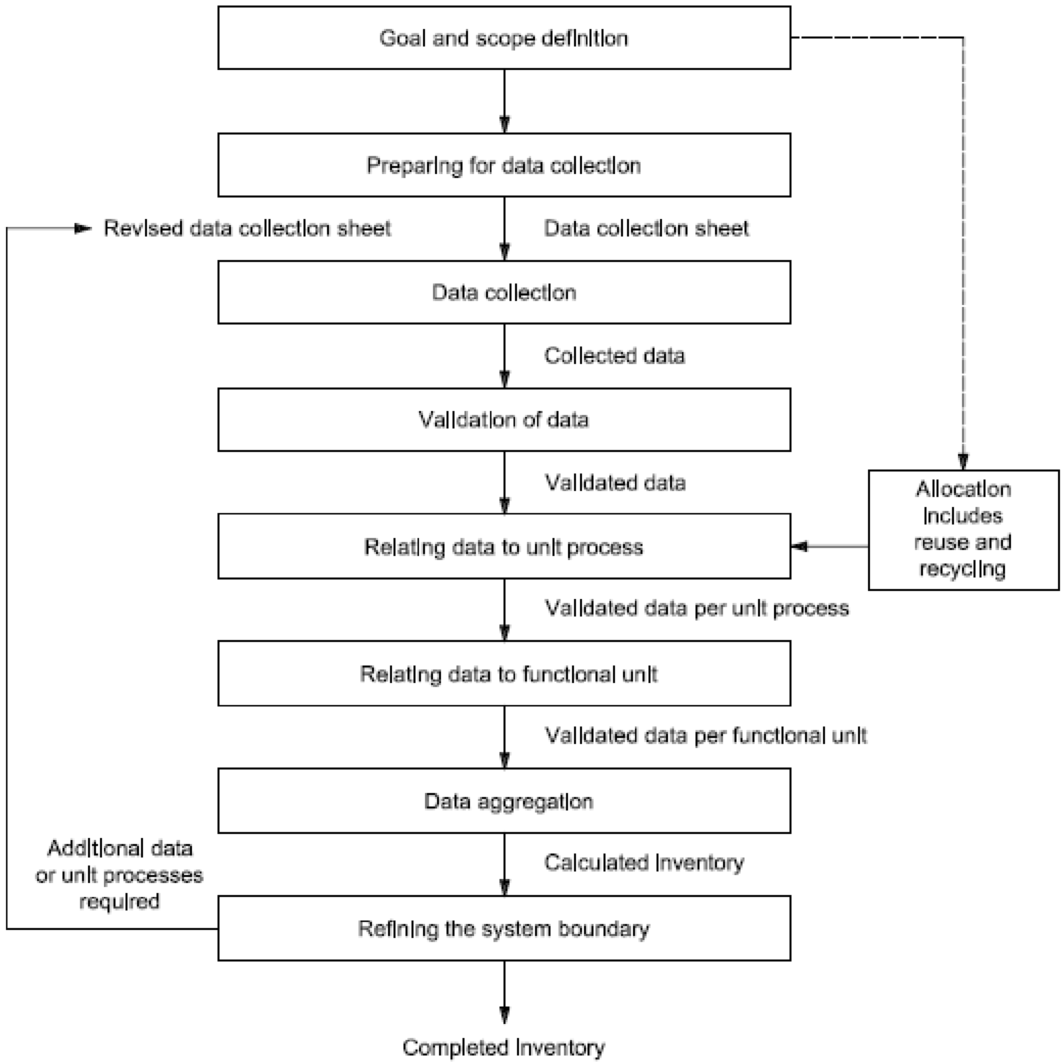


Figure 22. Steps for the inventory analysis.

7.5.1 Production phase A1-A2-A3: single-family house envelope characteristic

Again, as explained in previous chapters, the first step of the life cycle of a product is the production phase, which covers the phase from the raw material extraction to the manufacture.

A description of the different materials that are used for the study is explained bellow with all the characteristics.

For the purpose of calculating the incorporated energy and its CO2 eq. emissions, the following phases of product development are considered:

- The extraction of raw materials.
- Transport to the factory.

- The manufacturing process and packaging of the final product.
- The journeys necessary for its production.

External Walls

The façade of the whole building is a one-leaf façade with external insulation, 'ETICS' system covering 138,16 m^2, consisting of an outside coating, a main sheet and, also, an interior finishing:

- Outside Coating: thermal insulation with the OpenSystem "BAUMIT", consisting of: rigid expanded polystyrene panel, OpenReflect "BAUMIT", 80 mm thick, with white reflective coating, fixed to the substrate with adhesive mortar KlebeSpachtel W (OpenContact) "BAUMIT" and mechanical fastenings with expansion plug and polypropylene nail Universal dowel STR U 2G "BAUMIT"; adhesive mortar regulator layer KlebeSpachtel W (OpenContact) "BAUMIT"; water-repellent top coat, NanoporTop "BAUMIT", Kratz finish 1.5, on primer, UniPrimer "BAUMIT", rainproof and water vapour permeable;
- Main Sheet: 11 cm thick factory sheet, made of perforated acoustic ceramic brick, for cladding, received with industrial cement mortar, supplied in bulk; lintel formation by means of prefabricated joist, clad with ceramic pieces, placed with high adherence mortar;
- Interior Base Coating: Cement rendering, visible, rough surface finish, with cement mortar.
- Interior Finishing: Manual application of two coats of plastic paint, the first coat diluted with 20% water and the next undiluted, after application of a coat of primer based of acrylic copolymers in aqueous suspension, on plaster or plaster inner wall.

The next picture shows the different layers of the external walls:

1. Decorative mortar 0.2 cm
2. Base mortar 0.2 cm
3. Base mortar 0.2 cm
4. Expanded polystyrene rigid panel 8 cm
5. Base mortar 0.4 cm
6. Perforated ceramic brick factory 11 cm
7. Cement plastering 1.5 cm
8. Plastic paint on plaster interior wall or plaster ---

Total thickness 21.5 cm

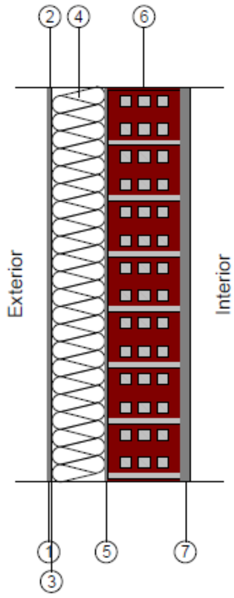


Figure 23. External Walls

The external walls have the following characteristics:

- Limitation of energy demand Um: 0.33 W/(m²-K)
- Noise protection:
  Surface mass: 143.10 kg/m²
  Surface mass of the base element: 132.90 kg/m²
  Acoustic characterization per test, Rw(C; Ctr): 41.1(-1; -7) dB
  Protection against moisture Degree of waterproofing achieved: 5

Internal Walls

The internal walls of the household are all the walls that separates the building into different rooms. The internal walls are single-skinned wall panel with luting on both sides and cover an area of 83,80 m^2, consisting of:

- Lining on the left: direct lining, "KNAUF" system, made of laminated plasterboard, received with bonding paste on the vertical wall; 65 mm total thickness;
- Main Sheet: 11 cm thick sheet of perforated acoustic ceramic brick for cladding, received with industrial cement mortar, supplied in bulk;

- Lining on the right: direct lining, "KNAUF" system, made of laminated plasterboard, received with bonding paste on the vertical face; 55 mm total thickness.

The next picture shows the different layers of the internal walls:

1.	Plastic paint on interior wall of plaster or plaster	---
2.	Laminated plasterboard	1 cm
3.	Expanded polystyrene panel and aluminium sheet	4 cm
4.	Perforated ceramic brick factory	11 cm
5.	Expanded polystyrene panel and aluminium sheet	3 cm
6.	Laminated plasterboard	1 cm
7.	Plastic paint on interior wall of plaster or plaster	---
	Total thickness:	20 cm

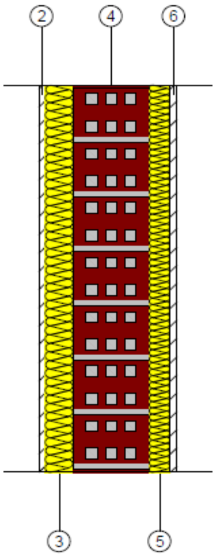


Figure 24. Internal walls

The internal walls have the following characteristics

- Limitation of energy demand Um: 0.38 W/(m²-K)
- Noise protection
  Surface mass: 117.60 kg/m²
  Surface mass of the base element: 99.00 kg/m²
  Acoustic characterization per test, Rw(C; Ctr): 38.1(-1; -2) dB
  Improvement of the overall noise reduction index of the coating, DR: 24 dBA
- Fire safety Fire resistance: EI 240

Internal Flooring

There are two types of flooring in contact with the ground used in this study, one type (A) for bedrooms and living/dining room, and the other type (B) for the kitchen and bathrooms, it only changes the external layer of the floor (layer 1). The floor cover 145,70 m^2 and consist of the next layers:

- FLOOR COVERING
  Pavement (A): Laminated flooring, laid on a complex made of high quality polyethylene, for impact sound insulation, covered on one side with a polyethylene film that acts as a vapour barrier, with a proportional part of polyethylene banding 5 mm thick, placed on a thin layer of floor levelling paste, 2 mm thick.
  Pavement (B): Ceramic tile flooring, water absorption capacity E<3%, received with cementitious adhesive for interior use only, and grouted with white cement grout
  Radiant Floor: Underfloor heating and cooling system, composed of polyethylene film, polyethylene foam (PE) band, 150x10 mm, expanded polystyrene insulation panel (EPS),

Paving Base: Base for sand pavement, stabilized with 100 kg of cement for each m³ of dry sand

- STRUCTURAL ELEMENT

  Reinforced concrete floor slab, made of concrete and steel; pre-stressed beam with expanded polystyrene and electro welded mesh, in a layer of compression, on a support wall of perforated ceramic brick (coarse), to cover.

The next picture shows the different layers of the flooring:

1A. Laminate flooring 0.7 cm / 1B. Flooring of glazed stoneware ceramic tiles 1 cm

2A. Closed cell polyethylene foam and polyethylene film 0.25cm

3A. Self-levelling cement mortar 0.2 cm

4A/2B. Self-levelling mortar, 5 cm

5A/3B. Expanded polystyrene insulation panel (EPS), 2.5 cm

6A/4B. Polyethylene film, 0.02 cm

7A/5B. Crushed sand base stabilized with cement 4 cm

8A/6B. 25+5 cm one-way slab (Flush moulded EPS vault) 30 cm

Total thickness A:42.67 cm and B:42,52 cm

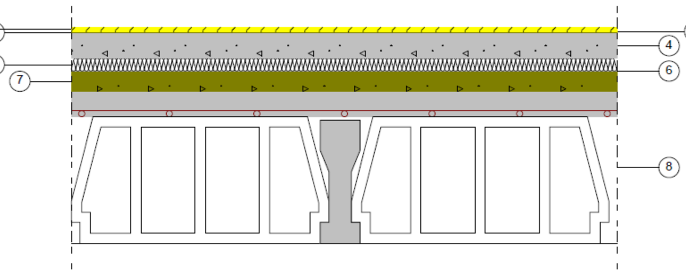


Figure 266. Type A floor

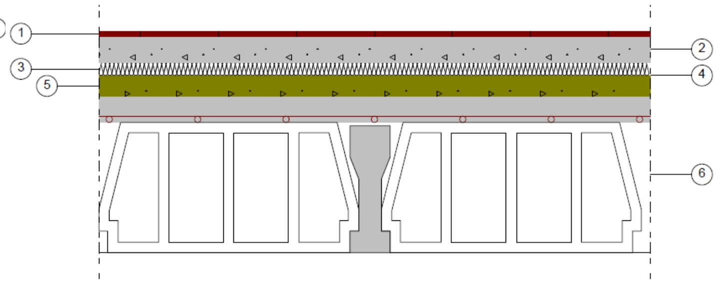


Figure 26. Type B floor

The characteristics for both floor types are:

- Energy demand limitation: Us(A): 0.22 W/(m²-K) and Us(B): 0.23 W/(m²-K)
- Calculation detail (Us)
  Floor area, A: 166.05 m²
  Floor slab perimeter, P: 62.15 m
  Average depth of the sanitary chamber below the level of the ground, z: 1.23 m
  Thermal resistance of the floor slab, Rf(A):1.86 m²K/W and Rf(B):1.75 m²K/W

Coefficient of thermal transmission of the perimeter wall, Uw: 1.09 W/(m²-K)
Wind protection factor, fw: 0.05

- Noise protection
  Surface mass: A:412.57 kg/m² and B: 430.27 kg/m²
  Surface mass of the base element: 299.52 kg/m²
  Acoustic characterization, Rw(C; Ctr): 52.9(-1; -3) dB
  Standardized overall impact noise pressure level, Ln,w: 81.1 dB

Roof

The roof has an area of 145.68 m² and is cover with plaster at a glance with a flat roof that cannot be walked on, ventilated, self-protected, waterproofed with asphalt sheets. (Unidirectional slab). It is composed of the following layers:

- OUTSIDE COATING: Non-transitable, ventilated, self-protected flat roof, conventional type, consisting of: slope formation: hollow ceramic tongue and groove board supported on lightened walls; thermal insulation: insulating felt made of mineral wool, 80 mm thick; double-layer waterproofing: bitumen sheet, after priming with anionic asphalt emulsion, and bitumen sheet adhered to the previous one with a torch, without matching its joints.
- STRUCTURAL ELEMENT: Reinforced concrete structure, made of concrete and steel, on a continuous formwork system, consisting of: unidirectional, horizontal, prestressed beam, double girder, mechanised expanded polystyrene vault, electrowelded compression layer mesh.
- ROOF COATING. Continuously lined roof, consisting of:
  Base Coating: plaster covering for construction
  Finishing Coat: manual application of two coats of plastic paint colour of your choice, matt finish, smooth texture, the first coat diluted with 20% water and the next without diluting; after applying one coat of primer on a base coat.

The next picture shows the different layers of the roof:

1.	Bonded two-layer asphalt waterproofing	0.64 cm
2.	Air chamber	10 cm
3.	Mineral wool	8 cm
4.	30+5 cm unidirectional slab (EPS vault)	35 cm
5.	Plaster trim	1.5 cm
6.	Plastic paint on interior wall of plaster or plaster	---

Total thickness: 55.14 cm

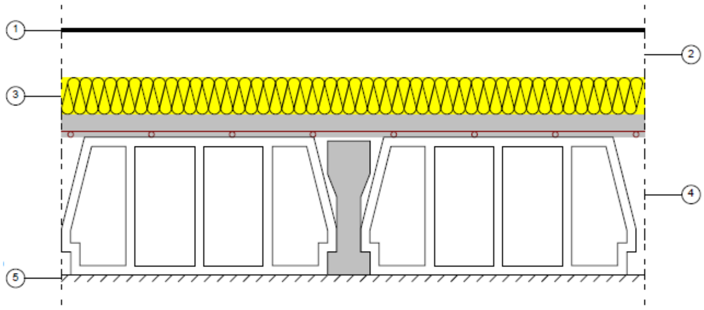


Figure 27. Roof

The characteristics for the roof are:

- Limitation of energy demand
  Uc cooling: 0.27 W/(m²-K) and Uc heating: 0.29 W/(m²-K)
- Noise protection
  Surface mass: 271.96 kg/m²
  Surface mass of base element: 263.08 kg/m²
  Acoustic characterization, Rw(C; Ctr): 50.8(-1; -3) dB
- Protection against moisture
  Type of roofing: Not passable, with self-protected film
  Type of waterproofing: Modified bituminous/bituminous material
  With ventilated air chamber

Doors

The doors are divided into two groups, entrance door and interior doors.

A. ENTRANCE DOOR

The entrance door is security armoured with these dimensions: 203x92,5x4,5 cm. There is only one entrance door.

It has the next characteristics:

- Thermal Characterization:
  Thermal Transmittance, U: 1.79 W/(m²-K)
  Absorbency, α_S: 0.6 (intermediate colour)

-Acoustic Characterization: Absorption, α_{500Hz} = 0.06; α_{1000Hz} = 0.08; α_{2000Hz}=0.10

B. INTERIOR DOORS

The internal doors are internal folding doors, blind, with a single-leaf, with the dimensions 203x82.5x3.5 cm, made of chipboard, with hanging and closing fittings. In the dwelling, 6 internal doors are placed.

It has the next characteristics:

- Thermal Characterization:
  Thermal Transmittance, U: 2.03 W/(m²-K)
  Absorbency, α_S: 0.6 (intermediate colour)

-Acoustic Characterization: Absorption, α_{500Hz} = 0.06; α_{1000Hz} = 0.08; α_{2000Hz}=0.10

Windows

Four different sizes of windows are used. However, the glass characteristics are the same for all of sizes, it only changes the carpentry.

First, the general glass and carpentry characteristics are shown, and after, the different carpentry sizes characteristics used for the widows.

A. Glass: Double glazing with low thermal emissivity and acoustic insulation. Characteristics of glass:
   - Thermal transmittance, Ug: 1.10 W/(m²-K)
   - Solar factor, g: 0.56
   - Sound insulation, Rw (C;Ctr): 50 (0;0) dB

B. Carpentry:

   Characteristics of the carpentry
   - Thermal transmission, Uf: 2.20 W/(m²-K)
   - Type of opening: Tilt-and-turn or tilt type
   - Air permeability of joinery (EN 12207): Class 4
   - Absorbency, α_S: 0.8 (dark color)

C. Segmentation by window sizes.

Dimensions width x height	**Thermic transmission U_w [W/(m²·K)]**	**Solar factor**		**Acoustic characterization**	**Nº Units**
		F	**F_H**	**R_w (C; C_{tr}) [dB]**	
100x100cm	1.63	0.31	0.26	38 (0;-4)	2
100x100cm	1.63	0.31	0.31	38 (0;-4)	4
110x120cm	1.57	0.35	0.29	38 (0;-4)	1
210x120cm	1.50	0.37	0.37	38 (0;-4)	2

Table 6. Carpentry Characteristics

7.5.2 Construction phase A4-A5

The second phase of the LCA is the construction phase, which is responsible for the transportation of the products, and, the installation and construction of the dwelling f the study.

This part includes the inventory for the construction phase from the beginning of the construction until it is completed. It corresponds to the transport of the product from the factory to the construction site, including the movements required during the distribution process. And, corresponds to the process of construction and installation of the products, including the movement within the construction site.

It is assumed that the products are transported by diesel-engine trucks for average load and consumption, per km travelled and per kg of load transported. All the products that make up the building and its packaging are considered to be transported from the factory to the entrance of the building site. Considering the distance as 50km. These calculations are made by the software CYPE.

The process of product installation and construction includes the energy and emissions produced by the machinery, auxiliary equipment and the transport of the waste generated to the landfill.

7.5.4 Use phase B1-B6

The use phase, is the second phase of the Life Cycle Assessment that has to be analysed.

In this study, not all the use phase stages are considered, only the use process and the operational energy use process.

Two different types of heating and cooling systems (HVAC systems) will be compared in this study. The first on will be an electric boiler with solar energy, radiant floor heating and solar energy source, and the second one, a biomass heating with radiators.

Typology A	**Typology B**
Electric Boiler	Biomass Boiler
Radiant floor heating	Radiators

Table 7. Heating and Cooling

This part analyses the energy consumption and CO_2 emissions of the use phase of the building in its first 10 years. The calculations are made with the software HULC.

7.5.5 End of Life phase

Even though this phase is not considered in the study, the waste generated in the demolition is explained bellow.

All possible construction and demolition waste generated on site has been codified in accordance with current legislation on waste management, "Order MAM 304/2002. Waste recovery and disposal operations and the European Waste List", giving rise to the following groups:

- Level I CDW: Uncontaminated earth and materials from excavation works

  As an exception, they do not have the legal status of waste:

  Soil and stones not contaminated by dangerous substances, reused on the same site, on a different site or in a restoration, conditioning or filling activity, provided that proof of their use for reuse can be provided.

- Level II CDW: Waste generated mainly in the activities of the construction sector, from demolition, from home repairs and from the implementation of services.

A classification of generated CDW has been established, according to the types of materials of which they are composed:

Material according to "Order MAM 304/2002. Waste recovery and disposal operations and the European Waste List".
Level I CDW
1 Earth and stony earth from the excavation
Level II CDW
CDW of a non-earth nature
1 Asphalt
2 Wood
3 Metals (including their alloys)
4 Paper and cardboard
5 Plastic
6 Glass
7 Plaster
8 Garbage
CDW of stony nature
1 Sand, gravel and other aggregates
2 Concrete
3 Bricks, tiles and ceramic materials
4 Stone
Potentially dangerous CDW
1 Other

Table 8. Construction and Demolition Waste Classification

The amount of waste generated on site has been estimated from the project measurements at function of the weight of constituent materials in the performance of the corresponding prices decomposed of each unit of work, determining the weight of the remains of the surplus materials (shrinkage, breakage, blunting, etc.) and of the packaging of the products supplied.

The volume of excavation of the earth and stone materials not used in the work has been calculated depending on the size of the project, affected by a sponginess coefficient according to the type of terrain.

From the weight of the residue, its volume has been estimated using an apparent density defined by the quotient between the weight of the waste and the volume it occupies once deposited in the container.

The results are summarized in the following table (Table 11) and bellow the table is a graph (Figure 30), also, in relation to the intended use of non-reusable or non-recoverable waste "in situ", the type of treatment is expressed:

MATERIAL ACCORDING TO "ORDER MAM 304/2002. WASTE RECOVERY AND DISPOSAL OPERATIONS AND THE EUROPEAN WASTE LIST".	**LER[3]**	**APPARENT DENSITY (T/M³)**	**WEIGHT (T)**	**VOLUME (M³)**	**TREATMENT**
LEVEL II CDW					
CDW OF A NON-EARTH NATURE					
1 ASPHALT					
BITUMINOUS MIXTURES OTHER THAN THOSE SPECIFIED IN THE LER 17 03 01.	17 03 02	1,0000	0,8890	0,8990	Recycling
2 WOOD					
WOOD	17 02 01	1,1000	0,4440	0,4040	Recycling
3 METALS (INCLUDING THEIR ALLOYS)					
ALUMINIUM	17 04 02	1,5000	0,0430	0,0290	Recycling
IRON AND STEEL	17 04 05	2,1000	0,6910	0,3290	Recycling
MIXED METALS	17 04 07	1,5000	0,1150	0,0770	Recycling
CABLES OTHER THAN THOSE SPECIFIED IN LER 17 04 10	17 04 11	1,5000	0,0710	0,0470	Recycling
4 PLASTIC					
PLASTIC	17 02 03	0,6000	0,1000	0,1670	Recycling
5 GLASS					
GLASS	17 02 02	1,0000	0,0260	0,0260	Recycling
6 PLASTER					
PLASTER-BASED CONSTRUCTION MATERIALS OTHER THAN THOSE SPECIFIED IN LER 17 08 01	17 08 02	1,0000	13,4180	13,4180	Recycling
CDW OF STONY NATURE					
1 SAND, GRAVEL AND OTHER AGGREGATES					

[3] LER: European Waste List

WASTE GRAVEL AND CRUSHED ROCKS OTHER THAN THOSE OF SPECIFIED IN 01 04 07.	01 04 08	1,5000	0,4610	0,3070	Recycling
2 CONCRETE					
CONCRETE	17 01 01	1,5000	66,7560	44,5040	Recycling / Landfill
3 BRICKS, TILES AND CERAMIC MATERIALS					
BRICKS	17 01 02	1,2500	68,3950	54,7160	Recycling
TILES AND CERAMIC MATERIALS	17 01 03	1,2500	0,0000	0,0000	Recycling
4 STONE					
WASTE FROM STONE CUTTING AND SAWING OTHER THAN THOSE SPECIFIED IN LER 01 04 07.	01 04 13	1,5000	2,5150	1,6770	Not specific treatment
POTENTIALLY DANGEROUS CDW					
1 OTHER					
INSULATING MATERIALS OTHER THAN THOSE SPECIFIED IN LER 17 06 01 AND 17 06 03.	17 06 04	0,6000	0,3460	0,5770	Recycling
MIXED CONSTRUCTION AND DEMOLITION WASTES OTHER THAN THOSE SPECIFIED IN LER 17 09 01, 17 09 02 AND 17 09 03.	17 09 04	1,5000	0,3980	0,2650	Deposit / Treatment

Table 9. Waste from Demolition

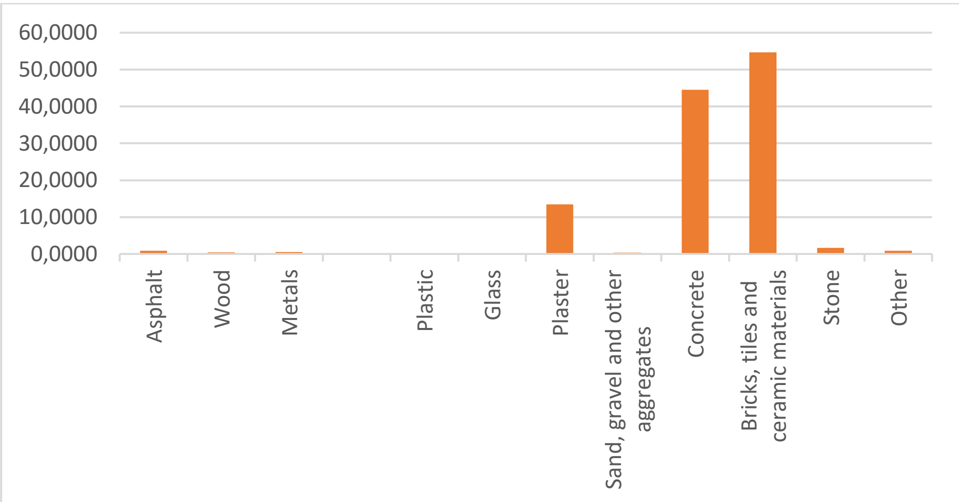


Figure 28. Wastes from Demolition

Measures For The Separation Of Waste On Site

Waste shall be separated into the following fractions when, in such a way that individualized for each of these fractions, the expected amount of generation for the total of the following quantities:

- Concrete: 80 t.
- Bricks, tiles and ceramic materials: 40 t.
- Metals (including their alloys): 2 t.
- Wood: 1 t.
- Glass: 1 t.
- Plastic: 0,5 t.
- Paper and cardboard: 0.5 t.

The following table shows the total weight, expressed in tonnes, of the different types of waste generated in the work object of the present study, and the obligation or not of its separation in situ.

WASTE TYPE	TOTAL WASTE (t)	SEPARATION "IN SITU"
Concrete	3,217	NOT MANDATORY
Bricks, tiles and ceramic materials	7,231	NOT MANDATORY
Metals (including their alloys)	0,28	NOT MANDATORY
Wood	1,134	MANDATORY
Glass	0,006	NOT MANDATORY
Plastic	0,178	NOT MANDATORY
Paper and cardboard	0,544	MANDATORY

Table 10. Waste quantities

7.6 LIFE CYCLE IMPACT ASSESSMENT

Life Cycle Impact Assessment (LCIA) is the third stage of the analysis of the LCA. The technique used in this stage is a relative approach based on a functional unit, very different from environmental performance evaluation, environmental impact assessment and risk assessment.

Impact assessment is a technical process for the characterisation and analysis of the environmental burdens identified in the inventory. The mission of the impact assessment stage is to interpret the results obtained in the inventory, indicating the capacity to distort the environment of the product or activity evaluated in the different impact categories, such as climate change, ozone layer destruction, toxicity, acidification, etc.

To achieve the previous stages and the objectives of the LCA study, the LCIA should be plan carefully. The LCIA should be coordinated with the previous phases considering the following possible omissions and sources of uncertainty, as it is explained on ISO 14044:2006:

a Whether the quality of the LCI data and results is sufficient to conduct the LCIA in accordance with the study goal and scope definition.
b Whether the system boundary and data cut-off decisions have been sufficiently reviewed to ensure the availability of LCI results necessary to calculate indicator results for the LCIA.
c Whether the environmental relevance of the LCIA results is decreased due to the LCI functional unit calculation, system wide averaging, aggregation and allocation.

The LCIA product system's profile is represented by the collection of the results of the indicator for the different impact categories.

In this phase, the list of inventories made in the last stage (LCI) containing the materials, consumed energy and CO_2 emissions are interpreted and transform into impact indicators.

The LCIA consists of mandatory and optional elements (Figure 31).

- Mandatory elements:
  - Selection of impact categories, category indicators and characterization models: identifying relevant environmental impacts (e.g, global warming, acidification…)
  - Classification: Assignment of LCI results to the selected impact categories
  - Characterization: Calculation of category indicator results
- Optional:
  - Normalization: calculating the magnitude of category indicator results relative to reference information;
  - Grouping: sorting and possibly ranking of the impact categories;
  - Weighting: converting and possibly aggregating indicator results across impact categories using numerical factors based on value-choices; data prior to weighting should remain available;
  - Data quality analysis: better understanding the reliability of the collection of indicator results, the LCIA profile.

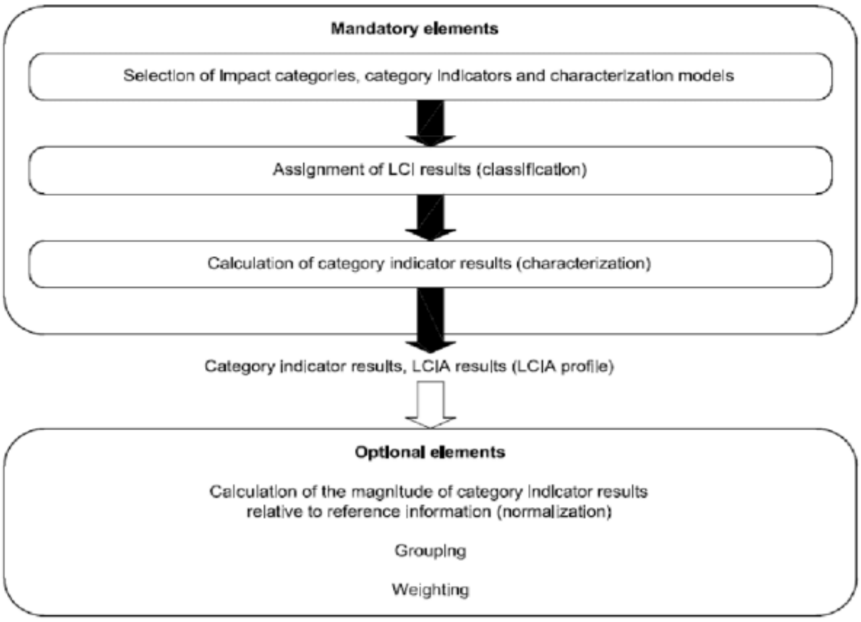


Figure 29. LCIA Elements

ISO 14044:2006 define the term impact category as: "class representing environmental issues of concern to which life cycle inventory analysis results may be assigned", and the term impact category indicator as: "quantifiable representation of an impact category", in order to comprehend the concepts. In Table 11, some commonly used LCIA are exposed.

Figure 32 expose the concept of category indicators based on an environmental mechanism. The impact category "acidification" is used as an example. Every impact category has its own environmental mechanism.

Characterization models mirror the environmental mechanism by depicting the connection between the Life Cycle Inventory results, category indicators and category endpoint(s). This model is employed to acquire the characterization factors.

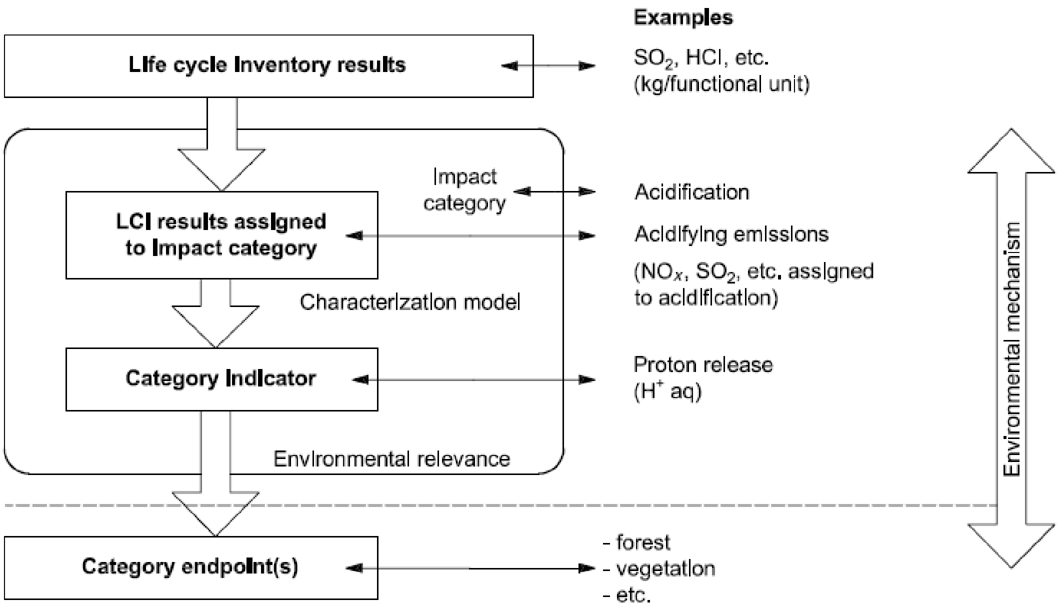


Figure 30. Impact Category Indicators

Additionally, ISO 14044:2006 also defines the concept of characterization factor as: "factor derived from a characterization model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator". And, category endpoint, as: "attribute or aspect of natural environment, human health, or resources, identifying an environmental issue giving cause for concern".

There are two types of impact categories, midpoint and endpoint:

- Midpoint: A midpoint indicator can be characterized as a parameter in a cause-effect chain or system (environmental mechanism) for a specific impact category that is between the inventory data and the category endpoints. Midpoint indicators have the advantage of relying on scientific information and well-proven facts.
- Endpoint: Endpoint indicators are estimated to reflect contrasts between stressors at an endpoint in a cause-effect chain and might be of direct importance to society's comprehension of the final effect, for example, measures of biodiversity change There can be more than one endpoint. Endpoint indicators have the advantage of presenting information in an appealing and understandable way.

Impact Category	Scale	Examples of LCI Data (i.e. classification)	Characterization Factor	Associated Endpoints
Global Warming	Global	Carbon Dioxide (CO2) Nitrogen Dioxide (NO2) Methane (CH4)	Global Warming Potential	Polar melt, soil moisture loss, longer seasons, forest loss /change, and

		Chlorofluorocarbons (CFCs) Hydrochlorofluorocarbons (HCFCs) Methyl Bromide (CH3Br)		change in wind and ocean patterns.
Stratospheric Ozone Depletion	Global	Chlorofluorocarbons (CFCs) Hydrochlorofluorocarbons (HCFCs) Halons Methyl Bromide (CH3Br)	Ozone Depleting Potential	Increased ultraviolet radiation
Acidification	Regional Local	Sulfur Oxides (SOx) Nitrogen Oxides (NOx) Hydrochloric Acid (HCL) Hydroflouric Acid (HF) Ammonia (NH4)	Acidification Potential	Building corrosion, water body acidification,vegetation effects, and soil effects
Eutrophication	Local	Phosphate (PO4) Nitrogen Oxide (NO) Nitrogen Dioxide (NO2) Nitrates Ammonia (NH4)	Eutrophication Potential	Nutrients enter water bodies, such as lakes, estuaries and slow-moving streams, causing excessive plant growth and oxygen depletion.
Photochemical Smog	Local	Non-methane hydrocarbon (NMHC)	Photochemical Oxident Creation Potential	“Smog,” decreased visibility, eye irritation, respiratory tract and lung irritation, and vegetation damage.
Terrestrial Toxicity	Local	Toxic chemicals with a reported lethal concentration to rodents	LC50	Decreased production and biodiversity and decreased wildlife for hunting or viewing.
Aquatic Toxicity	Local	Toxic chemicals with a reported lethal concentration to fish	LC50	Decreased aquatic plant and insect production and biodiversity and decreased commercial or recreational fishing
Human Health	Global Regional Local	Total releases to air, water, and soil.	LC50	Increased morbidity and mortality
Resource Depletion	Global Regional Local	Quantity of minerals used Quantity of fossil fuels used	Resource Depletion Potential	Decreased resources for future generations.
Land Use	Global Regional Local	Quantity disposed of in a landfill or other land modifications	Land Availability	Loss of terrestrial habitat for wildlife and decreased landfill space.
Water Use	Regional Local	Water used or consumed	Water Shortage Potential	Loss of available water from groundwater and surface water sources.

Table 11. Commonly Used Life Cycle Impact Categories

Typically, impact indicators are characterized using the following equation:

$$Inventory\ Data\ \times Characterization\ Factor = Impact\ Indicator$$

In this study, as mentioned in previous chapters, the impact category chosen, is Climate Change, with the utilization of the results of CO_2 emissions given in the inventory phase of the LCA.

7.7 LIFE CYCLE INTERPRETATION

Interpretation is a systematic evaluation of the results obtained in the previous phases of the analysis. According to the UNE EN ISO 14.040 standard, the main objectives of this stage are:

1. Analyse the results, draw conclusions, explain the limitations, and establish recommendations based on the data obtained in the previous stages of the analysis, reproducing the results obtained in a transparent manner.
2. Present in a simple and easily understandable way, complete and consistent the results of the analysis, in accordance with the guidelines set out in the section on the definition of scope and objectives.

In this regard, it should be noted that the interpretation of the results does not will always be simple due, among other things, to the estimates, approximations, and hypotheses that will have proved necessary to make throughout the process.

The interpretation phase is the point at which the results of the analysis are combined with the impact assessment, verifying that the results obtained are coherent with the objective set out in the evaluation.

Interpretation should be transparent, identifying the environmental variables or burdens most likely to be affected. (contribution analysis) and the critical stages (prevalence analysis), from the point of view of the generation of environmental impact, of the phases of the life cycle.

The conclusions may be presented in the form of recommendations for the taking of decisions, definition of improvement strategies aimed at reducing impact identification of environmentally preferable alternatives in the environmental field, and case studies, etc., always in a manner consistent with the objective defined.

According to ISO 14044:2006, The life cycle interpretation phase of an LCA is composed of several elements as shown in Figure 33, as follows:

- Identification of the significant issues based on the results of the LCI and LCIA phases of LCA
- An evaluation that considers completeness, sensitivity and consistency checks

- Conclusions, limitations, and recommendations.

The results of the study are discussed and presented in the next chapter.

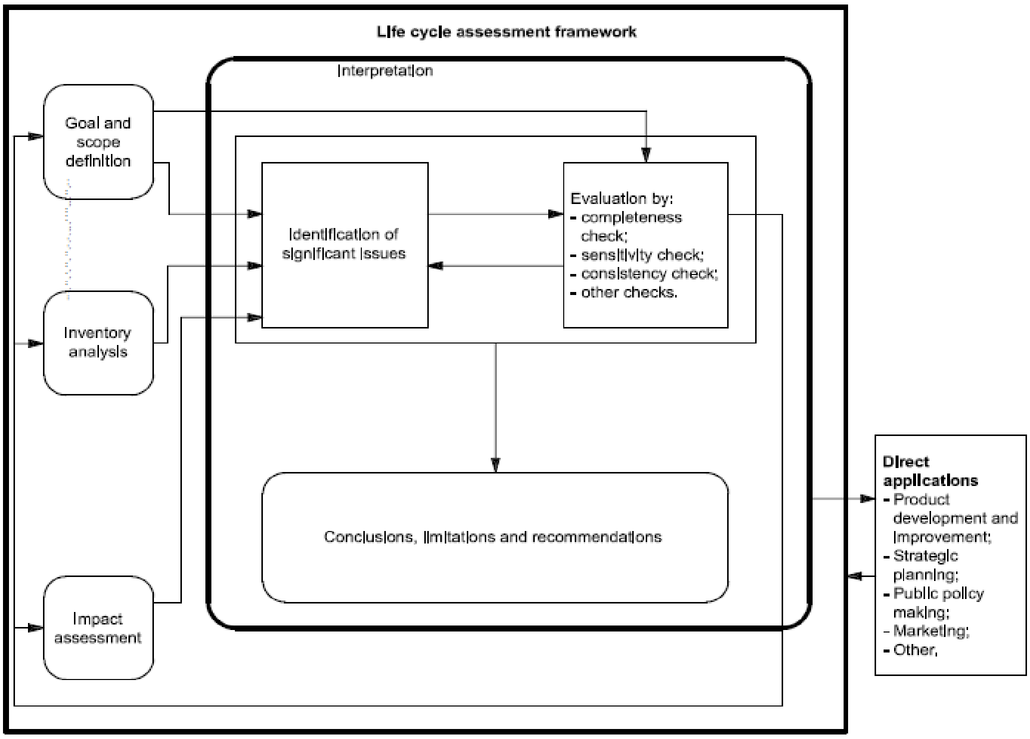


Figure 31. Relationships between elements within the interpretation phase with the other phases of LCA. Source: EPA

8. RESULTS AND CONCLUSION

The results will be firstly divided within the phases, and after, a general result.

8.1 Results for the Production and Construction Phase

The software use for the study gives the results for both production and construction phase together, dividing them into embodied energy and CO2 emissions.

As it is explained above, the different phases are divided into three groups, A, B and C, that is the reason why the production and construction phase results are shown together.

Each phase has been calculated considering certain characteristics which are explained bellow.

A1-A2-A3 Calculation Process

The determination of the building inventory has been carried out by quantifying the weights of products and their packaging, using project measurements and the decomposition of the work units.

For each product, its embodied energy and CO_2 emissions are determined, depending on the type and the weight of the material which it is composed, including the packaging.

Complex products are broken down into the simple materials in which they are composed to determine the embodied energy and emissions values.

A4 Calculation Process

Depending on the transport distance, the following 'Scenarios' are defined:

- Local
- Regional
- National
- Importing

Assigning each family of materials its corresponding scenario, in this case, the scenario is the Iberian Peninsula.

The transport of materials of low apparent density (insulators, polystyrene vaults, etc.) is calculated according to their volume, establishing an equivalence between the weight and the volume transported.

A5 Calculation process

<u>Machinery</u>

The energy consumed and the emissions due to the machinery are determined by the consumption of diesel.

Auxiliary equipment

The energy consumption of the auxiliary equipment is determined from the displacements of the products within the construction site, the use of auxiliary machinery or tools and illumination used on the work site.

Two types of transport are distinguished, vertical or between plants, which consume more energy because they must overcome the action of gravity, and horizontal or displacements in the same plant.

The energy consumed due to vertical displacements is calculated according to the weight of the products, the total number of floors of the building (below and above ground level) and the heights between floors, affected by a correction factor that includes the transport of weight in height.

The energy consumed by horizontal displacements is also determined by the weight of the products and the average surface area of the plants.

Results

In Table 8, the embodied energy and CO_2 emissions results are shown for both typologies used in the LCA study for the construction and building phase. However, in the Appendix C can be found the tables including all the numeric values for each phase, typology, and the total.

Construction Phase A1-A2-A3		
	Typology A	**Typology B**
Embodied Energy (kWh)	336.078,77	328.031,72
CO2 Emissions (kg)	89.400,00	87.770,00

Building Phase A4-A5		
	Typology A	**Typology B**
Embodied Energy (kWh)	6.385,16	6.203,11
CO2 Emissions (kg)	1.700,00	1.650,00

Table 12. Results Phase A

It should be noted that there is not a considerable difference between the two different typologies studied for the phase A.

8.2 Results for the Use phase

Table 12 summarizes the results of the energy consumption and the CO2 emission. However, in the Appendix D can be found the tables including all the numeric values for each phase, and the total.

		Per m^2	**Per year**	**10 years**
Typology A	Total Consumption (kWh)	106,30	21.368,00	213.680,00
	Total CO_2 Emissions (kg CO_2)	18,00	3.619,70	36.197,00
Typology B	Total Consumption (kWh)	23,40	4.967,20	49.672,00
	Total CO_2 Emissions (kg CO_2)	4,20	845,90	8.459,00

Table 13. Results for use phase

In Figure 32, a comparison of the total embodied energy and CO_2 emissions can be seen in the respective graphs.

The use energy consumption and CO_2 emissions corresponds to the maintenance of the first 10 years of the building, as the first 10 years are the more important due to the energy use, because after those ten years the type of energy supply might change.

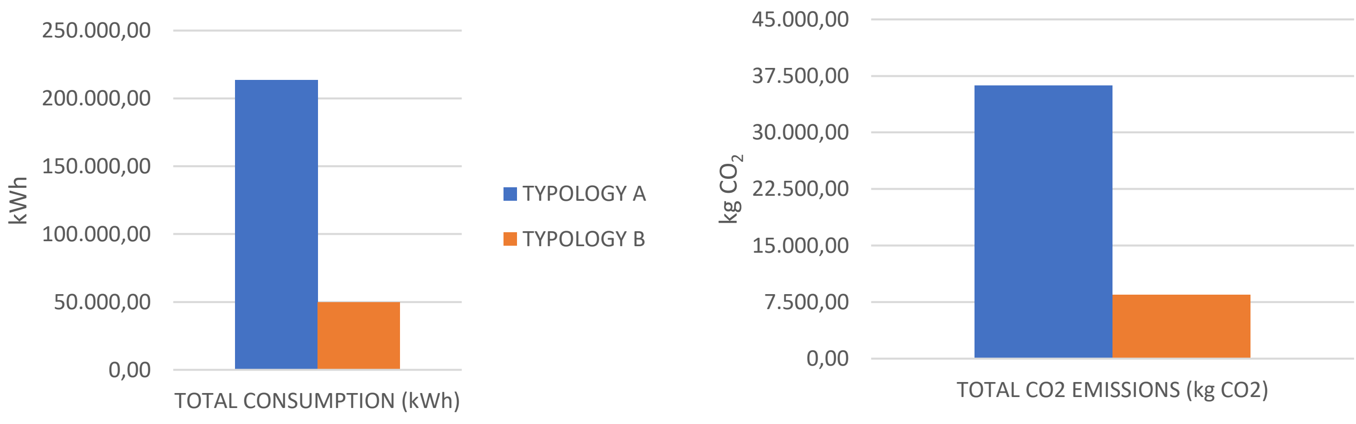


Figure 32. Phase B comparison

It should be highlighted, that the typology B is than the typology A, as it can be seen on Figure 29. This is due to the use of a biomass boiler in the typology B even if solar thermal energy is not used, as it is used in Typology A with an electric boiler.

The Appendix D not only have the results for the energy demand and consumptions and CO2 emission, but also has the energy efficiency certificates, which are explained in the first chapter of the study.

The building rating is divided into non-renewable primary energy consumption (kWh/m^2·year) and Carbon Dioxide emissions (kgCO_2/m^2). The Table 10 has the summarize results for each typology, however in the Appendix D the results are shown in an extended manner.

Typology	**Non-renewable primary energy consumption (kWh/m^2·year)**	**Carbon Dioxide emissions (kgCO_2/m^2).**
A	106,30C	18,01B
B	23,37A	4,21A

Table 14. Building Ratings

8.3 Results

Previously, the results for each phase were presented. In this chapter, the conclusions will be discussed.

The energy consumed by the building, over the 10 years of useful life considered, is obtained as an addition to the energy consumed in the construction and operation phases.

The contribution of each of the phases considered to the overall consumption of the life cycle of the dwelling in question is presented below in the form of a graph.

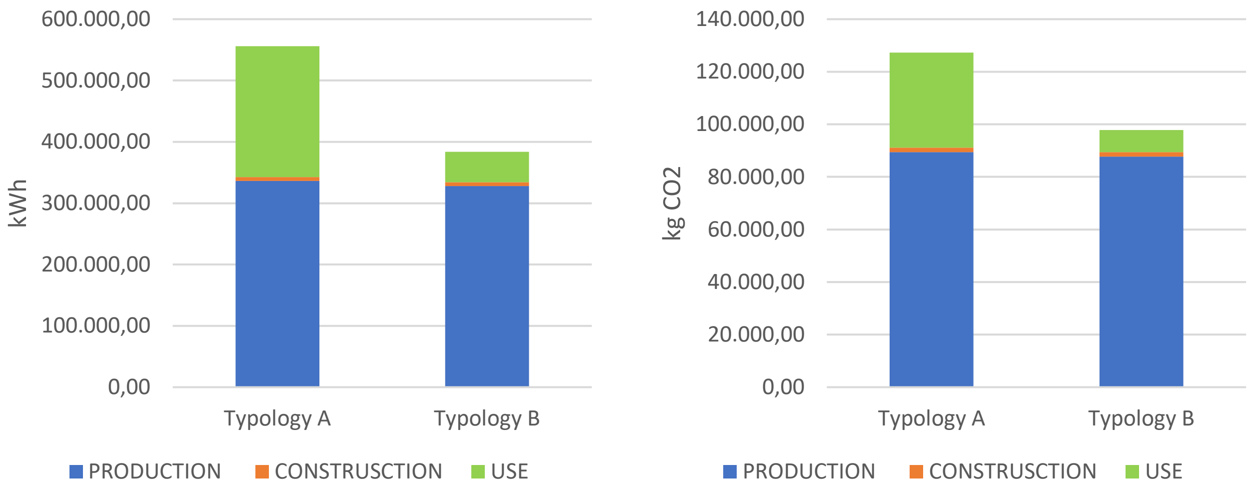


Figure 33. Final energy consumption and CO2 emissions

In the figure above (Figure 34), a comparison between the energy and the CO2 emissions for each phase considered in the study is presented:

It can be observed, that the Embodied energy for the production phase is almost the same, with a difference of 8.047,05kWh that is not noticeable in the graph due to the total high values.

In Figure 34, the embodied energy is divided in the different construction areas to compare the energy consumed in each one. The energy consumed in the production of the structures is the highest, as expected.

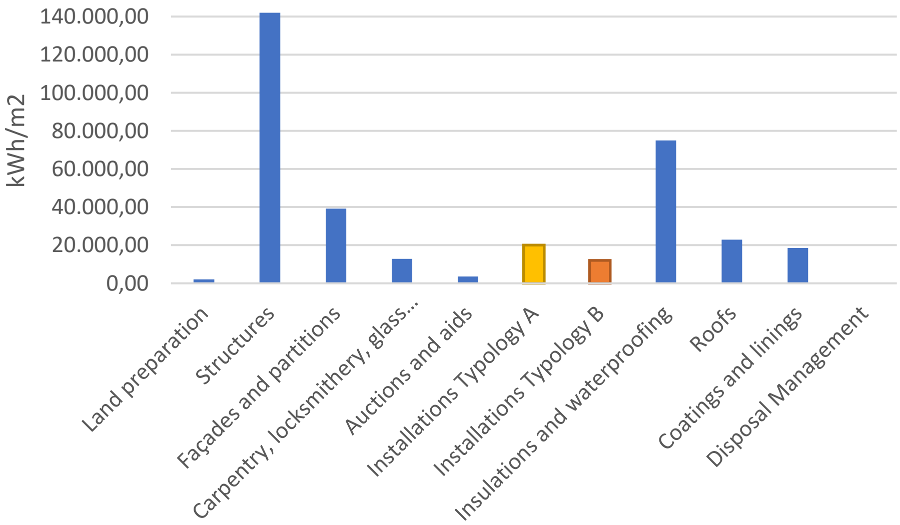


Figure 34. Embodied Energy in Production Phase

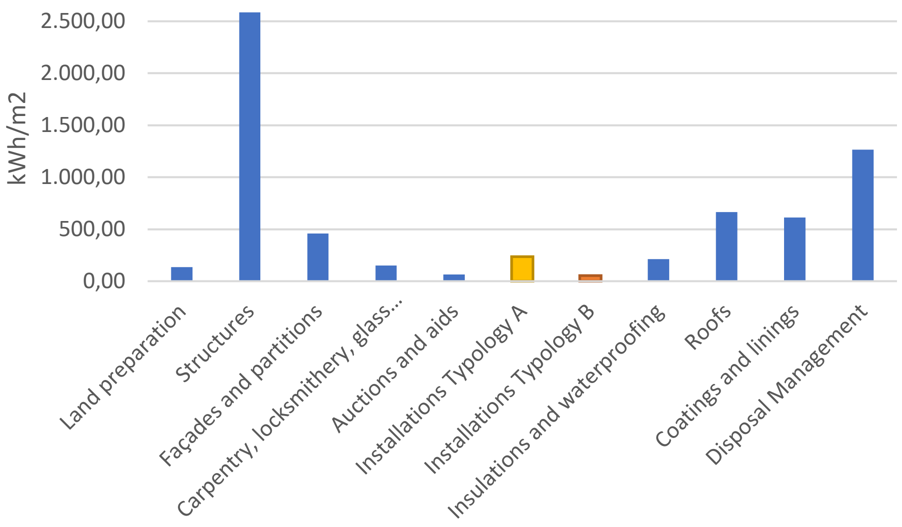


Figure 35. Embodied Energy in Construction Phase

In Figure 35, the embodied energy utilized during the construction phase is represented with the division of the different areas.

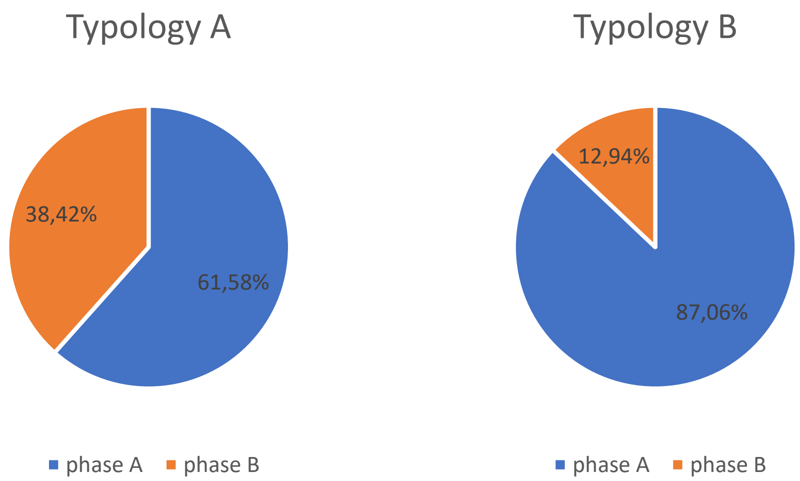


Figure 36. Energy Distribution

Normally, in LCA studies, the energy is distributed differently, compared with this case study. Normally, the energy during the use is responsible of an 80-90% and the embodied energy of a 10-20% [RAME10]. In this case, the energy distribution is very different from the average, and it also varies from the different typologies considered in this study, these differences are shown in the Figure 36.

The main reason for the energy differences might be the different stages considered in each phase, as a consequence of the analyse of only two stages for the Phase B.

In other hand, the normalised energy use per m^2 is between 150-400 kWh/m^2, and, in this case, the energy use for the typology A is 106.3 kWh/m^2 and for typology B is 23.4 kWh/m^2. Being the values of these study lower than the normalise ones.

One of the objectives of this LCA study is the renovation activities of the dwelling. Two different typologies were analysed in this study changing the HVAC system using different types of boilers (electric and biomass) and heating/cooling systems (radiant floors and radiators).

Typology A is less energy efficient as typology B, as can be seen in the energy ratings of the previous chapter and in the Appendix D. with the results of this study, an energy renovation activity could be the change of the electric boiler with a biomass boiler, as it is much more efficient.

9. ECONOMIC STUDY

9.1. INTRODUCTION

The second part of this thesis is the Economic Study for the production and maintenance of the single-family house considering the phases of the Life Cycle Assessment, production and construction phase, and the use and maintenance for the first 10 years.

The quotation for each phase, in euros, is done with the program CYPE using the software Arquimedes (explained in the first part of the thesis).

The cost of the workers is not included. It is included the production, building and maintenance of the materials/products,

9.2. PHASE A BUDGET

The phase A consists of the production (A1-A2-A3) and the construction phase (A4-A5). In this chapter, the budget of this phase is realized and exposed in a table including all the elements. However, the complete budget explaining all the elements can be found in the Appendix 1: Phase A Budget.

In the next table, Table 19, a summary of the budget can be found dividing it in the different areas. Moreover, in Figure 41, a comparation between the budget from the different areas is shown.

SUMARRY	**AMOUNT (€)**
Land Conditioning	1.022,66
Structure	33.752,99
Façade and partitions	6.102,99
Carpentry, locksmith, glass and solar protection	10.723,91
Auctions and aids	929,44
Installations Typology A	34.199,03
Installations Typology B	31.790,91
Insulation and waterproofing	16.481,07
Roof	13.088,06
Coatings and linings	18.047,12
TOTAL A	**134.347,27**

TOTAL B	131.939,15

Table 15. Phase A Budget

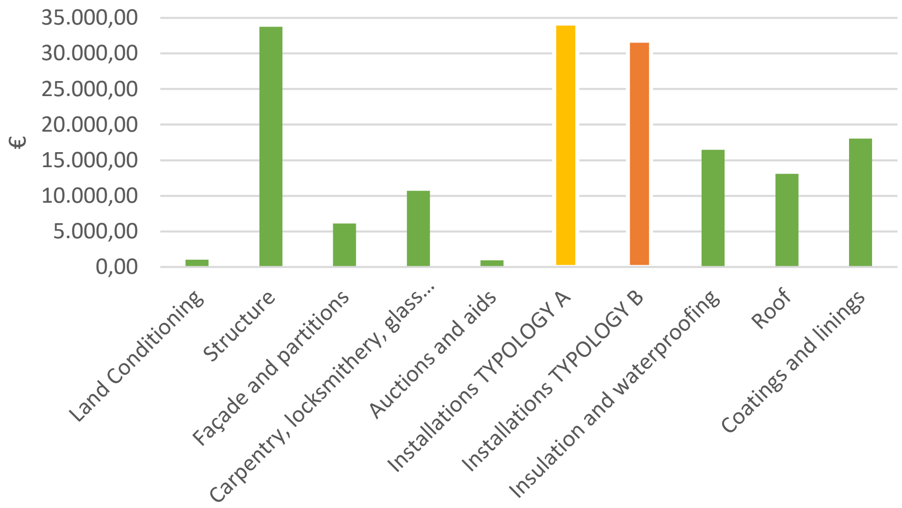


Figure 37. Phase A Budget

In both representations of Phase A budget, the Installations chapter is divided in the two different typologies of the study, with the aim of comparing them, as the budget changes in both typologies due to the HVAC system.

The typology B is 2.408,12€ cheaper than the typology A for the first phase. However, further on in the document a general comparison considering each part of the study will be done.

9.3. PHASE B BUDGET

The second, and last, phase of the LCA study is the use phase, also named as phase B, which is composed of six sub-phases. Although, only two of the six phases are considered for this study: use and operational energy use (as can be seen on Figure 22).

In this chapter, the budget of this phase is realized and exposed in a table including all the elements and the complete budget explaining all the elements can be found in the Appendix 2: Phase B Budget.

In the next table, Table 22, a summary of the budget can be found dividing it in the different areas. Moreover, in Figure 40, a comparation between the budget from the different areas is shown.

In this case, differing with the Phase A of the LCA study, the typology A is more economical than the typology B for the second phase. However, further on in the document a general comparison considering each part of the study will be done.

SUMARRY	AMOUNT (€)
Land Conditioning	65,94
Structure	1.804,97
Façade and partitions	235,85
Carpentry, locksmithery, glass and solar protection	1.370,82
Installations Typology A	8.828,20
Installations Typology B	9.221,26
Insulation and waterproofing	800,75
Roof	4.192,76
Coatings and linings	7.042,66
TOTAL A	**24.341,95**
TOTAL B	**24.735,01**

Table 16. Phase B Budget

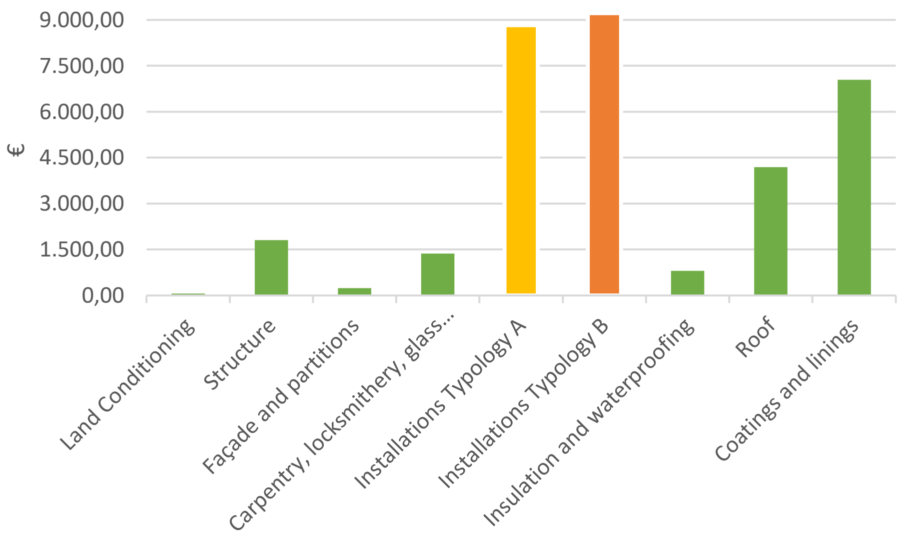


Figure 38. Phase B Budget

9.4. RESULTS AND CONCLUSIONS

The cost for each phase and the total are shown in the Table 24 and Figure 44.

TOTAL COSTS (€)		
	TYPOLOGY A	**TYPOLOGY B**
PHASE A	134.347,27	131.939,15
PHASE B	24.341,95	24.735,01
TOTAL	158.689,22	156.674,16

Table 17. Total Costs

Comparing both typologies, the total cost is approximately the same, with a difference of 2.015,06€. The difference between the costs might influence in the decision of the use of the different HVAC systems for each typology, due to the different boilers and heating systems used.

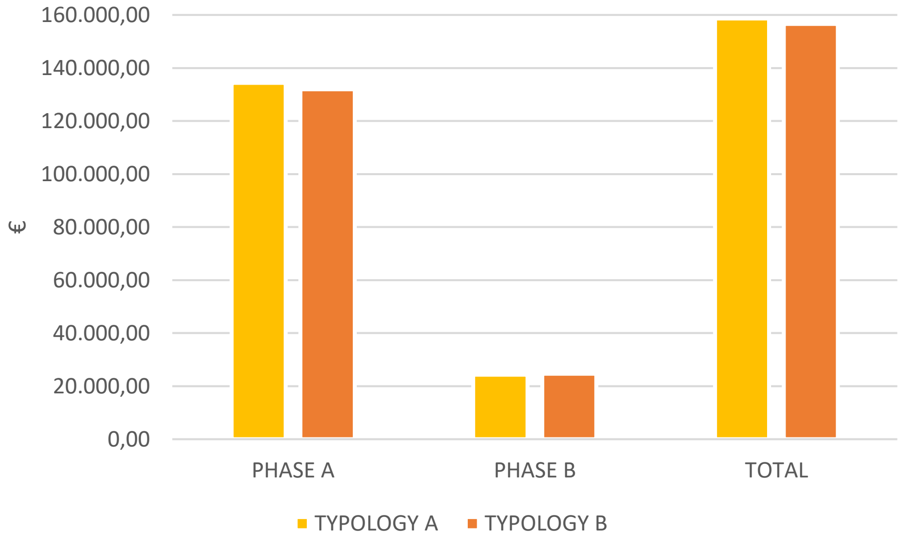


Figure 39. Costs comparison

APPENDIX A: Climate Zones in Spain

Table 18. Climatic Zones

Province	Climatic Zone	Reference Altitud (m)
Albacete	D3	677
Alicante	B4	7
Almería	A4	0
Avila	E1	1054
Badajoz	C4	168
Barcelona	C2	1
Bilbao	C1	214
Burgos	E1	861
Cáceres	C4	385
Cádiz	A3	0
Castellón	B3	18
Ceuta	B3	0
Ciudad Real	D3	630
Córdoba	B4	113
Coruña	C1	0
Cuenca	D2	975
Donostia- San Sebastián	C1	5
Girona	C2	1353
Granada	C3	754
Guadalajara	D3	708
Huelva	B4	50
Huesca	D2	432
Jaén	C4	436
León	E1	346
Lleida	D3	131
Logroño	D2	379
Lugo	D1	412
Madrid	D3	589
Málaga	A3	0
Melilla	A3	130
Murcia	B3	25
Orense	C2	327
Oviedo	C1	214
Palencia	D1	722
Palma de Mallorca	B3	1
Las Palmas	A3	114
Pamplona	D1	456
Pontevedra	C1	77
Salamanca	D2	770
Santa Curz de	A3	0
Santander	C1	1
Segovia	D2	1013
Sevilla	B4	9
Soria	E1	984
Tarragona	B3	1
Teruel	D2	995
Toledo	C4	445
Valencia	B3	8
Valladolid	D2	704
Vitoria- Gasteiz	D1	512
Zamora	D2	617
Zaragoza	D3	207

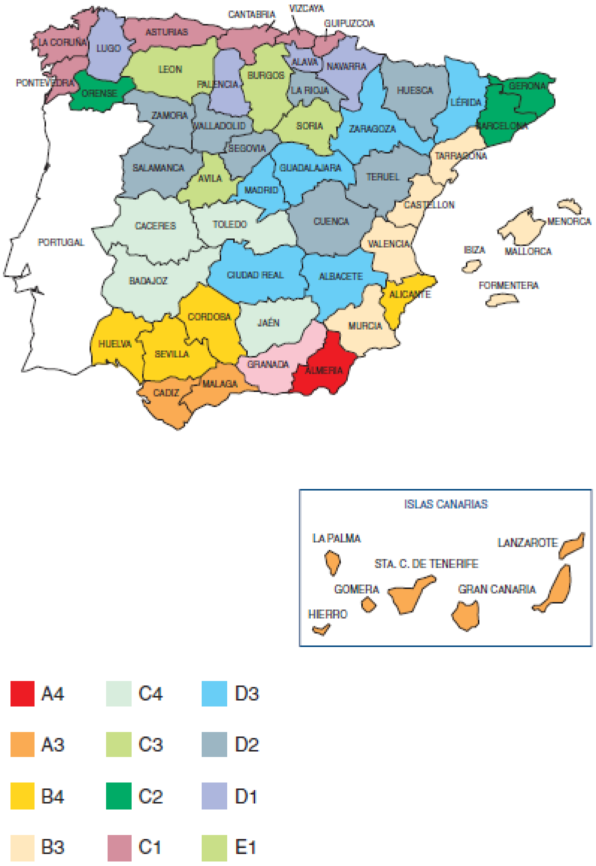


Figure 40. Spain divided into climatic zones

APPENDIX B: Temperature, Wind and Irradiation

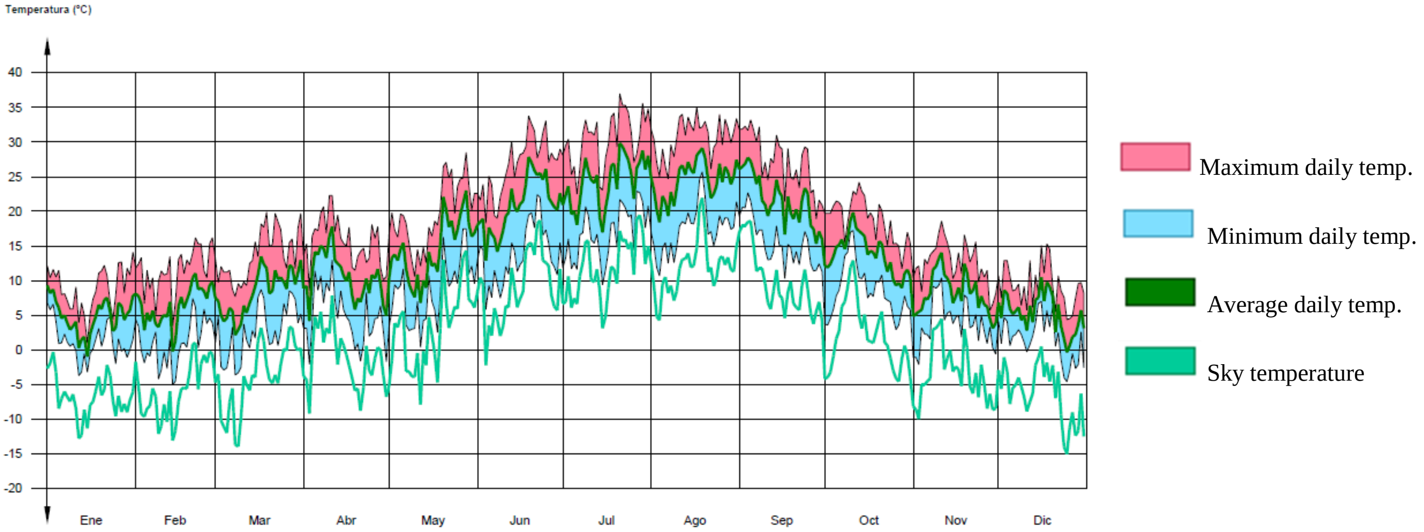


Figure 41. Temperature Evolution

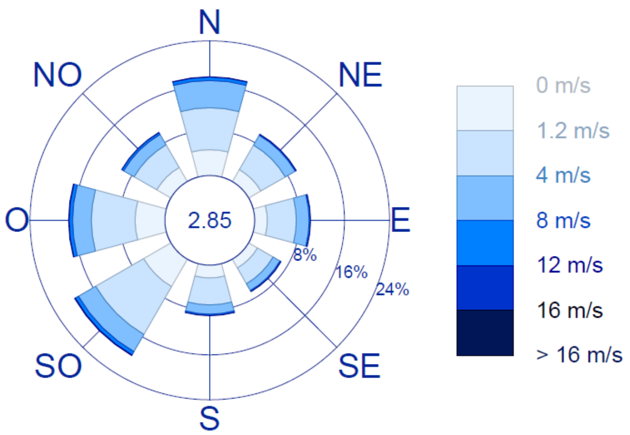


Figure 43. Wind distribution

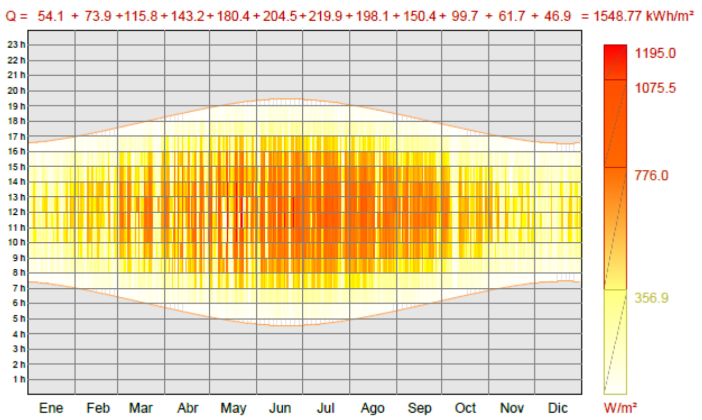


Figure 42. Global irradiation on the horizontal plane

The figure above, contains the data used for the CYPETHERM H software.

APPENDIX C: Embodied Energy and CO_2 Emission Results for Phase A

EMBODIED ENERGY(MJ)				
	PRODUCTION A1-A2-A3	TRANSPORT A4	CONSTRUCTION A5	TOTAL
Land preparation	7.205,45	171,58	315,40	7.692,43
Structures	511.032,49	9.302,45	3,32	520.338,26
Façades/partitions	141.035,40	1.645,57	0,00	142.680,97
Carpentry	46.384,46	544,61	0,00	46.929,07
Auctions and aids	12.796,41	236,97	0,00	13.033,38
Installations TypA	72.200,61	849,21	0,04	73.049,86
Installations Typ B	43.233,53	193,91	0,04	43.427,48
Insulations and waterproofing	269.963,90	761,35	0,00	270.725,25
Roofs	82.521,20	2.394,77	0,00	84.915,97
Coatings and linings	66.646,87	2.206,79	0,00	68.853,66
Disposal Management	0,00	0,00	4.552,66	4.552,66
Total Typology A	1.209.786,79	17.941,72	4.871,42	1.232.771,51
Total Typology B	1.180.819,71	17.458,00	4.871,42	1.203.149,13

Table 19. Embodied energy by phases A

CO2 EMISSIONS EQ. (Ton)				
	PRODUCTION A1-A2-A3	TRANSPORT A4	CONSTRUCTION A5	TOTAL
Land preparation	0,68	0,01	0,02	0,71
Structures	41,45	0,69	0,00	42,14
Façades/partitions	10,78	0,12	0,00	10,90
Carpentry, locksmithery, glass and solar protection	4,30	0,04	0,00	4,34
Auctions and aids	1,12	0,02	0,00	1,14
Installations Typology A	7,31	0,06	0,00	7,37
Installations Typology B	5,68	0,01	0,00	5,69
Insulations and waterproofing	11,51	0,06	0,00	11,57
Roofs	7,23	0,18	0,00	7,41
Coatings and linings	5,02	0,16	0,00	5,18
Disposal Management	0,00	0,00	0,34	0,34

Total Typology A	89,40	1,34	0,36	91,10
Total Typology B	87,77	1,29	0,36	89,42

Table 20. CO2 emissions by phases A

APPENDIX D: Energy and CO_2 Emission Results for Phase B

TYPOLOGY A

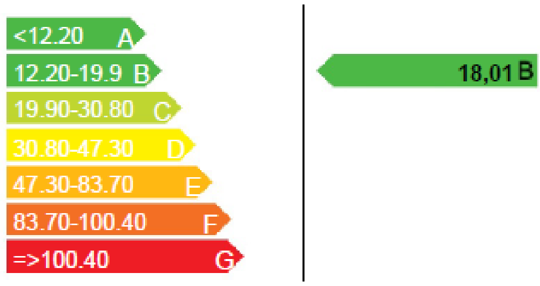
Non-Renewable Primary Energy Consumption (kWh/m2·year)	Carbon Dioxide Emissions (kgCO2/m2·year)
	

Table 21. Building rating typology A

	Rating Class	kWh/m²	kWh/year
Heating Demand	C	53,20	10.703,60
Cooling demand	A	7,90	1.591,30
	Rating Class	**kgCO2/m²**	**kgCO2/ year**
Heating CO2 Emissions	C	16,10	3.241,60
Cooling CO2 Emissions	A	1,10	217,60
DHW CO2 Emissions	A	0,80	160,50
Total CO2 Emissions	B	18,00	3.619,70
	Rating Class	**kWh/m²**	**kWh/ year**
Heating Primary Energy Consumption	C	95,20	19.136,20
Cooling Primary Energy Consumption	A	6,40	1.284,30
DHW Primary Energy Consumption	A	4,70	947,50
Total Primary Energy Consumption	C	106,3	21.368,1

Table 22. Numeric values for use phase B for typology A

<u>TYPOLOGY B</u>

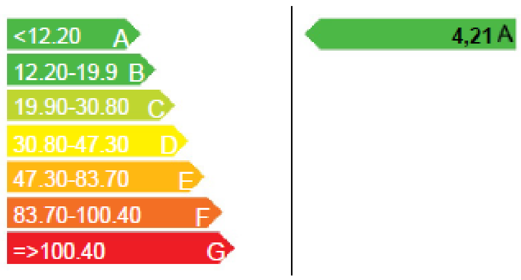
Non-Renewable Primary Energy Consumption (kWh/m2·year)	Carbon Dioxide Emissions (kgCO2/m2·year)
	

Table 23. Building rating typology B

	Rating Class	kWh/m²	kWh/year
Heating Demand	C	55,10	11.081,60
Cooling demand	A	7,60	1.534,40
	Rating Class	**kgCO2/m²**	**kgCO2/ year**
Heating CO2 Emissions	A	1,2	250,8
Cooling CO2 Emissions	A	1,0	209,8
DHW CO2 Emissions	B	1,9	385,3
Total CO2 Emissions	A	4,2	845,9
	Rating Class	**kWh/m²**	**kWh/ year**
Heating Primary Energy Consumption	A	5,9	1.184,3
Cooling Primary Energy Consumption	A	6,2	1.286,3
DHW Primary Energy Consumption	D	11,3	2.274,6
Total Primary Energy Consumption	A	23,4	4.967,2

Table 24. Numeric values for use phase B for typology B

APPENDIX E: Phase A Budget

CODE	TYPE	UNIT	SUMARRY	AMOUNT	PRICE (€)	AMOUNT (€)
A	**Chapter**		**Land Conditioning**		**1.022,66**	**1.022,66**
AS	**Chapter**		**Horizontal drainage network**		**1.022,66**	**1.022,66**
ASA010	Item	Unit	Registrable manhole casket, with internal dimensions 60x60x50 cm, with prefabricated reinforced concrete lid, on a mass concrete floor screed.	2,000	192,84	385,68
ASB010	Item	m	General sewerage connection to the municipality general network, made of smooth PVC, SN-4 series, nominal annular stiffness 4 kN/m², 160 mm in diameter, bonded with adhesive.	6,270	65,37	409,87
ASB020	Item	Unit	Connection of the building connection to the general sewerage network of the municipality.	1,000	206,62	206,62
ASC010	Item	m	Underground sewerage collector, without manholes, by means of an adjustable integral system, in smooth PVC, series SN-2, nominal annular stiffness 2 kN/m², diameter 160 mm, with elastic seal.	0,830	24,69	20,49
E	**Chapter**		**Structure**		**33.752,99**	**33.752,99**
EH	**Chapter**		**Reinforced concrete**		**33.752,99**	**33.752,99**
EHU005	Item	m²	Reinforced concrete floor slab, edge 30 = 25+5 cm, made of HRA-25/B/20/IIa concrete made in a central location and poured with cupola, volume 0.102 m³/m², and UNE-EN 10080 B 500 S steel, weight 11 kg/m²; pre-stressed, mechanised vault beam made of expanded polystyrene, 62.5x125x25 cm and electrowelded mesh ME 20x20 Ø 5-5 B 500 T 6x2.20 UNE-EN 10080, in compression layer, on a support wall 80 cm high and 24 cm thick perforated ceramic brick (coarse), for covering, 24x11x5 cm.	166,050	101,33	16.825,85
EHU020	Item	m²	Reinforced concrete structure, made of HRA-25/B/20/IIa concrete, manufactured in a plant and poured with cupola, total volume of concrete 0.191 m³/m², and steel UNE-EN 10080 B 500 S with a total amount of 16 kg/m², on a continuous formwork system, consisting of: unidirectional, horizontal, edge 35 = 30+5 cm; prestressed beam, double; machined expanded polystyrene vault, 62.5x125x30 cm; electro welded mesh ME 20x20 Ø 5-5 B 500 T 6x2.20 UNE-EN 10080, in compression layer; flat beams; columns with free height up to 3 m.	166,050	101,94	16.927,14
F	**Chapter**		**Façade and partitions**		**6.102,99**	**6.102,99**
FF	**Chapter**		**Non-structural masonry**		**6.102,99**	**6.102,99**
FFZ010	Item	m²	Exterior façade cladding sheet, 11 cm thick, made of perforated acoustic ceramic brick, for cladding, 24x11x10 cm, received with industrial cement mortar, grey colour, M-5, supplied in bulk; lintel formation by means of prefabricated joists, clad with ceramic pieces, placed with high adherence mortar.	160,330	25,21	4.041,92

FFQ010	Item	m²	11 cm thick, factory-built, perforated acoustic ceramic brick interior partition sheet for cladding, 24x11x10 cm, received with industrial cement mortar, grey colour, M-5, supplied in bulk.	93,600	22,02	2.061,07
L	**Chapter**		**Carpentry, locksmithery, glass and solar protection**		**10.723,91**	**10.723,91**
LC	**Chapter**		**Carpentry**		**5.436,79**	**5.436,79**
LCP060	Item	Unit	PVC window, two opening leaves with opening towards the inside, dimensions 2100x1200 mm, with security lock, standard finish on both sides, white, without pre-frame.	2,000	372,18	744,36
LCP060b	Item	Unit	PVC window, one tilt-and-turn door leaf with opening towards the inside, dimensions 1000x1000 mm, standard finish on both sides, white, without pre-frame.	6,000	200,63	1.203,78
LCP060c	Item	Unit	PVC window, one tilting leaf with opening towards the inside, dimensions 1100x1200 mm, leaf finish on both sides, colour to be chosen, without pre-frame. Built-in thermal shutter box (monoblock), PVC slat roller shutter with double hitch, with automatic drive by electric motor.	1,000	494,45	494,45
LCP060d	Item	Unit	PVC window, one tilting and one opening leaf with opening towards the inside, dimensions 1700x1200 mm, leaf finish on both sides, colour to be chosen, without pre-frame. Built-in thermal shutter box (monoblock), rolling shutter with injected aluminium slats, with automatic drive by electric motor.	4,000	748,55	2.994,20
LE	**Chapter**		**Entrance door**		**488,66**	**488,66**
LEM010	Item	Unit	Reinforced interior entrance door 203x92.5x4.5 cm, chipboard sheet, sapele veneered, workshop varnished; country pine frame 130x40 mm; MDF rebate, sapele veneer 130x20 mm; MDF flashing, sapele veneer 70x10 mm.	1,000	488,66	488,66
LP	**Chapter**		**Interior doors**		**1.387,32**	**1.387,32**
LPM010	Item	Unit	Internal folding door, blind, single-leaf, 203x82.5x3.5 cm, agglomerated board, veneered with country pine, varnished in the workshop, with straight-shaped ceiling panels; 90x35 mm country pine frame; MDF rebate, with wood veneer, 90x20 mm country pine; MDF flashing, with wood veneer, 70x10 mm country pine; with hanging and closing hardware.	6,000	231,22	1.387,32
LV	**Chapter**		**Glass**		**3.411,14**	**3.411,14**
LVC020	Item	m²	Double glazing LOW.S low thermal emissivity + acoustic insulation "CONTROL GLASS ACOUSTIC AND SOLAR", Sonor 10+10/14/8 LOW.S, fixed on woodwork with shims and continuous sealing on the outside and continuous profile on the inside, for glass sheets with a surface area between 6 and 7 m².	16,020	212,93	3.411,14
H	**Chapter**		**Auctions and aids**		**929,44**	**929,44**
HY	**Chapter**		**Masonry aid**		**929,44**	**929,44**
HYA010	Item	m²	Masonry aid in a single-family building for the installation of plumbing.	145,680	6,38	929,44

I	**Chapter**		**Installations**			**A: 34.199,03** **B: 31.790,91**
IL	**Chapter**		**Telecommunications infrastructure**		**854,92**	**854,92**
ILA010	Item	Unit	Supply and installation of a prefabricated input box for ICT of 400x400x600 mm of interior dimensions, with hooks for traction, frame and cover, up to 20 user access points, for connection between the telecommunication power supply networks of the different operators and the common telecommunication infrastructure of the building, placed on a 10 cm thick HM-20/B/20/I mass concrete floor.	1,000	325,71	325,71
ILA020	Item	m	Underground supply and installation of external ductwork between the entrance pit and the lower junction box inside the dwelling, made up of 1 polyethylene tube (TBA+STDP) of 63 mm diameter, supplied in rolls, 450 N compression resistance, 20 Joules impact resistance, executed in a 45x75 cm trench, with the tube embedded in a HM-20/B/20/I mass concrete prism with 6 cm of upper and lower cover and 5.5 cm of lateral covering.	2,120	11,01	23,34
ILE030	Item	m	Supply and installation on the surface of the upper connection pipe between the upper general entrance point of the building and the RITS, RITU or RITM, for multi-family buildings, made up of 2 rigid PVC pipes of 40 mm in diameter, compressive strength greater than 1250 N, impact strength 2 joules, with IP 547. Including accessories, clamping elements and guide wire.	1,000	53,82	53,82
ILI010	Item	m	Supply and installation of internal user conduit inside the house that connects the network termination register with the different tapping registers, made up of 1 flexible PVC tube, reinforced with a diameter of 20 mm, 320 N compression resistance, 2 joules impact resistance, for cable laying. Including accessories, clamping elements and guide wire.	198,660	1,47	292,03
ILI020	Item	Unit	Supply and installation of a built-in socket register, made up of a universal box, with connection on both sides and a BAT or user socket, medium range, with a white blind cover and a frame with jaws, for the provision of new services. Including accessories, special parts and fasteners.	15,000	6,81	102,15
IA	**Chapter**		**Audiovisuals**		**1.603,10**	**1.603,10**
IAA031	Item	Unit	Supply and installation of a mast for fixing 1 antenna, made of steel tube with anti-corrosion treatment, 3 m high, 40 mm in diameter and 2 mm thick. Even anchorages and as many accessories as necessary for its correct installation.	1,000	89,67	89,67
IAA034	Item	Unit	Supply and installation of a circular FM external antenna for the reception of analogue sound broadcasting signals from terrestrial broadcasts, with a gain of 0 dB and a length of 500 mm. Even	1,000	43,38	43,38

			anchorages and as many accessories as necessary for its correct installation.			
IAA034b	Item	Unit	Supply and installation of an external DAB antenna for capturing digital sound broadcasting signals from terrestrial emissions, 1 element, 0 dB gain, 15 dB D/A ratio and 555 mm length. Even anchorages and as many accessories as necessary for its correct installation.	1,000	41,70	41,70
IAA034c	Item	Unit	Supply and installation of an external UHF antenna for the reception of analogue television, digital terrestrial television (DTT) and high definition television (HDTV) signals from terrestrial broadcasts, channels 21 to 60, with 13 elements, 13 dB gain, 25 dB D/A ratio. Even anchorages and as many accessories as necessary for its correct installation.	1,000	52,96	52,96
IAA040	Item	Unit	Supply and installation of headend equipment, consisting of: 1 single-channel UHF amplifier, 50 dB gain; 1 FM amplifier; 1 DAB amplifier, all with self-separating at the input and automix at the output (housed in the RITS or RITU). Including power supply, support, interconnection bridges, resistive loads, distributor, mixers and all the necessary accessories for its correct installation.	1,000	428,19	428,19
IAA100	Item	m	Supply and installation of RG-6 coaxial cable of 75 Ohm with medium characteristic impedance, reaction to fire class Eca, with central copper conductor of 1.15 mm diameter, cellular polyethylene dielectric, aluminium/polypropylene/aluminium tape screen, copper braided wire mesh and PVC outer sheath of 6.9 mm diameter in white colour. Including accessories and fasteners.	132,860	1,34	178,03
IAA115	Item	Unit	Supply and installation of a 5-1000 MHz distributor with 8 outputs and 12 dB insertion loss.	1,000	26,45	26,45
IAA115b	Item	Unit	Supply and installation of a 5-2400 MHz distributor with 8 outputs, 14 dB insertion loss at 850 MHz and 17 dB insertion loss at 2150 MHz.	1,000	16,55	16,55
IAA120	Item	Unit	Supply and installation of double socket, TV-R, 5-1000 MHz, with cover.	5,000	11,37	56,85
IAA120b	Item	Unit	Supply and installation of a 5-2400 MHz TV/R-SAT double separator socket with cover.	5,000	12,35	61,75
IAF070	Item	Unit	Supply and installation of a rigid U/UTP non flame propagating cable with 4 twisted copper pairs, category 6, reaction to fire class Dca-s2,d2,a2 according to UNE-EN 50575, with copper unifilar conductor, polyethylene insulation and outer sheath made of halogen-free thermoplastic polyolefin LSFH, with low smoke and corrosive gas emission, 6.2 mm in diameter. Including accessories and fasteners.	65,820	2,14	140,85
IAF075	Item	Unit	Supply and installation of a mains termination rosette consisting of an 8-pin RJ-45 female connector, category 6, with a 47x64.5x25.2 mm surface box, white colour.	1,000	15,33	15,33
IAF085	Item	Unit	Suministro e instalación de multiplexor pasivo de 1 entrada y 6 salidas, con conectores hembra tipo RJ-45 de 8 contactos, categoría 6, color blanco y latiguillo de conexión de 0,5 m de longitud formado por cable rígido U/UTP no	1,000	30,09	30,09

			propagador de la llama de 4 pares de cobre, categoría 6, con conductor unifilar de cobre, aislamiento de polietileno y vaina exterior de PVC LSFH libre de halógenos, con baja emisión de humos y gases corrosivos y conector macho tipo RJ-45 de 8 contactos, categoría 6, en ambos extremos.			
IAF090	Item	Unit	Supply and installation of passive multiplexer with 1 input and 6 outputs, with 8-pin RJ-45 female connectors, category 6, white colour and 0.5 m long connection hose made up of rigid U/UTP cable with 4 copper pairs, category 6, with single-wire copper conductor, polyethylene insulation and outer sheath made of halogen-free LSFH PVC, with low smoke and corrosive gas emission and 8-pin RJ-45 male connector, category 6, on both ends.	5,000	18,47	92,35
IAO035	Item	Unit	Supply and installation of fibre optic rosette consisting of double SC type connector and surface box.	1,000	32,07	32,07
IAV020	Item	Unit	Installation of vandal-proof electronic door entry system kit for single-family homes, consisting of: exterior vandal-proof street panel with call button, power supply and telephone. Including electric locks, visor, wiring and boxes.	1,000	296,88	296,88
IC	**Chapter**		**Heating, cooling and DHW- TYPOLOGY A**		**20.134,87**	**20.134,87**
ICI011	Item	Unit	Wall-mounted mixed electric boiler for heating and DHW, power 21.0 kW, with temperature regulation of the circuit by means of a control unit with an external probe acting on the three-way motorised valve and electronic room thermostat with digital display, with multiple programming possibilities.	1,000	3.491,67	3.491,67
ICS005	Item	Unit	Filling point made up of 2 m of cross-linked polyethylene pipe , with oxygen barrier , 16 mm outside diameter and 2 mm thick, PN=6 atm, for air-conditioning, placed on the surface, insulated with flexible elastomeric foam shell.	1,000	99,19	99,19
ICS010	Item	m	Primary circuit of solar thermal systems made up of rigid copper pipe, 13/15 mm in diameter, placed on the surface outside the building, with insulation by means of a glass wool shell protected with an asphalt emulsion coated with protective paint for white insulation.	37,890	24,35	922,62
ICS010b	Item	m	Hot and cold water distribution pipe made of cross-linked polyethylene pipe, with oxygen barrier, 25 mm outside diameter and 2.3 mm thick, PN=6 atm, recessed in the wall, insulated with flexible elastomeric foam shell.	15,330	17,44	267,36
ICS010c	Item	m	Hot and cold water distribution pipe made of cross-linked polyethylene pipe, with oxygen barrier, 32 mm external diameter and 2.9 mm thick, PN=6 atm, recessed in the wall, insulated with flexible elastomeric foam shell.	5,380	24,67	132,72
ICS010d	Item	m	DHW Distribution pipework made of random copolymer polypropylene pipe (PP-R), 32 mm outer diameter, PN=10 atm, placed on the surface inside the building, with elastomeric foam insulation.	2,790	21,86	60,99
ICS015	Item	Unit	Emptying point made up of 2 m of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier	1,000	26,51	26,51

			(EVOH), 25 mm outside diameter and 2.3 mm thick, PN=6 atm, for air conditioning, placed on the surface.			
ICS020	Item	Unit	Three-stage centrifugal electric pump, cast iron, with a power of 0.071 kW.	1,000	386,41	386,41
ICS075	Item	Unit	Solar kit for connection of gas water heater to solar DHW. interaccumulator.	1,000	208,34	208,34
ICS075b	Item	Unit	1/2" 3-way valve, mixer, with 230 V actuator.	1,000	194,23	194,23
ICE100	Item	Unit	Modular manifold made of reinforced polyamide, model Vario M "UPONOR IBERIA", for 5 circuits, female 16 mm x 3/4" Eurocone fittings, model Vario, ball valves for closing the manifold circuit, model Vario, plastic pipe bender, model Fix, mounted in 80x700x770 mm cabinet, model Vario CI with door, model Vario CI.	2,000	848,39	1.696,78
ICE110	Item	m²	UPONOR IBERIA" underfloor heating and cooling system, consisting of polyethylene film, polyethylene foam (PE) band, 150x10 mm, Multi Autofixing model, expanded polystyrene insulating panel (EPS), with Velcro strips for fixing the pipes, 30 kg/m³ density, 10000x1000 mm and 25 mm thickness, model Klett Neorol G, cross-linked polyethylene tube (PE-Xa) with oxygen barrier (EVOH), 16 mm outside diameter and 2 mm thick, with external velcro spiral strips for fixing to insulating panels, model Klett Autofijación Confort Pipe PLUS, and self-levelling mortar, CA - C20 - F4 according to UNE-EN 13813, 50 mm thick.	16,570	86,07	1.426,18
ICE110b	Item	m²	UPONOR IBERIA" underfloor heating and cooling system, consisting of polyethylene film, polyethylene foam (PE) band, 150x10 mm, Multi Autofixing model, expanded polystyrene insulating panel (EPS), with Velcro strips for fixing the pipes, 30 kg/m³ density, 10000x1000 mm and 25 mm thickness, model Klett Neorol G, cross-linked polyethylene tube (PE-Xa) with oxygen barrier (EVOH), 16 mm outside diameter and 2 mm thick, with external velcro spiral strips for fixing to insulating panels, model Klett Autofijación Confort Pipe PLUS, and self-levelling mortar, CA - C20 - F4 according to UNE-EN 13813, 50 mm thick.	63,340	77,63	4.917,08
ICE150	Item	Unit	UPONOR IBERIA" temperature regulation system, consisting of a control unit, for a maximum of 8 control thermostats at 230 V and 16 electrothermal heads, model Base 8X UK 230V, with programmable digital thermostat, model Base T-26 230V, and electrothermal heads, model Smart S, at 230 V.	2,000	690,30	1.380,60
ICE161	Item	Unit	Drive unit for controlling the circulation pump in heating systems, with control unit, horizontal installation in collector, suitable for underfloor heating systems up to 30 kW.	1,000	2.175,21	2.175,21
ICB005	Item	Unit	Complete solar thermal collector, split, for individual installation, for installation on flat roof, consisting of: a panel of 1160x1930x90 mm, total useful area 2.02 m², optical efficiency 0.819 and primary loss ratio 4.227 W/m²K, according to UNE-EN 12975-2, 200 l tank, individual pumping group, programmable solar thermal unit.	1,000	2.748,98	2.748,98

IC	Chapter		Heating, cooling and DHW- TYPOLOGY B		17.726,75	17.726,75
ICA010	Item	Unit	Electric water heater for A.C.S. service, vertical wall, armoured resistance, capacity 100 l, power 2.2 kW, height 913 mm and diameter 450 mm.	1,000	300,03	300,03
ICQ015	Item	Unit	Pellet boiler, model Vap 30 "ECOFOREST", rated thermal output 30 kW, efficiency 93%, class 5, grey colour.	1,000	7.179,88	7.179,88
ICQ030	Item	Unit	Pellet feeding system for biomass boiler consisting of a basic flexible pellet extractor kit, consisting of 1 m long extractor tube and 0.55 kW drive motor, for single-phase 230 V supply, 3 m flexible pellet extractor extension tube, 1 m flexible pellet extractor connection tube.	1,000	1.945,32	1.945,32
ICQ060	Item	Unit	Surface tank for pellet storage, made of synthetic fabric, with steel structure and hopper, 1.70x1.70 m and adjustable height from 1.80 to 2.50 m, maximum capacity 3.2 t, with automatic fuel extraction system.	1,000	2.747,62	2.747,62
ICS005	Item	Unit	Filling point made up of 2 m of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier (EVOH), 16 mm outside diameter and 2 mm thick, PN=6 atm, for air-conditioning, placed on the surface, insulated with flexible elastomeric foam shell.	1,000	99,19	99,19
ICS010	Item	m	General hot and cold water distribution pipe for conditioning made of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier (EVOH), 16 mm outside diameter and 2 mm thick, PN=6 atm, recessed in the wall, insulated with flexible elastomeric foam shell.	123,680	13,96	1.726,57
ICS010b	Item	m	General hot and cold water distribution pipe for conditioning made of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier (EVOH), 20 mm outside diameter and 2 mm thick, PN=6 atm, recessed in the wall, insulated with flexible elastomeric foam shell.	13,110	15,18	199,01
ICS010c	Item	m	General hot and cold water distribution pipe for conditioning made of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier (EVOH), 25 mm outside diameter and 2.3 mm thick, PN=6 atm, recessed in the wall, insulated with flexible elastomeric foam shell.	10,460	17,44	182,42
ICS015	Item	Unit	Emptying point made up of 2 m of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier (EVOH), 25 mm outside diameter and 2.3 mm thick, PN=6 atm, for air conditioning, placed on the surface.	1,000	26,51	26,51
ICS020	Item	Unit	Three speed centrifugal electric pump, made of cast iron, with a power of 0,071 kW.	1,000	386,41	386,41
ICE040	Item	Unit	Die-cast aluminium radiator, with 556.5 kcal/h heat output, 7-element, 421 mm high, with front panel with openings, for installation with twin tube system, with thermostatic shut-off valve.	2,000	154,96	309,92
ICE040b	Item	Unit	Die-cast aluminium radiator, with 636 kcal/h heat output, 8-element, 421 mm high, with front panel with openings, for installation with twin tube system, with thermostatic shut-off valve.	2,000	170,20	340,40
ICE040c	Item	Unit	Die-cast aluminium radiator, with 715,5 kcal/h heat output, 9-element, 421 mm high, with front	2,000	185,45	370,90

			panel with openings, for installation with twin tube system, with thermostatic shut-off valve.			
ICE040d	Item	Unit	Die-cast aluminium radiator, with 795 kcal/h heat output, 10-element, 421 mm high, with front panel with openings, for installation with twin tube system, with thermostatic shut-off valve.	2,000	200,67	401,34
ICE040e	Item	Unit	Die-cast aluminium radiator, with 874,5 kcal/h heat output, 11-element, 421 mm high, with front panel with openings, for installation with twin tube system, with thermostatic shut-off valve.	7,000	215,89	1.511,23
IE	**Chapter**		**Electric Installations**		**6.373,39**	**6.373,39**
IEP010	Item	Unit	Grounding net for building concrete structure with 90 m bare copper conductor of 35 mm² and 20 spades.	1,000	2.062,95	2.062,95
IEP030	Item	Unit	Equipotential bonding network in wet rooms.	2,000	45,46	90,92
IEO010b	Item	m	Built-in ducting in PVC corrugated pipe construction element, black, 20 mm nominal diameter, with IP 545 degree of protection.	208,790	1,05	219,23
IEO010c	Item	m	Built-in ducting in PVC corrugated pipe construction element, black, 25 mm nominal diameter, with IP 545 degree of protection.	35,250	1,15	40,54
IEO010d	Item	m	Built-in ducting in PVC corrugated pipe construction element, black, 32 mm nominal diameter, with IP 545 degree of protection.	3,160	1,37	4,33
IEO010e	Item	m	Built-in ducting in PVC corrugated pipe construction element, black, 50 mm nominal diameter, with IP 545 degree of protection.	2,270	2,03	4,61
IEH010	Item	m	Single-pole cable ES07Z1-K (AS), reaction to fire class Cca-s1b,d1,a1, with multi-core copper conductor class 5 (-K), 10 mm² cross-section, insulated with halogen-free polyolefin-based thermoplastic compound with low smoke and corrosive gas emissions (Z1).	11,350	3,20	36,32
IEH010b	Item	m	Single-pole cable H07V-K, with a rated voltage of 450/750 V, reaction to fire class Eca, with multi-core copper conductor class 5 (-K) of 1.5 mm² section, PVC (V) insulation.	848,670	0,68	577,10
IEH010c	Item	m	Single-pole cable H07V-K, with a rated voltage of 450/750 V, reaction to fire class Eca, with multi-core copper conductor class 5 (-K) of 2.5 mm² section, PVC (V) insulation.	574,590	0,84	482,66
IEH010d	Item	m	Single-pole cable H07V-K, with a rated voltage of 450/750 V, reaction to fire class Eca, with multi-core copper conductor class 5 (-K) of 4 mm² section, PVC (V) insulation.	51,780	1,08	55,92
IEH010e	Item	m	Single-pole cable H07V-K, with a rated voltage of 450/750 V, reaction to fire class Eca, with multi-core copper conductor class 5 (-K) of 6 mm² section, PVC (V) insulation.	105,750	1,62	171,32
IEH010f	Item	m	Single-pole cable H07V-K, with a rated voltage of 450/750 V, reaction to fire class Eca, with multi-core copper conductor class 5 (-K) of 10 mm² section, PVC (V) insulation.	15,800	2,33	36,81
IEC010	Item	Unit	Protection and measuring box CPM2-S4, up to 63 A current, for 1 three-phase meter, installed	1,000	271,57	271,57

			inside a wall niches, in a single family or local house.			
IEI070	Item	Unit	Housing panel made up of an insulated box and the control and protection devices.	1,000	1.321,20	1.321,20
IEI090	Item	Unit	Components for the electrical distribution network inside the home: basic range mechanisms (key or cover and frame: white; cover: white); flush mounting boxes with fixing screws, junction boxes with covers and connection strips.	1,000	785,07	785,07
IF	**Chapter**		**Plumbing**		**1.201,13**	**1.201,13**
IFA010	Item	Unit	Underground connection for drinking water supply, 1.02 m long, made up of PE 100 polyethylene pipe, 32 mm external diameter, PN=10 atm and 2 mm thick, and cutting key housed in a prefabricated polypropylene box.	1,000	171,81	171,81
IFB010	Item	Unit	Drinking water supply, 4.56 m long, buried, made of seamlessly drawn galvanised steel tube, 3/4" DN 20 mm in diameter.	1,000	104,57	104,57
IFC010	Item	Unit	Pre-installation of a 1 1/4" DN 32 mm general water meter, placed in a niche, with a general shut-off valve for a gate.	1,000	118,82	118,82
IFI008	Item	Unit	Brass seat valve, 3/4" diameter, with stainless steel handle and cover.	6,000	18,51	111,06
IFI100	Item	Unit	Piping for internal installation, consisting of cross-linked polyethylene pipe (PE-Xa), series 5, 16 mm outer diameter, PN=6 atm, 46,234 m long, cross-linked polyethylene pipe (PE-Xa), series 5, 20 mm outer diameter, PN=6 atm, 42,7526 m long and 16 tees, 38 elbows 90°, 4 elbows with fixing base and female threaded outlet, 14 elbows with female threaded outlet.	1,000	676,42	676,42
IFW010	Item	Unit	Brass seat valve, 3/4" diameter, with stainless steel handle and cover.	1,000	18,45	18,45
IS	**Chapter**		**Water evacuation**		**966,56**	**966,56**
ISB040	Item	m	Piping for primary ventilation of the water drainage network, made up of 75 mm diameter polypropylene pipe with mineral charge, joined with elastic joint.	9,370	17,23	161,45
ISB044	Item	Unit	Ventilation cap made of PVC, 75 mm diameter, bonded with adhesive.	2,000	18,89	37,78
ISD005	Item	m	Small evacuation net, soundproofed, recessed, polypropylene with mineral charge, diameter 40 mm, connection with elastic seal.	11,770	8,00	94,16
ISD005b	Item	m	Small evacuation net, soundproofed, recessed, polypropylene with mineral charge, diameter 75 mm, connection with elastic seal.	1,280	12,79	16,37
ISD005c	Item	m	Small evacuation net, soundproofed, recessed, polypropylene with mineral charge, diameter 90 mm, connection with elastic seal.	1,810	15,82	28,63
ISD005d	Item	m	Small evacuation net, soundproofed, recessed, polypropylene with mineral charge, diameter 110 mm, connection with elastic seal.	8,190	20,87	170,93

ISD008	Item	Unit	Soundproofed PVC siphon canister, 110 mm diameter, with stainless steel blind lid, recessed.	2,000	29,21	58,42
ISS010	Item	m	Soundproofed suspended collector made of polypropylene with mineral charge of 110 mm diameter, connection with elastic seal.	13,710	29,09	398,82
IV	**Chapter**		**Ventilation**		**3.065,06**	**3.065,06**
IVA010	Item	Unit	Supply and installation of adjustable intake aerator, in aluminium lacquered in colour to be chosen from the RAL chart, maximum flow rate 10 l/s, 1200x80x12 mm, with an opening of 800x12 mm, acoustic insulation of 39 dBA and anti-pollution filter.	7,000	53,21	372,47
IVA010b	Item	Unit	Supply and installation of self-adjusting extraction nozzle, maximum flow rate 21 l/s, acoustic insulation of 39.8 dBA made up of white grille, white plastic body 150x33x150 mm with a 125 mm diameter connection neck, rubber gasket and plastic regulator with silicone membrane and recovery spring.	2,000	24,94	49,88
IVA010c	Item	Unit	Supply and installation of self-adjusting extraction nozzle, maximum flow rate 25 l/s, 56 dBA soundproofing consisting of a grille, white plastic body with 170 mm outer diameter and 125 mm diameter connection neck and plastic regulator.	1,000	18,56	18,56
IVM036	Item	Unit	Supply and installation at the outer end of the exhaust duct (exhaust port) of a helicoidal roof fan, with fibreglass-reinforced plastic propeller, aluminium body and cap, galvanised steel base and motor for single-phase power supply at 230 V and 50 Hz, with thermal protection, insulation class F, protection IP 65, 835 rpm, power consumption 0.22 kW, maximum flow rate 3900 m³/h, sound pressure level 52 dBA, with mesh to protect against ingress of leaves and birds, for extraction duct 450 mm in diameter. Including accessories and fasteners.	1,000	1.111,83	1.111,83
IVM036b	Item	Unit	Supply and installation at the outer end of the exhaust duct (exhaust port) of a helicoidal roof fan, with fibreglass-reinforced plastic propeller, aluminium body and cap, galvanised steel base and motor for single-phase power supply at 230 V and 50 Hz, with thermal protection, insulation class F, protection IP 65, 835 rpm, power consumption 0.22 kW, maximum flow rate 3900 m³/h, sound pressure level 52 dBA, with mesh to protect against ingress of leaves and birds, for extraction duct 450 mm in diameter. Including accessories and fasteners.	1,000	1.111,83	1.111,83
IVK010	Item	Unit	Supply and installation of extra-flat extractor hood with 2 suction motors, with flexible aluminium tube connection section to extraction duct for smoke extraction.	1,000	122,26	122,26
IVK030	Item	Unit	Supply and installation at the outer end of the exhaust duct (exhaust port) of a rotating aluminium extractor with dynamic cap (Hardness H-24), for 350 mm external diameter exhaust duct, for kitchen ventilation.	1,000	252,19	252,19
IVV020	Item	m	Supply and installation of a circular ventilation duct made of galvanised steel sheet tube with a single helical wall, 100 mm in diameter and 0.5	1,080	10,08	10,89

			mm thick, placed in a vertical position. Including auxiliary material for assembly and fastening on site, accessories and special parts.			
IVV020b	Item	m	Supply and installation of a circular ventilation duct made of galvanised steel sheet tube with a single helical wall, 135 mm in diameter and 0.5 mm thick, placed in a vertical position. Including auxiliary material for assembly and fastening on site, accessories and special parts.	0,540	13,66	7,38
IVV020c	Item	m	Supply and installation of a circular ventilation duct made of galvanised steel sheet tube with a single helical wall, 100 mm in diameter and 0.5 mm thick, placed horizontally. Including auxiliary material for assembly and fastening on site, accessories and special parts.	0,930	8,36	7,77
N	**Chapter**		**Insulation and waterproofing**		**16.481,07**	**16.481,07**
NA	**Chapter**		**Thermal insulation**		**16.481,07**	**16.481,07**
NAA010	Item	m	Thermal insulation of pipes in A.C.S. interior installation, recessed in the wall, for the distribution of hot fluids (from +40°C to +60°C), made up of elastomeric foam shells, with a high resistance factor to the diffusion of water vapour, with an internal diameter of 16.0 mm and a thickness of 9.5 mm.	15,690	5,24	82,22
NAA010b	Item	m	Thermal insulation of pipes in A.C.S. interior installation, recessed in the wall, for the distribution of hot fluids (from +40°C to +60°C), made up of elastomeric foam shells, with a high resistance factor to the diffusion of water vapour, 23.0 mm internal diameter and 10.0 mm thickness.	2,900	6,15	17,84
NAA010c	Item	m	Thermal insulation of pipes in A.C.S. interior installation, placed on the surface, for the distribution of hot fluids (from +60°C to +100°C), made up of an elastomeric foam shell, 19 mm inside diameter and 25 mm thick.	5,820	22,42	130,48
NAA010d	Item	m	Thermal insulation of pipes in A.C.S. interior installation, placed on the surface, for the distribution of hot fluids (from +60°C to +100°C), made up of elastomeric foam shells, 23 mm inside diameter and 25 mm thick.	21,770	24,35	530,10
NAS030	**Chapter**	m²	Thermal insulation on the outside of facades with the OpenSystem "BAUMIT", with DITE - 09/0256, consisting of: rigid expanded polystyrene panel, OpenReflect "BAUMIT", 80 mm thick, with white reflective coating, fixed to the substrate with adhesive mortar KlebeSpachtel W (OpenContact) "BAUMIT" and mechanical fastenings with expansion plug and polypropylene nail Universal dowel STR U 2G "BAUMIT"; KlebeSpachtel W (OpenContact) "BAUMIT" adhesive mortar regularising layer, reinforced with anti-alkaline glass fibre mesh, Star Tex "BAUMIT", 4x4 mm mesh size, 145 g/m² surface mass and 0,5 mm thickness; water-repellent, NanoporTop "BAUMIT", white finish, Kratz 1,5 finish, on primer, UniPrimer "BAUMIT", colourless, rainproof and water vapour permeable.	184,080	85,40	15.720,43
Q	**Chapter**		**Roof**		**13.088,06**	**13.088,06**

QA	**Chapter**		**Flat**		**13.088,06**	**13.088,06**
QAE010	Item	m²	Flat roof non-transitable, ventilated, self-protected, conventional type, slope from 1% to 15%, made up of: slope formation: hollow ceramic tile tongue and groove panel 80x25x3.5 cm supported on lightened partitions of hollow ceramic brick 24x11x8 cm, arranged every 80 cm and with an average height of 30 cm; thermal insulation: mineral wool insulating felt, according to UNE-EN 13162, coated on one side with a complex of kraft paper with polyethylene acting as a vapour barrier, 80 mm thick; double-layer waterproofing adhered: SBS elastomer modified bitumen sheet, LBM(SBS)-30-FV, after priming with anionic asphalt emulsion with EB type fillers, and SBS elastomer modified bitumen sheet, LBM(SBS)-40/G-FP bonded to the previous one with a torch, without matching the joints.	166,050	78,82	13.088,06
R	**Chapter**		**Coatings and linings**		**18.047,12**	**18.047,12**
RI	**Chapter**		**Paints on interior walls**		**2.773,37**	**2.773,37**
RIP030	Item	m²	Manual application of two coats of white plastic paint, matt finish, smooth texture, the first coat diluted with 20% water and the next without dilution, (yield: 0.1 l/m² each coat); after application of a primer coat based on acrylic copolymers in aqueous suspension, on interior plaster or plaster, vertical, up to 3 m high.	324,820	5,91	1.919,69
RIT010	Item	m²	Manual application of two coats of tempera paint, white colour, matt finish, textured texture with a fine drop, the first coat diluted with a maximum of 40% water and the next without diluting, (yield: 0.55 kg/m² each coat); on an interior wall of cement mortar, horizontal, up to 3 m high.	145,680	5,86	853,68
RP	**Chapter**		**Traditional conglomerates**		**3.830,32**	**3.830,32**
RPE005	Item	m²	Cement rendering, visible, applied on an interior vertical wall, up to 3 m high, rough surface finish, with cement mortar, type GP CSII W0.	150,580	15,54	2.340,01
RPG010	Item	m²	Garnished with B1 construction plaster with a good view, on a horizontal wall, up to 3 m high, after installing anti-alkalis mesh when changing material, without lifeguards.	145,680	10,23	1.490,31
RS	**Chapter**		**Flooring**		**6.008,56**	**6.008,56**
RSB005	Item	m²	Base for crushing sand pavement with a diameter of 0 to 5 mm, stabilised with 100 kg of Portland CEM II/A-P 32.5 R cement per m³ of dry sand, in a 4 cm thick layer.	145,680	12,32	1.794,78
RSA020	Item	m²	Thin layer of floor levelling paste CT - C20 - F6 according to UNE-EN 13813, 2 mm thick, applied manually, for the regularisation and levelling of the surface of the internal concrete or mortar substrate, after application of a modified synthetic resin primer, which acts as a bonding bridge (not including the preparation of the substrate), prepared to receive ceramic, cork, wood, laminate, flexible or textile flooring (not included in this price).	104,040	9,48	986,30

RSG010	Item	m²	Glazed stoneware ceramic tile flooring, 25x25 cm, 8 €/m², water absorption capacity E<3%, group BIb, slip resistance Rd<=15, class 0, received with cementitious adhesive for interior use only, Ci without any additional characteristics, grey colour and grouted with white cement grout, L, BL-V 22.5, for minimum joint (between 1.5 and 3 mm), coloured with the same shade as the pieces.	41,640	23,99	998,94
RSL010	Item	m²	Laminate flooring, 1200x190 mm slats, Class 22: Domestic general, AC2 abrasion resistance, consisting of HDF base board decorative laminate in pine, assembled with adhesive, placed on complex made of high quality polyethylene, closed cells, for impact sound insulation, coated on one side with a polyethylene film acting as a vapour barrier of 2.5 mm thick, with a proportional part of placement of polyethylene strip 5 mm thick.	104,040	21,42	2.228,54
RR	**Chapter**		**Linings**		**5.434,87**	**5.434,87**
RRY012	Item	m²	Direct laying, W631.es "KNAUF" system, made of laminated plasterboard - 9.5+30 Polyplac + Aluminium (XPE-BV)|, received with bonding paste on the vertical wall; 55 mm total thickness.	86,570	30,33	2.625,67
RRY012b	Item	m²	Direct laying, W631.es "KNAUF" system, made of laminated plasterboard - 9.5+30 Polyplac + Aluminium (XPE-BV)|, received with bonding paste on the vertical wall; 65 mm total thickness.	86,570	32,45	2.809,20

APPENDIX F: Phase B Budget

CODE	TYPE	UNIT	SUMARRY	AMOUNT	Maintenance cost (€)	10-year maintenance valuation (€)
A	**Chapter**		**Land Conditioning**			**65,94**
AS	**Chapter**		**Horizontal drainage network**			**65,94**
ASA010	Item	Unit	Registrable manhole casket, with internal dimensions 60x60x50 cm, with prefabricated reinforced concrete lid, on a mass concrete floor screed.	2,000	9,36	18,72
ASB010	Item	m	General sewerage connection to the municipality general network, made of smooth PVC, SN-4 series, nominal annular stiffness 4 kN/m², 160 mm in diameter, bonded with adhesive.	6,270	5,71	35,80
ASB020	Item	Unit	Connection of the building connection to the general sewerage network of the municipality.	1,000	10,03	10,03
ASC010	Item	m	Underground sewerage collector, without manholes, by means of an adjustable integral system, in smooth PVC, series SN-2, nominal annular stiffness 2 kN/m², diameter 160 mm, with elastic seal.	0,830	1,68	1,39
E	**Chapter**		**Structure**			**1.804,97**
EH	**Chapter**		**Reinforced concrete**			**1.804,97**
EHU005	Item	m²	Reinforced concrete floor slab, edge 30 = 25+5 cm, made of HRA-25/B/20/IIa concrete made in a central location and poured with cupola, volume 0.102 m³/m², and UNE-EN 10080 B 500 S steel, weight 11 kg/m²; pre-stressed, mechanised vault beam made of expanded polystyrene, 62.5x125x25 cm and electrowelded mesh ME 20x20 Ø 5-5 B 500 T 6x2.20 UNE-EN 10080, in compression layer, on a support wall 80 cm high and 24 cm thick perforated ceramic brick (coarse), for covering, 24x11x5 cm.	166,050	3.94	654.24
EHU020	Item	m²	Reinforced concrete structure, made of HRA-25/B/20/IIa concrete, manufactured in a plant and poured with cupola, total volume of concrete 0.191 m³/m², and steel UNE-EN 10080 B 500 S with a total amount of 16 kg/m², on a continuous formwork system, consisting of: unidirectional, horizontal, edge 35 = 30+5 cm; prestressed beam, double; machined expanded polystyrene vault, 62.5x125x30 cm; electro welded mesh ME 20x20 Ø 5-5 B 500 T 6x2.20 UNE-EN 10080, in compression layer; flat beams; columns with free height up to 3 m.	166,050	6.93	1.150,73
F	**Chapter**		**Façade and partitions**			**235,85**
FF	**Chapter**		**Non-structural masonry**			**235,85**
FFZ010	Item	m²	Exterior façade cladding sheet, 11 cm thick, made of perforated acoustic ceramic brick, for cladding, 24x11x10 cm, received with	160,330	1,22	195,60

			industrial cement mortar, grey colour, M-5, supplied in bulk; lintel formation by means of prefabricated joists, clad with ceramic pieces, placed with high adherence mortar.			
FFQ010	Item	m²	11 cm thick, factory-built, perforated acoustic ceramic brick interior partition sheet for cladding, 24x11x10 cm, received with industrial cement mortar, grey colour, M-5, supplied in bulk.	93,600	0,43	40,25
L	**Chapter**		**Carpentry, locksmithery, glass and solar protection**			**1.370,82**
LC	**Chapter**		**Carpentry**			**475,06**
LCP060	Item	Unit	PVC window, two opening leaves with opening towards the inside, dimensions 2100x1200 mm, with security lock, standard finish on both sides, white, without pre-frame.	2,000	32,52	65,04
LCP060b	Item	Unit	PVC window, one tilt-and-turn door leaf with opening towards the inside, dimensions 1000x1000 mm, standard finish on both sides, white, without pre-frame.	6,000	17,53	105,18
LCP060c	Item	Unit	PVC window, one tilting leaf with opening towards the inside, dimensions 1100x1200 mm, leaf finish on both sides, colour to be chosen, without pre-frame. Built-in thermal shutter box (monoblock), PVC slat roller shutter with double hitch, with automatic drive by electric motor.	1,000	43,20	43,20
LCP060d	Item	Unit	PVC window, one tilting and one opening leaf with opening towards the inside, dimensions 1700x1200 mm, leaf finish on both sides, colour to be chosen, without pre-frame. Built-in thermal shutter box (monoblock), rolling shutter with injected aluminium slats, with automatic drive by electric motor.	4,000	65,41	261,64
LE	**Chapter**		**Entrance door**			**52,19**
LEM010	Item	Unit	Reinforced interior entrance door 203x92.5x4.5 cm, chipboard sheet, sapele veneered, workshop varnished; country pine frame 130x40 mm; MDF rebate, sapele veneer 130x20 mm; MDF flashing, sapele veneer 70x10 mm.	1,000	52,19	52,19
LP	**Chapter**		**Interior doors**			**148,14**
LPM010	Item	Unit	Internal folding door, blind, single-leaf, 203x82.5x3.5 cm, agglomerated board, veneered with country pine, varnished in the workshop, with straight-shaped ceiling panels; 90x35 mm country pine frame; MDF rebate, with wood veneer, 90x20 mm country pine; MDF flashing, with wood veneer, 70x10 mm country pine; with hanging and closing hardware.	6,000	24,69	148,14
LV	**Chapter**		**Glass**			**695,43**
LVC020	Item	m²	Double glazing LOW.S low thermal emissivity + acoustic insulation "CONTROL GLASS ACOUSTIC AND SOLAR", Sonor 10+10/14/8 LOW.S, fixed on woodwork with	16,020	43,41	695,43

			shims and continuous sealing on the outside and continuous profile on the inside, for glass sheets with a surface area between 6 and 7 m².			
I	**Chapter**		**Installations**			**A: 8.828,20** **B: 9221,26**
IL	**Chapter**		**Telecommunications infrastructure**			**41,21**
ILA010	Item	Unit	Supply and installation of a prefabricated input box for ICT of 400x400x600 mm of interior dimensions, with hooks for traction, frame and cover, up to 20 user access points, for connection between the telecommunication power supply networks of the different operators and the common telecommunication infrastructure of the building, placed on a 10 cm thick HM-20/B/20/I mass concrete floor.	1,000	15,81	15,81
ILA020	Item	m	Underground supply and installation of external ductwork between the entrance pit and the lower junction box inside the dwelling, made up of 1 polyethylene tube (TBA+STDP) of 63 mm diameter, supplied in rolls, 450 N compression resistance, 20 Joules impact resistance, executed in a 45x75 cm trench, with the tube embedded in a HM-20/B/20/I mass concrete prism with 6 cm of upper and lower cover and 5.5 cm of lateral covering.	2,120	0,53	1,12
ILE030	Item	m	Supply and installation on the surface of the upper connection pipe between the upper general entrance point of the building and the RITS, RITU or RITM, for multi-family buildings, made up of 2 rigid PVC pipes of 40 mm in diameter, compressive strength greater than 1250 N, impact strength 2 joules, with IP 547. Including accessories, clamping elements and guide wire.	1,000	0,56	2,81
ILE040	Item	Unit	Supply and installation of a built-in network termination register, consisting of a plastic box for the arrangement of the equipment, mainly vertical, of 500x600x80 mm. Including cover, accessories, special parts and fixings.	1,000	2,61	2,61
ILI010	Item	m	Supply and installation of internal user conduit inside the house that connects the network termination register with the different tapping registers, made up of 1 flexible PVC tube, reinforced with a diameter of 20 mm, 320 N compression resistance, 2 joules impact resistance, for cable laying. Including accessories, clamping elements and guide wire.	198,660	0,07	13,91
ILI020	Item	Unit	Supply and installation of a built-in socket register, made up of a universal box, with connection on both sides and a BAT or user socket, medium range, with a white blind cover and a frame with jaws, for the provision of new services. Including accessories, special parts and fasteners.	15,000	0,33	4.95
IA	**Chapter**		**Audiovisuals**			**412,62**

IAA031	Item	Unit	Supply and installation of a mast for fixing 1 antenna, made of steel tube with anti-corrosion treatment, 3 m high, 40 mm in diameter and 2 mm thick. Even anchorages and as many accessories as necessary for its correct installation.	1,000	34,82	34,82
IAA034	Item	Unit	Supply and installation of a circular FM external antenna for the reception of analogue sound broadcasting signals from terrestrial broadcasts, with a gain of 0 dB and a length of 500 mm. Even anchorages and as many accessories as necessary for its correct installation.	1,000	16,85	16,85
IAA034b	Item	Unit	Supply and installation of an external DAB antenna for capturing digital sound broadcasting signals from terrestrial emissions, 1 element, 0 dB gain, 15 dB D/A ratio and 555 mm length. Even anchorages and as many accessories as necessary for its correct installation.	1,000	16,20	16,20
IAA034c	Item	Unit	Supply and installation of an external UHF antenna for the reception of analogue television, digital terrestrial television (DTT) and high definition television (HDTV) signals from terrestrial broadcasts, channels 21 to 60, with 13 elements, 13 dB gain, 25 dB D/A ratio. Even anchorages and as many accessories as necessary for its correct installation.	1,000	20,57	20,57
IAA040	Item	Unit	Supply and installation of headend equipment, consisting of: 1 single-channel UHF amplifier, 50 dB gain; 1 FM amplifier; 1 DAB amplifier, all with self-separating at the input and automix at the output (housed in the RITS or RITU). Including power supply, support, interconnection bridges, resistive loads, distributor, mixers and all the necessary accessories for its correct installation.	1,000	91,46	91,46
IAA100	Item	m	Supply and installation of RG-6 coaxial cable of 75 Ohm with medium characteristic impedance, reaction to fire class Eca, with central copper conductor of 1.15 mm diameter, cellular polyethylene dielectric, aluminium/polypropylene/aluminium tape screen, copper braided wire mesh and PVC outer sheath of 6.9 mm diameter in white colour. Including accessories and fasteners.	132,860	0,07	9,30
IAA115	Item	Unit	Supply and installation of a 5-1000 MHz distributor with 8 outputs and 12 dB insertion loss.	1,000	3,85	3,85
IAA115b	Item	Unit	Supply and installation of a 5-2400 MHz distributor with 8 outputs, 14 dB insertion loss at 850 MHz and 17 dB insertion loss at 2150 MHz.	1,000	2,41	2,41
IAA120	Item	Unit	Supply and installation of double socket, TV-R, 5-1000 MHz, with cover.	5,000	*1,66*	*8,30*
IAA120b	Item	Unit	Supply and installation of a 5-2400 MHz TV/R-SAT double separator socket with cover.	5,000	*1,80*	*9,00*
IAF070	Item	Unit	Supply and installation of a rigid U/UTP non flame propagating cable with 4 twisted	65,820	*0,17*	*11,19*

			copper pairs, category 6, reaction to fire class Dca-s2,d2,a2 according to UNE-EN 50575, with copper unifilar conductor, polyethylene insulation and outer sheath made of halogen-free thermoplastic polyolefin LSFH, with low smoke and corrosive gas emission, 6.2 mm in diameter. Including accessories and fasteners.			
IAF075	Item	Unit	Supply and installation of a mains termination rosette consisting of an 8-pin RJ-45 female connector, category 6, with a 47x64.5x25.2 mm surface box, white colour.	1,000	*3,72*	*3,72*
IAF085	Item	Unit	Suministro e instalación de multiplexor pasivo de 1 entrada y 6 salidas, con conectores hembra tipo RJ-45 de 8 contactos, categoría 6, color blanco y latiguillo de conexión de 0,5 m de longitud formado por cable rígido U/UTP no propagador de la llama de 4 pares de cobre, categoría 6, con conductor unifilar de cobre, aislamiento de polietileno y vaina exterior de PVC LSFH libre de halógenos, con baja emisión de humos y gases corrosivos y conector macho tipo RJ-45 de 8 contactos, categoría 6, en ambos extremos.	1,000	*7,30*	*7,30*
IAF090	Item	Unit	Supply and installation of passive multiplexer with 1 input and 6 outputs, with 8-pin RJ-45 female connectors, category 6, white colour and 0.5 m long connection hose made up of rigid U/UTP cable with 4 copper pairs, category 6, with single-wire copper conductor, polyethylene insulation and outer sheath made of halogen-free LSFH PVC, with low smoke and corrosive gas emission and 8-pin RJ-45 male connector, category 6, on both ends.	5,000	*4,48*	*22,40*
IAO035	Item	Unit	Supply and installation of fibre optic rosette consisting of double SC type connector and surface box.	1,000	*2,49*	*2,49*
IAV020	Item	Unit	Installation of vandal-proof electronic door entry system kit for single-family homes, consisting of: exterior vandal-proof street panel with call button, power supply and telephone. Including electric locks, visor, wiring and boxes.	1,000	*152,76*	*152,76*
IC	**Chapter**		**Heating, cooling and DHW- Typology A**			**4602,04**
ICI011	Item	Unit	Wall-mounted mixed electric boiler for heating and DHW, power 21.0 kW, with temperature regulation of the circuit by means of a control unit with an external probe acting on the three-way motorised valve and electronic room thermostat with digital display, with multiple programming possibilities.	1,000	1593,29	1593,29
ICS005	Item	Unit	Filling point made up of 2 m of cross-linked polyethylene pipe , with oxygen barrier , 16 mm outside diameter and 2 mm thick, PN=6 atm, for air-conditioning, placed on the surface, insulated with flexible elastomeric foam shell.	1,000	22,15	22,15
ICS010	Item	m	Primary circuit of solar thermal systems made up of rigid copper pipe, 13/15 mm in	37,890	1,89	71,61

			diameter, placed on the surface outside the building, with insulation by means of a glass wool shell protected with an asphalt emulsion coated with protective paint for white insulation.			
ICS010b	Item	m	Hot and cold water distribution pipe made of cross-linked polyethylene pipe, with oxygen barrier, 25 mm outside diameter and 2.3 mm thick, PN=6 atm, recessed in the wall, insulated with flexible elastomeric foam shell.	15,330	1,35	20,70
ICS010c	Item	m	Hot and cold water distribution pipe made of cross-linked polyethylene pipe, with oxygen barrier, 32 mm external diameter and 2.9 mm thick, PN=6 atm, recessed in the wall, insulated with flexible elastomeric foam shell.	5,380	1,92	10,33
ICS010d	Item	m	DHW Distribution pipework made of random copolymer polypropylene pipe (PP-R), 32 mm outer diameter, PN=10 atm, placed on the surface inside the building, with elastomeric foam insulation.	2,790	1,70	4,74
ICS015	Item	Unit	Emptying point made up of 2 m of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier (EVOH), 25 mm outside diameter and 2.3 mm thick, PN=6 atm, for air conditioning, placed on the surface.	1,000	2,06	2,06
ICS020	Item	Unit	Three-stage centrifugal electric pump, cast iron, with a power of 0.071 kW.	1,000	176,33	176,33
ICS075	Item	Unit	Solar kit for connection of gas water heater to solar DHW. interaccumulator.	1,000	56,64	56,64
ICS075b	Item	Unit	1/2" 3-way valve, mixer, with 230 V actuator.	1,000	52,80	52.80
ICE100	Item	Unit	Modular manifold made of reinforced polyamide, model Vario M "UPONOR IBERIA", for 5 circuits, female 16 mm x 3/4" Eurocone fittings, model Vario, ball valves for closing the manifold circuit, model Vario, plastic pipe bender, model Fix, mounted in 80x700x770 mm cabinet, model Vario CI with door, model Vario CI.	2,000	41,18	82,36
ICE110	Item	m²	UPONOR IBERIA" underfloor heating and cooling system, consisting of polyethylene film, polyethylene foam (PE) band, 150x10 mm, Multi Autofixing model, expanded polystyrene insulating panel (EPS), with Velcro strips for fixing the pipes, 30 kg/m³ density, 10000x1000 mm and 25 mm thickness, model Klett Neorol G, cross-linked polyethylene tube (PE-Xa) with oxygen barrier (EVOH), 16 mm outside diameter and 2 mm thick, with external velcro spiral strips for fixing to insulating panels, model Klett Autofijación Confort Pipe PLUS, and self-levelling mortar, CA - C20 - F4 according to UNE-EN 13813, 50 mm thick.	16,570	4,18	69,26
ICE110b	Item	m²	UPONOR IBERIA" underfloor heating and cooling system, consisting of polyethylene film, polyethylene foam (PE) band, 150x10 mm, Multi Autofixing model, expanded polystyrene insulating panel (EPS), with Velcro strips for fixing the pipes, 30 kg/m³	63,340	3,77	238,79

			density, 10000x1000 mm and 25 mm thickness, model Klett Neorol G, cross-linked polyethylene tube (PE-Xa) with oxygen barrier (EVOH), 16 mm outside diameter and 2 mm thick, with external velcro spiral strips for fixing to insulating panels, model Klett Autofijación Confort Pipe PLUS, and self-levelling mortar, CA - C20 - F4 according to UNE-EN 13813, 50 mm thick.			
ICE150	Item	Unit	UPONOR IBERIA" temperature regulation system, consisting of a control unit, for a maximum of 8 control thermostats at 230 V and 16 electrothermal heads, model Base 8X UK 230V, with programmable digital thermostat, model Base T-26 230V, and electrothermal heads, model Smart S, at 230 V.	2,000	*33,51*	*67,02*
ICE161	Item	Unit	Drive unit for controlling the circulation pump in heating systems, with control unit, horizontal installation in collector, suitable for underfloor heating systems up to 30 kW.	1,000	*105,59*	*105,59*
ICB005	Item	Unit	Complete solar thermal collector, split, for individual installation, for installation on flat roof, consisting of: a panel of 1160x1930x90 mm, total useful area 2.02 m², optical efficiency 0.819 and primary loss ratio 4.227 W/m²K, according to UNE-EN 12975-2, 200 l tank, individual pumping group, programmable solar thermal unit.	1,000	*2.028,37*	*2.028,37*
IC	**Chapter**		**Heating, cooling and DHW- TYPOLOGY B**			**4.995,10**
ICA010	Item	Unit	Electric water heater for A.C.S. service, vertical wall, armoured resistance, capacity 100 l, power 2.2 kW, height 913 mm and diameter 450 mm.	1,000	*221,38*	*221,38*
ICQ015	Item	Unit	Pellet boiler, model Vap 30 "ECOFOREST", rated thermal output 30 kW, efficiency 93%, class 5, grey colour.	1,000	*3.136,84*	*3.136,84*
ICQ030	Item	Unit	Pellet feeding system for biomass boiler consisting of a basic flexible pellet extractor kit, consisting of 1 m long extractor tube and 0.55 kW drive motor, for single-phase 230 V supply, 3 m flexible pellet extractor extension tube, 1 m flexible pellet extractor connection tube.	1,000	*661,03*	*661,03*
ICQ060	Item	Unit	Surface tank for pellet storage, made of synthetic fabric, with steel structure and hopper, 1.70x1.70 m and adjustable height from 1.80 to 2.50 m, maximum capacity 3.2 t, with automatic fuel extraction system.	1,000	*213,41*	*213,41*
ICS005	Item	Unit	Filling point made up of 2 m of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier (EVOH), 16 mm outside diameter and 2 mm thick, PN=6 atm, for air-conditioning, placed on the surface, insulated with flexible elastomeric foam shell.	1,000	*22,15*	*22,15*
ICS010	Item	m	General hot and cold water distribution pipe for conditioning made of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier (EVOH), 16 mm outside diameter and 2 mm thick, PN=6 atm, recessed in the	123,680	*1,08*	*133,57*

			wall, insulated with flexible elastomeric foam shell.			
ICS010b	Item	m	General hot and cold water distribution pipe for conditioning made of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier (EVOH), 20 mm outside diameter and 2 mm thick, PN=6 atm, recessed in the wall, insulated with flexible elastomeric foam shell.	13,110	*1,18*	*15,47*
ICS010c	Item	m	General hot and cold water distribution pipe for conditioning made of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier (EVOH), 25 mm outside diameter and 2.3 mm thick, PN=6 atm, recessed in the wall, insulated with flexible elastomeric foam shell.	10,460	*1,35*	*14,12*
ICS015	Item	Unit	Emptying point made up of 2 m of cross-linked polyethylene pipe (PE-Xa), with oxygen barrier (EVOH), 25 mm outside diameter and 2.3 mm thick, PN=6 atm, for air conditioning, placed on the surface.	1,000	*2,06*	*2,06*
ICS020	Item	Unit	Three speed centrifugal electric pump, made of cast iron, with a power of 0,071 kW.	1,000	*176,33*	*176,33*
ICE040	Item	Unit	Die-cast aluminium radiator, with 556.5 kcal/h heat output, 7-element, 421 mm high, with front panel with openings, for installation with twin tube system, with thermostatic shut-off valve.	2,000	*21,06*	*42,12*
ICE040b	Item	Unit	Die-cast aluminium radiator, with 636 kcal/h heat output, 8-element, 421 mm high, with front panel with openings, for installation with twin tube system, with thermostatic shut-off valve.	2,000	*23,13*	*46,26*
ICE040c	Item	Unit	Die-cast aluminium radiator, with 715,5 kcal/h heat output, 9-element, 421 mm high, with front panel with openings, for installation with twin tube system, with thermostatic shut-off valve.	2,000	*25,21*	*50,42*
ICE040d	Item	Unit	Die-cast aluminium radiator, with 795 kcal/h heat output, 10-element, 421 mm high, with front panel with openings, for installation with twin tube system, with thermostatic shut-off valve.	2,000	*27,28*	*54,56*
ICE040e	Item	Unit	Die-cast aluminium radiator, with 874,5 kcal/h heat output, 11-element, 421 mm high, with front panel with openings, for installation with twin tube system, with thermostatic shut-off valve.	7,000	*29,34*	*205,38*
IE	**Chapter**		**Electric Installations**			**243,74**
IEP010	Item	Unit	Grounding net for building concrete structure with 90 m bare copper conductor of 35 mm² and 20 spades.	1,000	*40,06*	*40,06*
IEP030	Item	Unit	Equipotential bonding network in wet rooms.	2,000	*0,88*	*1,76*
IEO010b	Item	m	Built-in ducting in PVC corrugated pipe construction element, black, 20 mm nominal diameter, with IP 545 degree of protection.	208,790	*0,05*	*10,44*

IEO010c	Item	m	Built-in ducting in PVC corrugated pipe construction element, black, 25 mm nominal diameter, with IP 545 degree of protection.	35,250	*0,06*	*2,12*
IEO010d	Item	m	Built-in ducting in PVC corrugated pipe construction element, black, 32 mm nominal diameter, with IP 545 degree of protection.	3,160	*0,07*	*0,22*
IEO010e	Item	m	Built-in ducting in PVC corrugated pipe construction element, black, 50 mm nominal diameter, with IP 545 degree of protection.	2,270	*0,10*	*0,23*
IEH010	Item	m	Single-pole cable ES07Z1-K (AS), reaction to fire class Cca-s1b,d1,a1, with multi-core copper conductor class 5 (-K), 10 mm² cross-section, insulated with halogen-free polyolefin-based thermoplastic compound with low smoke and corrosive gas emissions (Z1).	11,350	*0,16*	*1,82*
IEH010b	Item	m	Single-pole cable H07V-K, with a rated voltage of 450/750 V, reaction to fire class Eca, with multi-core copper conductor class 5 (-K) of 1.5 mm² section, PVC (V) insulation.	848,670	*0,03*	*25,46*
IEH010c	Item	m	Single-pole cable H07V-K, with a rated voltage of 450/750 V, reaction to fire class Eca, with multi-core copper conductor class 5 (-K) of 2.5 mm² section, PVC (V) insulation.	574,590	*0,04*	*22,98*
IEH010d	Item	m	Single-pole cable H07V-K, with a rated voltage of 450/750 V, reaction to fire class Eca, with multi-core copper conductor class 5 (-K) of 4 mm² section, PVC (V) insulation.	51,780	*0,05*	*2,59*
IEH010e	Item	m	Single-pole cable H07V-K, with a rated voltage of 450/750 V, reaction to fire class Eca, with multi-core copper conductor class 5 (-K) of 6 mm² section, PVC (V) insulation.	105,750	*0,08*	*8,46*
IEH010f	Item	m	Single-pole cable H07V-K, with a rated voltage of 450/750 V, reaction to fire class Eca, with multi-core copper conductor class 5 (-K) of 10 mm² section, PVC (V) insulation.	15,800	*0,11*	*1,74*
IEC010	Item	Unit	Protection and measuring box CPM2-S4, up to 63 A current, for 1 three-phase meter, installed inside a wall niches, in a single family or local house.	1,000	*13,18*	*13,18*
IEI070	Item	Unit	Housing panel made up of an insulated box and the control and protection devices.	1,000	*64,14*	*64,14*
IEI090	Item	Unit	Components for the electrical distribution network inside the home: basic range mechanisms (key or cover and frame: white; cover: white); flush mounting boxes with fixing screws, junction boxes with covers and connection strips.	1,000	*38,11*	*38,11*
IF	**Chapter**		**Plumbing**			**73,37**
IFA010	Item	Unit	Underground connection for drinking water supply, 1.02 m long, made up of PE 100 polyethylene pipe, 32 mm external diameter, PN=10 atm and 2 mm thick, and cutting key housed in a prefabricated polypropylene box.	1,000	*8,34*	*8,34*

IFB010	Item	Unit	Drinking water supply, 4.56 m long, buried, made of seamlessly drawn galvanised steel tube, 3/4" DN 20 mm in diameter.	1,000	*5,08*	*5,08*
IFC010	Item	Unit	Pre-installation of a 1 1/4" DN 32 mm general water meter, placed in a niche, with a general shut-off valve for a gate.	1,000	*5,77*	*5,77*
IFI008	Item	Unit	Brass seat valve, 3/4" diameter, with stainless steel handle and cover.	6,000	*3,05*	*18,30*
IFI100	Item	Unit	Piping for internal installation, consisting of cross-linked polyethylene pipe (PE-Xa), series 5, 16 mm outer diameter, PN=6 atm, 46,234 m long, cross-linked polyethylene pipe (PE-Xa), series 5, 20 mm outer diameter, PN=6 atm, 42,7526 m long and 16 tees, 38 elbows 90°, 4 elbows with fixing base and female threaded outlet, 14 elbows with female threaded outlet.	1,000	*32,84*	*32,84*
IFW010	Item	Unit	Brass seat valve, 3/4" diameter, with stainless steel handle and cover.	1,000	*3,04*	*3,04*
IS	**Chapter**		**Water evacuation**			**75,33**
ISB040	Item	m	Piping for primary ventilation of the water drainage network, made up of 75 mm diameter polypropylene pipe with mineral charge, joined with elastic joint.	9,370	*0,84*	*7,87*
ISB044	Item	Unit	Ventilation cap made of PVC, 75 mm diameter, bonded with adhesive.	2,000	*0,92*	*1,84*
ISD005	Item	m	Small evacuation net, soundproofed, recessed, polypropylene with mineral charge, diameter 40 mm, connection with elastic seal.	11,770	*0,39*	*4,59*
ISD005b	Item	m	Small evacuation net, soundproofed, recessed, polypropylene with mineral charge, diameter 75 mm, connection with elastic seal.	1,280	*0,62*	*0,79*
ISD005c	Item	m	Small evacuation net, soundproofed, recessed, polypropylene with mineral charge, diameter 90 mm, connection with elastic seal.	1,810	*0,77*	*1,39*
ISD005d	Item	m	Small evacuation net, soundproofed, recessed, polypropylene with mineral charge, diameter 110 mm, connection with elastic seal.	8,190	*1,01*	*8,27*
ISD008	Item	Unit	Soundproofed PVC siphon canister, 110 mm diameter, with stainless steel blind lid, recessed.	2,000	*3,97*	*7,94*
ISS010	Item	m	Soundproofed suspended collector made of polypropylene with mineral charge of 110 mm diameter, connection with elastic seal.	13,710	*3,11*	*42,64*
IV	**Chapter**		**Ventilation**			**3.379,89**
IVA010	Item	Unit	Supply and installation of adjustable intake aerator, in aluminium lacquered in colour to be chosen from the RAL chart, maximum flow rate 10 l/s, 1200x80x12 mm, with an opening of 800x12 mm, acoustic insulation of 39 dBA and anti-pollution filter.	7,000	*2,58*	*18,06*

IVA010b	Item	Unit	Supply and installation of self-adjusting extraction nozzle, maximum flow rate 21 l/s, acoustic insulation of 39.8 dBA made up of white grille, white plastic body 150x33x150 mm with a 125 mm diameter connection neck, rubber gasket and plastic regulator with silicone membrane and recovery spring.	2,000	*1,21*	*2,42*
IVA010c	Item	Unit	Supply and installation of self-adjusting extraction nozzle, maximum flow rate 25 l/s, 56 dBA soundproofing consisting of a grille, white plastic body with 170 mm outer diameter and 125 mm diameter connection neck and plastic regulator.	1,000	*0,90*	*0,90*
IVM036	Item	Unit	Supply and installation at the outer end of the exhaust duct (exhaust port) of a helicoidal roof fan, with fibreglass-reinforced plastic propeller, aluminium body and cap, galvanised steel base and motor for single-phase power supply at 230 V and 50 Hz, with thermal protection, insulation class F, protection IP 65, 835 rpm, power consumption 0.22 kW, maximum flow rate 3900 m³/h, sound pressure level 52 dBA, with mesh to protect against ingress of leaves and birds, for extraction duct 450 mm in diameter. Including accessories and fasteners.	1,000	*1.522,02*	*1.522,02*
IVM036b	Item	Unit	Supply and installation at the outer end of the exhaust duct (exhaust port) of a helicoidal roof fan, with fibreglass-reinforced plastic propeller, aluminium body and cap, galvanised steel base and motor for single-phase power supply at 230 V and 50 Hz, with thermal protection, insulation class F, protection IP 65, 835 rpm, power consumption 0.22 kW, maximum flow rate 3900 m³/h, sound pressure level 52 dBA, with mesh to protect against ingress of leaves and birds, for extraction duct 450 mm in diameter. Including accessories and fasteners.	1,000	*1.522,02*	*1.522,02*
IVK010	Item	Unit	Supply and installation of extra-flat extractor hood with 2 suction motors, with flexible aluminium tube connection section to extraction duct for smoke extraction.	1,000	*195,86*	*195,86*
IVK030	Item	Unit	Supply and installation at the outer end of the exhaust duct (exhaust port) of a rotating aluminium extractor with dynamic cap (Hardness H-24), for 350 mm external diameter exhaust duct, for kitchen ventilation.	1,000	*115,07*	*115,07*
IVV020	Item	m	Supply and installation of a circular ventilation duct made of galvanised steel sheet tube with a single helical wall, 100 mm in diameter and 0.5 mm thick, placed in a vertical position. Including auxiliary material for assembly and fastening on site, accessories and special parts.	1,080	*1,37*	*1,48*
IVV020b	Item	m	Supply and installation of a circular ventilation duct made of galvanised steel sheet tube with a single helical wall, 135 mm in diameter and 0.5 mm thick, placed in a vertical position. Including auxiliary material	0,540	*1,86*	*1,00*

			for assembly and fastening on site, accessories and special parts.			
IVV020c	Item	m	Supply and installation of a circular ventilation duct made of galvanised steel sheet tube with a single helical wall, 100 mm in diameter and 0.5 mm thick, placed horizontally. Including auxiliary material for assembly and fastening on site, accessories and special parts.	0,930	*1,14*	*1,06*
N	**Chapter**		**Insulation and waterproofing**			**800,75**
NA	**Chapter**		**Thermal insulation**			**800,75**
NAA010	Item	m	Thermal insulation of pipes in A.C.S. interior installation, recessed in the wall, for the distribution of hot fluids (from +40°C to +60°C), made up of elastomeric foam shells, with a high resistance factor to the diffusion of water vapour, with an internal diameter of 16.0 mm and a thickness of 9.5 mm.	15,690	*0,25*	*3,92*
NAA010b	Item	m	Thermal insulation of pipes in A.C.S. interior installation, recessed in the wall, for the distribution of hot fluids (from +40°C to +60°C), made up of elastomeric foam shells, with a high resistance factor to the diffusion of water vapour, 23.0 mm internal diameter and 10.0 mm thickness.	2,900	*0,30*	*0,87*
NAA010c	Item	m	Thermal insulation of pipes in A.C.S. interior installation, placed on the surface, for the distribution of hot fluids (from +60°C to +100°C), made up of an elastomeric foam shell, 19 mm inside diameter and 25 mm thick.	5,820	*1,09*	*6,34*
NAA010d	Item	m	Thermal insulation of pipes in A.C.S. interior installation, placed on the surface, for the distribution of hot fluids (from +60°C to +100°C), made up of elastomeric foam shells, 23 mm inside diameter and 25 mm thick.	21,770	*1,18*	*25,69*
NAS030	Item	m²	Thermal insulation on the outside of facades with the OpenSystem "BAUMIT", with DITE - 09/0256, consisting of: rigid expanded polystyrene panel, OpenReflect "BAUMIT", 80 mm thick, with white reflective coating, fixed to the substrate with adhesive mortar KlebeSpachtel W (OpenContact) "BAUMIT" and mechanical fastenings with expansion plug and polypropylene nail Universal dowel STR U 2G "BAUMIT"; KlebeSpachtel W (OpenContact) "BAUMIT" adhesive mortar regularising layer, reinforced with anti-alkaline glass fibre mesh, Star Tex "BAUMIT", 4x4 mm mesh size, 145 g/m² surface mass and 0,5 mm thickness; water-repellent, NanoporTop "BAUMIT", white finish, Kratz 1,5 finish, on primer, UniPrimer "BAUMIT", colourless, rainproof and water vapour permeable.	184,080	*4,15*	*763,93*
Q	**Chapter**		**Roof**			**4.192,76**
QA	**Chapter**		**Flat**			**4.192,76**

QAE010	Item	m²	Flat roof non-transitable, ventilated, self-protected, conventional type, slope from 1% to 15%, made up of: slope formation: hollow ceramic tile tongue and groove panel 80x25x3.5 cm supported on lightened partitions of hollow ceramic brick 24x11x8 cm, arranged every 80 cm and with an average height of 30 cm; thermal insulation: mineral wool insulating felt, according to UNE-EN 13162, coated on one side with a complex of kraft paper with polyethylene acting as a vapour barrier, 80 mm thick; double-layer waterproofing adhered: SBS elastomer modified bitumen sheet, LBM(SBS)-30-FV, after priming with anionic asphalt emulsion with EB type fillers, and SBS elastomer modified bitumen sheet, LBM(SBS)-40/G-FP bonded to the previous one with a torch, without matching the joints.	166,050	*25,25*	*4.192,76*
R	**Chapter**		**Coatings and linings**			**7.042,66**
RI	**Chapter**		**Paints on interior walls**			**4.930,19**
RIP030	Item	m²	Manual application of two coats of white plastic paint, matt finish, smooth texture, the first coat diluted with 20% water and the next without dilution, (yield: 0.1 l/m² each coat); after application of a primer coat based on acrylic copolymers in aqueous suspension, on interior plaster or plaster, vertical, up to 3 m high.	324,820	*10,33*	*3.355,39*
RIT010	Item	m²	Manual application of two coats of tempera paint, white colour, matt finish, textured texture with a fine drop, the first coat diluted with a maximum of 40% water and the next without diluting, (yield: 0.55 kg/m² each coat); on an interior wall of cement mortar, horizontal, up to 3 m high.	145,680	*10,81*	*1.574,80*
RP	**Chapter**		**Traditional conglomerates**			**633,19**
RPE005	Item	m²	Cement rendering, visible, applied on an interior vertical wall, up to 3 m high, rough surface finish, with cement mortar, type GP CSII W0.	150,580	*2,57*	*386,99*
RPG010	Item	m²	Garnished with B1 construction plaster with a good view, on a horizontal wall, up to 3 m high, after installing anti-alkalis mesh when changing material, without lifeguards.	145,680	*1,69*	*246,20*
RS	**Chapter**		**Flooring**			**898,39**
RSB005	Item	m²	Base for crushing sand pavement with a diameter of 0 to 5 mm, stabilised with 100 kg of Portland CEM II/A-P 32.5 R cement per m³ of dry sand, in a 4 cm thick layer.	145,680	*0,60*	*87,41*
RSA020	Item	m²	Thin layer of floor levelling paste CT - C20 - F6 according to UNE-EN 13813, 2 mm thick, applied manually, for the regularisation and levelling of the surface of the internal concrete or mortar substrate, after application of a modified synthetic resin primer, which acts as a bonding bridge (not including the preparation of the substrate), prepared to receive ceramic, cork, wood,	104,040	*0,18*	*18,73*

			laminate, flexible or textile flooring (not included in this price).			
RSG010	Item	m²	Glazed stoneware ceramic tile flooring, 25x25 cm, 8 €/m², water absorption capacity E<3%, group BIb, slip resistance Rd<=15, class 0, received with cementitious adhesive for interior use only, Ci without any additional characteristics, grey colour and grouted with white cement grout, L, BL-V 22.5, for minimum joint (between 1.5 and 3 mm), coloured with the same shade as the pieces.	41,640	*3,96*	*164,89*
RSL010	Item	m²	Laminate flooring, 1200x190 mm slats, Class 22: Domestic general, AC2 abrasion resistance, consisting of HDF base board decorative laminate in pine, assembled with adhesive, placed on complex made of high quality polyethylene, closed cells, for impact sound insulation, coated on one side with a polyethylene film acting as a vapour barrier of 2.5 mm thick, with a proportional part of placement of polyethylene strip 5 mm thick.	104,040	*6,03*	*627,36*
RR	**Chapter**		**Linings**			**580,89**
RRY012	Item	m²	Direct laying, W631.es "KNAUF" system, made of laminated plasterboard - 9.5+30 Polyplac + Aluminium (XPE-BV)|, received with bonding paste on the vertical wall; 55 mm total thickness.	86,570	*3,24*	*280,49*
RRY012b	Item	m²	Direct laying, W631.es "KNAUF" system, made of laminated plasterboard - 9.5+30 Polyplac + Aluminium (XPE-BV)|, received with bonding paste on the vertical wall; 65 mm total thickness.	86,570	*3,47*	*300,40*

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