WP 2 – Task 2.2

D2.2: Identification of descriptors (quali-quantitative indicators and parameters)

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SUMMARY

This deliverable summarizes the activities carried out in Task 2.2 of the project ''Geo-clustering to deploy the potential of Energy efficient Buildings across EU". The proposed geo-cluster concept is based on the possibility to locate similarities across European regions by combining single or multiple parameters and indicators organized in homogeneous layers and sub-layers.

In Task 2.2, the following activities were performed:

- Analysis of existing knowledge and information gathered during this coordinated effort in order to identify a set of quali-quantitive parameters and indicators addressing both technological and non-technological aspects.
- Identification and characterization of a first set of layers gathering homogeneous indicators and parameters identified during the analysis. These layers will represent the basis to compare the main features of geo-clusters and they will be the pillars of the multi-dimensional maps.

The following layers and sub-layers were identified:

- Technological layer, consisting of energy-efficient technologies representing existing market solutions.
- Context layer, consisting for instance of climatic conditions, building typologies, raw materials availability, etc.
- Socio-economic layer consisting for instance of macroeconomic indicators, living habits and behavior aspects, construction business process, etc.
- Political-strategic layer consisting of applicable building directives and laws, standards and regulation, energy policies, etc.

For each layer, indicators, geo-descriptors, descriptors and parameters (see definition in § 2) have been defined addressing both technological and non-technological aspects. Data and information which are needed for the creation of the multi-dimension maps were collected across European regions based on EU wide data repositories and documents/reports publicly available. This information was complemented by other qualitative and quantitative data identified in Task 2.1. Further knowledge and information will be mobilized within the pilot clusters. However, the objective of the project is only to realize a proof of concept of a geocluster mapping tool. The tool should demonstrate that the geocluster approach can provide useful information to future users. It is not the objective of this project (coordination and support action) to develop a fully operational tool. Therefore, the data collection process has been limited.

In order to get a complete view of all information that will be needed for a specific key technology and how a given stakeholder may want to use this information, a pull and push scenario has been defined and analyzed.

1. INTRODUCTION

Energy efficiency in buildings will play a major role in responding to climate change and energy issues, if we are able to trigger large scale actions involving EU, all Member States and their regional and local authorities.

The concept of "Geo-clusters" is highly relevant, being virtual trans-national areas where strong similarities are found (i.e. climate, culture and behavior, construction typologies, economy, energy price and policies and gross domestic product, to name a few). In this framework, it is clear that the geo-cluster map will not be based on fixed geographic regions, but is to be considered as a multi-dimensional and dynamic tool.

The goal of the GE2O "Geo-clustering to deploy the potential of Energy efficient Buildings across EU" project is to locate similarities across enlarged EU by combining single or multiple parameters and indicators organized in homogeneous layers and sub-layers. This concept is schematically presented in Figure 1.

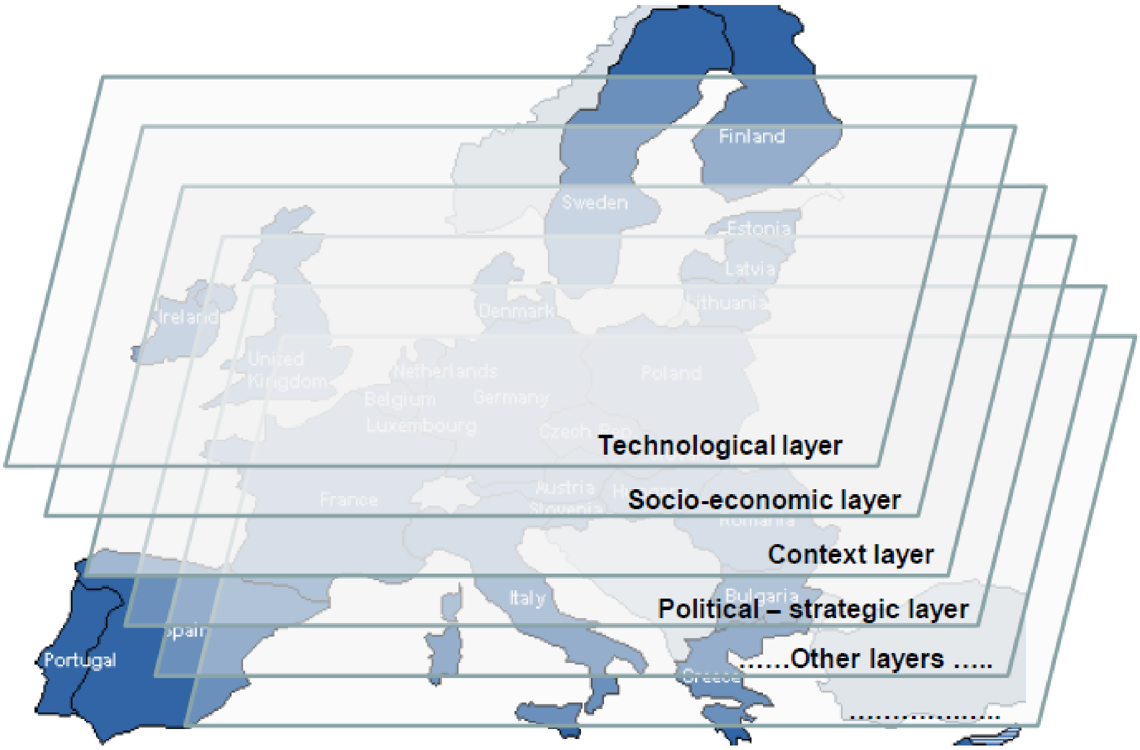

Figure 1: Overall geo-cluster concept

The different layers can be analyzed using a single descriptor, to identify for instance geographical areas which share similarities in climatic conditions or financial incentives, or they can be analyzed based on several layers and their corresponding descriptors for more complex investigations.

This deliverable will describe the different layers and sub-layers gathering homogeneous indicators and descriptors identified during the analysis performed in Task 2.2.

2. DEFINITIONS

The following section clarifies terminology used in Task 2.2, especially the identification of descriptors in chapter 4. Additionally, a terminology manual can be found at the end of this document

Category

The category includes a set of applications.[1]

Application

An application represents a task or function performed by one or more technology.

Technology

A technology is defined by a single set of performance indicators, products / systems characteristics, geo-descriptors, and descriptors. Technology consists of different products or systems.

Product / systems

Products or systems are all sub-classes of a technology. Through the performance indicators, the various products / systems can be compared to each other in a given environment (or context).

Performance indicators

The performance indicator gives the energy performance of a product/system in a given environment (climate, building typology, regulation).

Products / systems characteristics

Products / systems characteristics represent the main physical features of the system / product.

Geo-descriptors

In this project, geo-descriptors are related and defined through the territory description in general. So, geo-descriptors taken into account are sociological, environmental, climate, economic and the like. Thus in this report, geo-descriptors identified are geo-descriptors that significantly impact on the performance of a technology. In this case the geo-descriptors identified are only related to climate (technological layer). Geo-descriptors represent data like: Degree days DD, Heating degree days HDD, Cooling degree days CDD and also annual weather data necessary for assessing the performance indicator of the different technologies.

Others descriptors

They are not dependent of a single technology. Descriptors are used to describe the context (other than climate) in which the performances of a technology are identified.

3. DATA MODEL STRUCTURE

A brief presentation of the data model structure is given in this chapter. This presentation will be further developed in Del 2.3. The idea of this presentation is to explain how data and information that have been collected will be organized and correlated.

The starting point of the data model structure development was a concept of a “matrix”. This figure was chosen to highlight the potentials and the correlations aspects that the Geo-cluster mapping tool is supposed to reach. In order to fulfill this objective, instead of 2D space matrix, a 3D correlation matrix was preferred as it has one more degree of complexity.

The long-term objective of the Geo-cluster approach is to boost acceleration in implantation and increase the impact of energy efficient “solutions”. Based on similarities analysis across Europe, the geo-cluster mapping tool should provide relevant information about the following issues related to energy efficiency in buildings:

- where and how a product/system/service/programmed can be implemented/applied (push);
- which product/system/service can be used in a specific situation (pull);
- where are opportunities to develop a new product/system/service/programmed (pull).

The axes of the 3D space are identified as illustrated in Figure 2.

The x-axis corresponds to the main energy efficient technologies (see § 4Table 1: Non exhaustive list of energy-efficient technologies analyzed in the GE2O project) chosen initially from a complete overview of appropriate technological solutions2. These technologies represent existing solutions proposed by manufacturers (i.e. = X.1, X.2, X.3, X.n).

- For each technology the main performance indicators (see Table 1 “ Identified for the GE2O non exhaustive list of technologies” “of the document Annex I) are listed according the energy efficiency purposes (U-value, thickness, average cost, kind of application, energy consumption, etc. i.e. Y.1, Y.2, Y.3, Y.n = y-axis). Indicator is considered as a factor related to the technology and elaborated from few parameters; while a parameter is a factor strictly related to the technology.
- As they are all geo-referenced (location dependant), the non-technological aspects are considered in the third axis, as the geo-descriptors and geo-indicators (i.e. Z.1,Z.2, Z.3, Z.n = z-axis) that can promote or obstacle the use of previous listed key technologies.

[2] ECO-BUILD project - Specific Support Action for the Advancement and the Implementation of the Eco-Building Concept

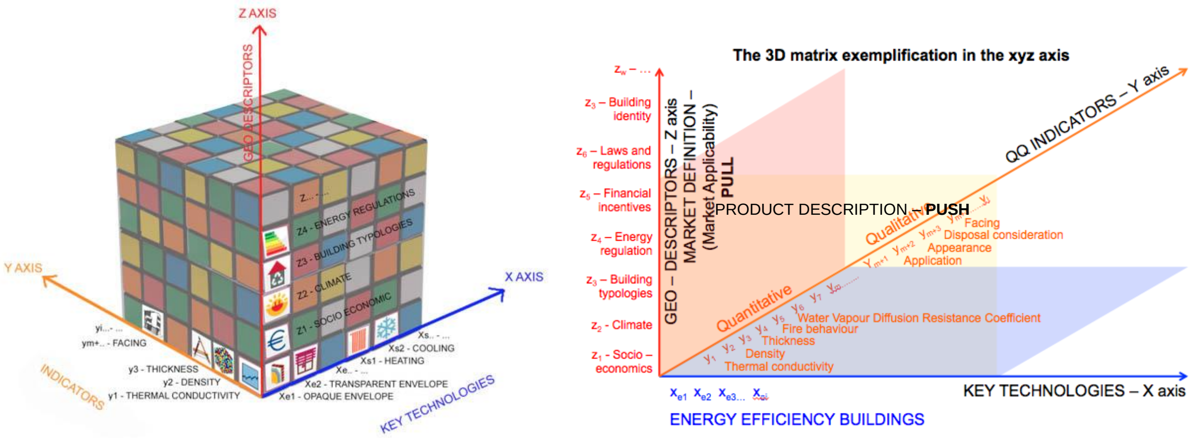

Figure 2: 3D representation of the data model structure in a cube (left) – First draft of 3D matrix exemplification on the xyz axis (right)

A performance indicator is considered as a technology indicator depending on geographic location. A geo-descriptors is a context indicator i.e. NOT dependent of a single technology. The correlation methodology proposed will be based on a semantic multi-dimensional matrix composed of different layers and sub-layers containing information of different nature and scale.

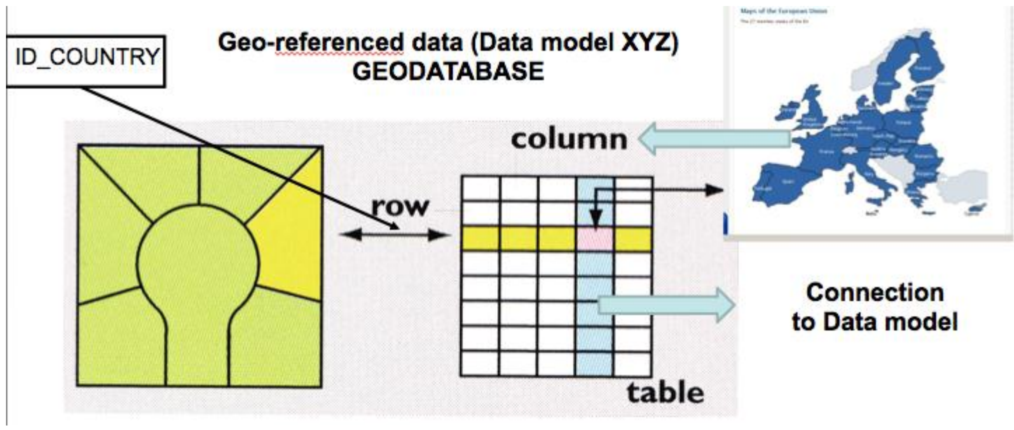

Figure 3: Exemplification of the multi-dimensional Data model and the special relationship Web GIS based

In order to understand the correlation between the three axis, we have to distinguish among the correlation between X and Y, and the one with Zs. However, both approaches are based on "Clustering Analysis" that defines different statistic procedures and respective computational algorithms capable of data set classification. This is done by gathering (clustering) in groups (clusters), which have numbers or their representative values (cluster points) that are usually initially unknown.

Every key technology (X) will have its own indicators (Y), specifically defined for that technology by its parameters. The correlation between XY can be defined by the "methods for numeric objects". In this case it is possible to have two kinds of limits:

- there is a min and max values and all other values are interpolated in this range (fuzzy methods);
- there are no values of the object but it is simply assigned as existing or NON existing (binary methods).

The correlation model we intend to use for Geo-cluster analysis will be defined in three phases.

Phase 1. ROUGH DATA MODEL (DM). We propose a data model and a general hypothetic matrix, as a first step. This is in fact XYZ matrix we have proposed thinking of geo-clusters that interface the parameters Y and geo-descriptors Z, that are strictly correlated between them.

Phase 2. SUB Key Technology Data Model (Sub-DM). For EVERY key technology identified we shall construct a data model, defining parameters Y and geo-descriptors Z that influence that particular key technology.

Phase 3. DM refining. All Sub-DM will enrich the general Data Model i.e. all X and Y identified for all key technologies will be included to form two global lists, one for Ys and and for Zs.

Many geo-descriptors of Z axis do not have numeric values but they refer to the qualitative data. In this case the **"methods for non-numeric objects"** will be applied. Since these variables are not represented by any number, some ad hoc "dissimilarity coefficients", able to quantify (qualitative) differences between non-numerical objects and capable of evidencing common characteristics or differences between two sets of data examined, will be defined. Successfully, these descriptors will be attributed to every single administrative unit examined (on NUTS3 level, as agreed among project partners) i.e. they will become GEO-descriptors.

In conclusion every X is described by a set of Y which are specific of that X – the values of those Y depend on the application of X and the implementation of every X depends on a set of Z. For every X, we define the set of influencing Z – the values of those Z depend only on the context, as illustrated in Figure 4.

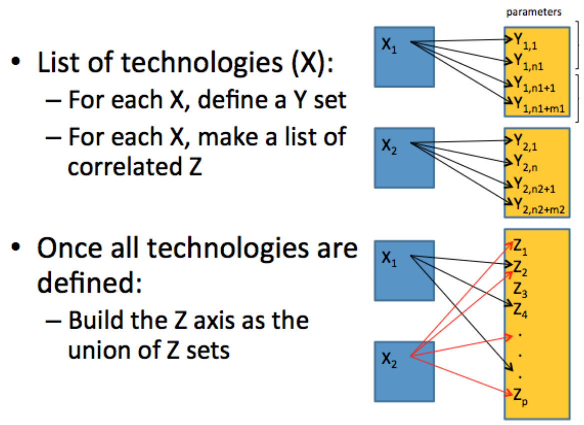

Figure 4: Correlation XYZ scheme

4. IDENTIFICATION OF DESCRIPTORS – TECHNOLOGICAL LAYER

4.1. Introduction

This chapter deals with the technological layer. The main objective is to identify the energy performance of different building related technologies in their established context (climate, building typology, regulation). The energy performance of a technology is identified through one or more performance indicators. A performance indicator is defined as a function of the technology systems / products characteristics, geo-descriptors (climate) and descriptors (building typology, regulation).

Through this approach, the different descriptors linked to climate, building typology and national regulations are identified and organized. These descriptors will constitute the structure of the geo-cluster database that will be later on implemented in the Geo-cluster Mapping tool.

A non-exhaustive list of the different technologies selected for this work is proposed. These energy-efficient technologies are described and relationships between technology performance indicators and others descriptors are established. For each technology, examples are given to illustrate the technology in its geo context.

4.2. Energy-efficient technologies

28 different energy-efficient technologies related to the building sector have been analyzed and described (see **Erreur ! Source du renvoi introuvable.**) by project partners. These technologies represent existing market solutions although some of them are not widely spread. Innovative solutions that are at their early stage of market development have not been considered.

Category	Application	Technology	Partner responsible for
Passive demand reduction	**Thermal insulation**	Panel, roll	CSTB / POLIMI
		Foam	
		Multi layers	
	Window & glazing	Double glazing	CSTB
		Triple glazing	
		Vacuum glazing	POLIMI
	Building envelope	Mono skin façade systems	ARCELLORMITTAL
		Double skin façade system	
		Mono skin and Double skin windows systems	

	Heat / cool storage	Phase change materials	IFS
Active demand reduction	**Artificial lighting**	Fluorescent lamps	TZUS
		Solid state lamps	
	Heat recovery ventilation	Air to air heat exchanger	CSTB / BBRI
		Rotary heat exchanger	
		Heat pipe heat exchanger	
	Building automation control system	Heating / cooling control	CSTB / ACCIONA
		Lighting control	
		Ventilation control	
		Blind control	
Active generation and storage	**Cooling**	Evaporative cooling	ZAG
		Desiccant cooling	
		Solar absorption cooling	
	Heating and DHW	Solar water heaters	CSTB
		Ground, air, water source heat pumps	
		High efficiency boilers	
		District heating	ASM
	Electricity production systems	PV panels	CSTB
		Cogeneration (CHP)	

Table 1: Non exhaustive list of energy-efficient technologies analyzed in the GE2O project

A description of these technologies is given in the following sections.

4.3. Passive demand reduction

One of the different ways to reduce the building energy demand is to use passive technologies. These technologies are called passive, as opposite to active, because they don't use any mechanical and electrical devices. In the passive demand reduction category, four main applications have been analyzed: Thermal Insulation, Windows and Glazing, Building envelope, and Heat and Cool storage.

4.3.1 Thermal insulation

Thermal insulation in buildings is a way to reduce annual energy consumption by reducing the heat transfer flow through the building envelope. In order to get a sufficient living comfort level, the main objective is to maintain an acceptable temperature in the building. So by insulating a building, energy efficiency is improved. Also, by reducing the heat transfer flow, thermal comfort is improved due to more uniform temperatures throughout the space (1). Even more, thermal insulation is long-term energy efficient and doesn't require maintenance. Thermal insulation products can also reduce noise and vibration.

4.3.1.1 Description

Three main types of thermal insulation technology have been indicated:

- Panel / roll
- Foam
- Multi layers
-

A non-exhaustive list of thermal insulation products is given in the following sections.

➢ ***Panel, roll***

Panel and roll thermal insulation technologies can be split into five different categories: Foam board, mineral wool, natural, aerogel and vacuum insulation systems / products. Figure 5 shows an example of panel, roll thermal insulation technology.

- Foam board

Foam boards, rigid panels of insulation, are generally used to insulate almost any part of the building (roof down, walls, foundation). Foam boards technology uses three different materials (2):

- ❖ Extruded polystyrene
- ❖ Expanded polystyrene
- ❖ Polyurethane rigid panel

- Mineral wool

Mineral wools are fibers made from natural or synthetic minerals. The term mineral wool includes fiberglass, ceramic fiber and stone wool. With its entangled structure, mineral wool is a porous material that traps the air. The porous and elastic structure of the wool also absorbs noise in the air, knocks and offers acoustic correction inside premise. Mineral wool is used to insulate building wall and roof. Two mineral wool materials are commonly used (2):

- Glass wool
- Stone wool

- Natural

In comparison with classical insulation materials, natural insulation materials are built from renewable and organic resources. Natural materials have low impact for the earth and have low embodied energy. Many types of natural material for thermal insulation are available (2).

- Aerogel

Aerogel is a synthetic porous material derived from a gel, in which the liquid component of the gel has been replaced with a gas. This allows the liquid to be slowly drawn without causing the solid matrix to collapse from capillary action, as would happen with conventional evaporation. The result is a solid structure with extremely low density and thermal conductivity. Two structures are used for aerogel technology:

- Air-filled SiO_2
- Vacuum SiO_2

- Vacuum insulation panels

A vacuum insulated panel is a form of thermal insulation consisting of a nearly gas-tight enclosure surrounding a rigid core, from which the air has been evacuated. Vacuum insulation panel is used in building construction to provide a better insulation performance than conventional insulation materials. Five solutions for vacuum insulation panel technology are presented here:

- Pure VIP: The panel core is encased in a special process using a gas-and moisture-proof multi-layer composite film, evacuated and then sealed with aluminium foil film
- Base VIP: The core is protected by 3mm thick rubber matrix
- Front VIP: The core is protected by 10mm thick polystyrene foam sheet
- Save VIP: The core is protected by 1.5mm thick glass fiber
- Site VIP: The core is protected by 4mm thick plastic plate and with concealed edge polystyrene.

- ***Foam***

Foam thermal insulation technology is composed of two different systems / products. We can distinguish spray foam and natural loose-fill insulation systems / products. The Figure 6 shows an example of foam thermal insulation technology.

- Spray foam

Insulation spray foam material is sprayed in place through a spray foam gun. The expanding form is applied by a two-component mixture (essentially Polyurethane and Isocyanate) that comes together at the tip of the gun. Spray foam application domain are diversified. It can be used onto concrete slabs, into wall cavities (unfinished wall), or through holes drilled in sheathing or drywall into the wall cavity (finished wall). Three materials are used for spray foam technology:

- Flexible elastomeric foam
- Polyurethane foam
- Polyethylene foam

- Natural loose-fill

Natural loose-fill materials are used to insulate cavity wall. Five different materials are studied for loose fill materials:

- Perlite loose-fill
- Vermiculite loose-fill
- Expanded clay
- Cellulose loose-fill
- Duck feather

➢ ***Multi layers***

Multi layers thermal insulation technology is composed of one specific system / product. This is multi foil reflective. The Figure 7 shows an example of panel, roll thermal insulation technology.

- Multi foil reflective

Multi-foil reflective films consist of a series of reflective layers interspersed with wadding and foam. High thermal performance of this technology is based on its ability to reflect long-wave radiative energy. Thereby, the heat transfer flow is reduced. Eight solutions for multi-foil reflective technology are presented here:

- Solution 1: Two layers of aluminum film and two fire-retardant polyethylene films
- Solution 2: Four layers of aluminum film, one layer of dry air bubbles and one fire-retardant polyethylene foam
- Solution 3: Two layers of aluminum reflective film with inside a 3 mm layers of PE
- Solution 4: Two layers of aluminum reflective film with inside a 3 mm layers of PE and a polystyrene panel with different possible thickness
- Solution 5: 14 components layers = Two metal films with reinforced grid - Four foam layers - Four intermediate reflective films - Four sheep wool layers
- Solution 6: 14 components layers = Two metal films with reinforced grid - Four intermediate reflective films – Four widen layers - Six foam layers
- Solution 7: 8 components layers = Two metal films - Two intermediate reflective films - Three foam layers -One reinforced grid
- Solution 8: 13 components layers = Two metal films with reinforced grid - Six foam layers - Four intermediate reflective films - one polyane transparent

Figure 5 : Panels, roll thermal insulation technology

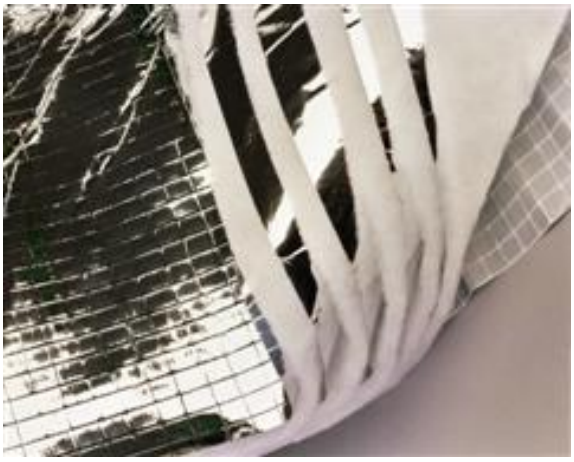

Figure 6 : Foam thermal insulation technology **Figure 7 : Multi layers thermal insulation technology**

4.3.1.2 Performance indicators

Thermal insulation technology performance indicators take into account the climate conditions where the insulation material is applied and take also into account the main physical properties of the products / systems. Two performance indicators have been defined for panel, roll, foam and multi layers products / systems. One is defined for the heating season, the other for the cooling season. This technology indicator is the energy loss per square meter of opaque construction (wall, roof, floor) during the heating ($Eati_{h,\,s}$) or cooling season ($Eati_{c,\,s}$).

Heating season thermal insulation performance indicator $Eati_{h,s}$

Cooling season thermal insulation performance indicator	$Eati_{c,s}$

Where the general expression of the thermal insulation technology indicator is given by:

$$Eati_{h,s} = \frac{HDD \times 24}{R \times 1000} \quad \text{and} \quad Eati_{c,s} = \frac{CDD \times 24}{R \times 1000}$$

Where:

- $Eati_{h,s}$: Energy loss per square meter of opaque construction during the heating season [kWh/m².year]
- $Eati_{c,s}$: Energy loss per square meter of opaque construction during the cooling season [kWh/m².year]
- HDD : Heating Degree Day [DD]
- CDD : Cooling Degree Day [DD]
- R : Thermal resistance of the wall [m².K/W]

Where the general expression of the thermal resistance of the opaque construction is given by [3]:

$$R = \frac{t}{\lambda}$$

Where:

- t: Thickness of the panel or roll [m]
- λ: Thermal conductivity of the material [W/m.K]

4.3.1.3 Database

Thermal insulation performance indicators rely on climate and product characteristics. The following sections give the description and some range of magnitude to assess the performance indicator.

➢ ***Geo-descriptors***

Thermal insulation technologies are related to two climate descriptors: The heating degree day (HDD) for the heating season, and the cooling degree days (CDD) for the cooling season.

➢ ***Product characteristics***

In order to remain as much generic as possible, i.e. not to introduce database of all manufactured products (thousands of products), only performance indicator ranges associated to each category of product are presented.

[3] Due to the huge diversity of construction techniques, the thermal resistance of the construction itself (without insulation layer) is neglected.

- ***Panel, roll***

Panels and roll product / system characteristics are detailed in the followings parts.

- Foam board

		Thermal conductivity		Thickness	
Product system	**Materials**	**λ_{min} [W/mK]**	**λ_{max} [W/mK]**	**t_{min} [mm]**	**t_{max} [mm]**
Foam board	**Extruded polystyrene**	0.029	0.04	40	120
	Expanded polystyrene	0.029	0.055	40	120
	Polyurethane rigid panel	0.022	0.035	20	120

Table 2 : Foam board product characteristics (1) (2)

- Mineral wool

		Thermal conductivity		Thickness	
Product system	**Materials**	**λ_{min} [W/mK]**	**λ_{max} [W/mK]**	**t_{min} [mm]**	**t_{max} [mm]**
Mineral Wool	**Glass wool**	0.03	0.04	40	180
	Stone wool	0.032	0.04	40	180

Table 3 : Mineral wool product characteristics (1) (2)

- Natural

Product system	Materials	Thermal conductivity		Thickness	
		λ_{min} [W/mK]	λ_{max} [W/mK]	t_{min} [mm]	t_{max} [mm]
Natural	Soft wood panels	0.037	0.049	40	80
	Hard wood panels	0.0.07	0.07	40	100
	Cellulose wool panels	0.039	0.042	40	160
	Expanded cork roll	0.04	0.049	2	6
	Expanded cork panels	0.032	0.045	20	120
	Hemp wool	0.039	0.08	5	200
	Coton wool	0.037	0.042	50	100
	Reed panels	0.056	0.056	20	50
	Sheep wool	0.035	0.045	100	110
	Straw bale (in the direction of rods)	0.08	0.08	200	800
	Straw bale (perpendicular to the rods)	0.052	0.065	200	800

Table 4 : Natural product characteristics (1) (2)

- Aerogel

Product system	Materials	Thermal conductivity		Thickness	
		λ_{min} [W/mK]	λ_{max} [W/mK]	t_{min} [mm]	t_{max} [mm]
Aerogel	Air-filled SiO2	0.013	0.02	10	22
	Vacuum siO2	0.011	0.013	10	22

Table 5 : Aerogel product characteristics (1) (2)

- Vacuum insulation panels

Product system	Materials	Thermal conductivity λ_{min} [W/mK]	Thermal conductivity λ_{max} [W/mK]	Thickness t_{min} [mm]	Thickness t_{max} [mm]
Vacuum insulation panels	Pure VIP	0.004	0.008	10	40
	Base VIP	0.005	0.008	13	43
	Front VIP	0.005	0.008	20	50
	Save VIP	0.005	0.008	13	43
	Site VIP	0.005	0.008	23	38

Table 6 : Vacuum insulation panels parameters technology (1) (2)

- ***Foam***

Foam product / system characteristics are detailed in the followings parts.

- Spray foam

Product system	Materials	Thermal conductivity λ_{min} [W/mK]	Thermal conductivity λ_{max} [W/mK]	Thickness tmin [mm]	Thickness tmax [mm]
Spray foam	Flexible elastomeric foam	0.045	0.055	20	200
	Polyuterane foam	0.045	0.055	20	200
	Polyethylene foam	0.045	0.055	20	200

Table 7 : Spray foam product characteristics (1) (2)

- Natural loose-fill

Product system	Materials	Thermal conductivity λ_{min} [W/mK]	Thermal conductivity λ_{max} [W/mK]	Thickness tmin [mm]	Thickness tmax [mm]
Natural loose fill	Perlite loose-fill	0.05	0.06	50	500
	Vermiculite loose-	0.06	0.08	50	500

	fill				
	Expanded clay	0.1	0.16	50	500
	Cellulose loose-fill	0.035	0.042	50	500
	Duck feather	0.033	0.042	50	500

Table 8 : Natural loose-fill product characteristics (1) (2)

- ***Multi layers***

Multi-layers product / system characteristics are detailed in the followings part.

- Multi-foil reflective

		Thermal resistance	
Product system	**Materials**	**R_{min} [m².K/W]**	**R_{max} [m².K/W]**
Multi-foil reflective	**Solution 1**	2.64	4.87
	Solution 2	5.7	5.7
	Solution 3	1.9	1.9
	Solution 4	2.1	3.5
	Solution 5	6.10	6.10
	Solution 6	5.0	5.0
	Solution 7	3.5	3.5
	Solution 8	1.0	1.0

Table 9 : Multi-foil reflective product characteristics (1) (2)

4.3.1.4 Example

Thermal insulation performance indicators depend on the context (climate). Figure 8 gives the superposition of administrative zones and climatic zones for France. Geo-descriptors corresponding to these zones are detailed in Table 10.

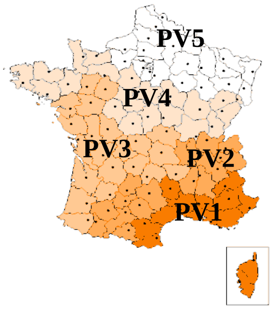

Figure 8 : French climatic zoning

Climatic zone	PV1	PV2	PV3	PV4	PV5
HDD	2100	2400	2500	2700	2800
CDD	68	52	38	32	15

Table 10 : Thermal insulation geo-parameters for 5 French climatic zones

The thermal annual energy loss per square meter of opaque construction has been calculated for different thermal insulation materials for the PV5 climatic zone. Results are given in Table 11.

		$Eati_{h,s}$ [kWh/m².year]		$Eati_{c,s}$ [kWh/m².year]	
Product system	**Materials**	**Min**	**Max**	**Min**	**Max**
Foam board	**Extruded polystyrene**	16,2	67,2	0,09	0,36
	Expanded polystyrene	16,2	92,4	0,09	0,50
	Polyurethane rigid panel	12,3	117,6	0,07	0,63
Mineral Wool	**Glass wool**	11,2	67,2	0,06	0,36
	Stone wool	11,9	67,2	0,06	0,36
Natural	**Soft wood panels**	31,1	82,3	0,17	0,44
	Hard wood panels	47,0	117,6	0,25	0,63
	Cellulose wool panels	16,4	70,6	0,09	0,38
	Expanded cork roll	448,0	1646,4	2,40	8,82
	Expanded cork panels	17,9	151,2	0,10	0,81

	Hemp wool	13,1	1075,2	0,07	5,76
	Coton wool	24,9	56,4	0,13	0,30
	Reed panels	75,3	188,2	0,40	1,01
	Sheep wool	21,4	30,2	0,11	0,16
	Straw bale (in the direction of rods)	6,7	26,9	0,04	0,14
	Straw bale (perpendicular to the rods)	4,4	21,8	0,02	0,12
Aerogel	**Air-filled SiO2**	39,7	134,4	0,21	0,72
	Vacuum siO2	33,6	87,4	0,18	0,47
Vacuum insulation panels	**Pure VIP**	6,7	53,8	0,04	0,29
	Base VIP	7,8	41,4	0,04	0,22
	Front VIP	6,7	26,9	0,04	0,14
	Save VIP	7,8	41,4	0,04	0,22
	Site VIP	8,8	23,4	0,05	0,13
Spray foam	**Flexible elastomeric**	15,1	184,8	0,08	0,99
	Polyuterane foam	15,1	184,8	0,08	0,99
	Polyethylene foam	15,1	184,8	0,08	0,99
Natural loose fill	**Perlite loose-fill**	6,7	80,6	0,04	0,43
	Vermiculite loose-fill	8,1	107,5	0,04	0,58
	Expanded clay	13,4	215,0	0,07	1,15
	Cellulose loose-fill	4,7	56,4	0,03	0,30
	Duck feather	4,4	56,4	0,02	0,30

Table 11 : Thermal insulation indicator for PV5 French climatic zone

4.3.2 Windows and glazing

In traditional buildings, windows and glazing are used for day-lighting and ventilation. Unfortunately, windows are usually sources of heat losses, discomfort, and condensation problems. Technological advance of these recent years advise some high-performance, energy efficient windows and glazing systems. Most progress has been evident in areas like lower heat loss, less air leakage, and warmer windows surfaces that improve comfort and minimize condensation.

4.3.2.1 Description

Three main types of windows systems have been identified: double glazing, triple glazing and vacuum glazing.

➢ ***Double glazing***

Double glazing technology stands for a double glass window panes separated by an air or other gas filled space to reduce heat transfer across a part of the building envelope. Figure 9 shows the composition of a double glazing window.

In order to improve energy efficiency of windows, two more technological points are developed. These features are the nature of the insulating gas sandwiched between panes and the specialized transparent glass coatings. Two gases are studied here: air and argon. Two coatings are presented: without coating and low emission glass coating (3) (4). The double glazing windows presented are:

- Air filled
- Argon filled
- Low E Glass, air filled
- Low E Glass, argon filled

➢ ***Triple glazing***

Triple glazing technology stands for a triple glass window panes separated by an air or other gas filled space to reduce heat transfer across a part of the building envelope. Figure 11 shows the composition of a triple glazing window. The solutions used to improve glazing performance are the same as described for double glazing.

➢ ***Vacuum glazing***

Vacuum glazing technology is represented by a double glass window panes separated by a vacuum space. Figure 10 shows the composition of a vacuum glazing.

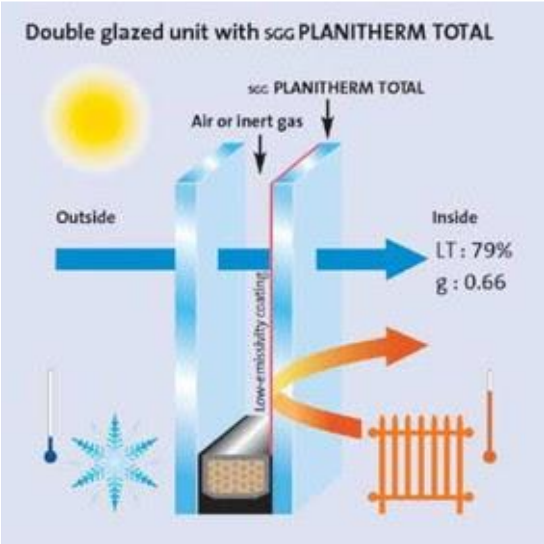

Figure 9 : Double glazing technology

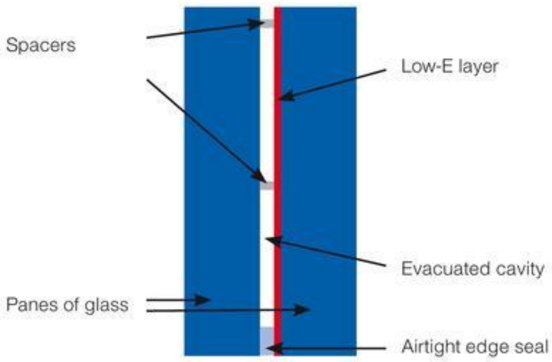

Figure 10 : Vacuum glazing technology

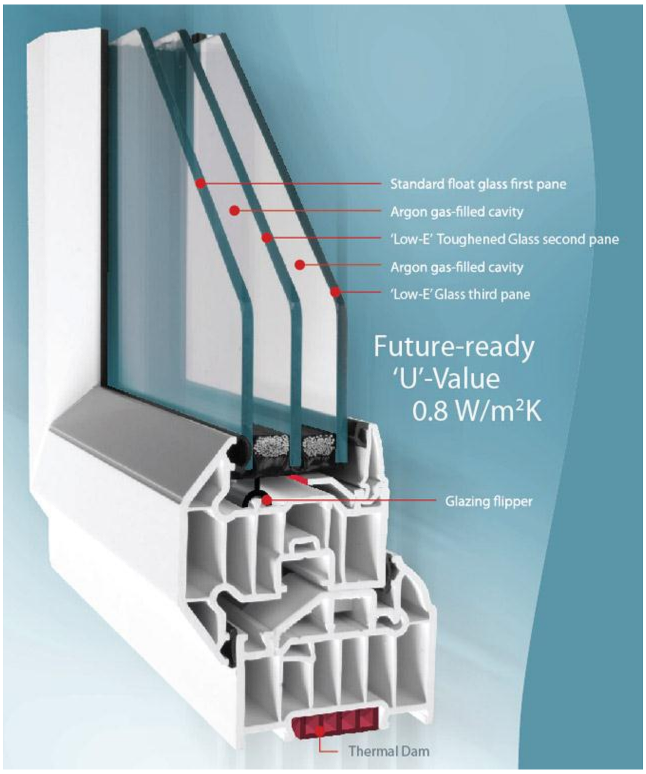

Figure 11 : Triple glazing technology

4.3.2.2 Performance indicators

In order to specify window and glazing systems, three main performance indicators have been defined whatever the system (double, triple and vacuum glazing):

Windows and Glazing performance indicators	**U-Value**
	SHGC
	$\mathbf{T_{Vis\text{-}glass}}$

Where:

- U-value: Thermal transmittance of the window [W/m².K]
- SHGC: Window Solar Heat Gain Coefficient [%]

- $T_{vis\text{-}glass}$: Glass visible transmittance [%]

4.3.2.3 Database

Windows and glazing performance indicators are only related to system characteristics. Performance indicator ranges associated to each category of product are presented in the next sections.

- ***Double glazing***

Table 12 details the value of these parameters for the different double glazing systems.

Technology	U-value Min [W/m².K]	U-value Max [W/m².K]	SHGC Min [%]	SHGC Max [%]	$T_{vis\text{-}glass}$ Min [%]	$T_{vis\text{-}glass}$ Max [%]
Air filled	2.7	3.1	70	80	75	80
Argon filled	2.6	2.9	70	80	70	75
Low E Glass, air filled	1.8	2.7	40	60	70	74
Low E glass, argon filled	1.7	2.5	30	50	69	73

Table 12 : Double glazing product / systems characteristics (3) (4)

- ***Triple glazing***

Table 13 details the value of these parameters for the different triple glazing systems.

Technology	U-value Min [W/m².K]	U-value Max [W/m².K]	SHGC Min [%]	SHGC Max [%]	$T_{vis\text{-}glass}$ Min [%]	$T_{vis\text{-}glass}$ Max [%]
Air filled	2.0	2.4	65	70	70	75
Argon filled	1.9	2.2	65	70	65	70
Low E Glass, air filled	1.4	2.1	50	65	40	50
Low E glass, argon filled	1.3	1.9	45	60	38	48

Table 13 : Triple glazing product / systems characteristics (3) (4)

➢ ***Vacuum glazing***

Table 14 details the value of these parameters for vacuum glazing systems.

Technology	**U-value Min [W/m².K]**	**U-value Max [W/m².K]**	**SHGC Min [%]**	**SHGC Max [%]**	**$T_{vis\text{-}glass}$ Min [%]**	**$T_{vis\text{-}glass}$ Max [%]**
Vacuum glazing	0.4	0.5	40	54	65	73

Table 14 : Vacuum glazing product / systems characteristics (3) (4)

4.3.3 Façade

The impacts of façade technology on all aspects of building performance are very large. Heating, cooling, and lighting loads are directly influenced by the façade technology performance. The impact of the façade design is very important and is a major determinant of the annual energy use, peak of heating / cooling, and electricity load shape.

4.3.3.1 Description

Three main types of facade typology have been reported: mono skin façade system, double skin façade system, and mono skin and double skin window system. These technologies are also split up into different products / systems. These systems are illustrated from Figure 12 to Figure 19.

➢ ***Mono skin façade system***

- Element façade

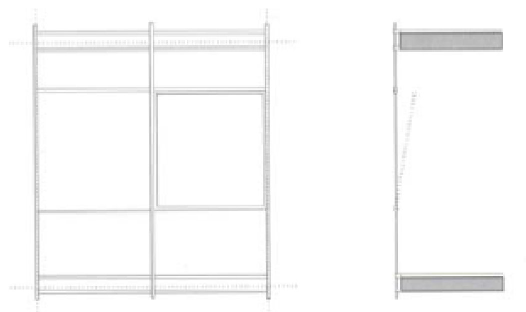

Figure 12 : Element façade system (5)

➢ ***Double skin façade system***

- Corridor façade
- Non segmented double skin façade
- Controllable double skin façade

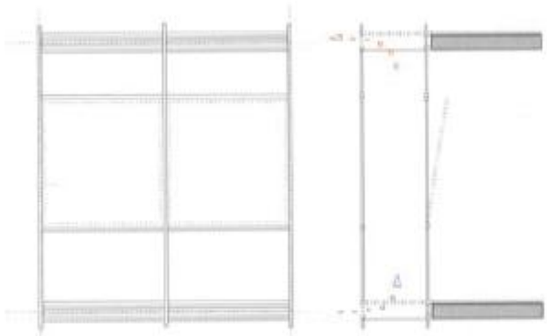

Figure 13: Corridor façade system (5)

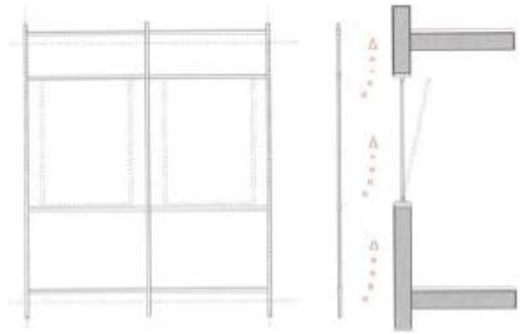

Figure 14: Non segmented double skin façade system (5)

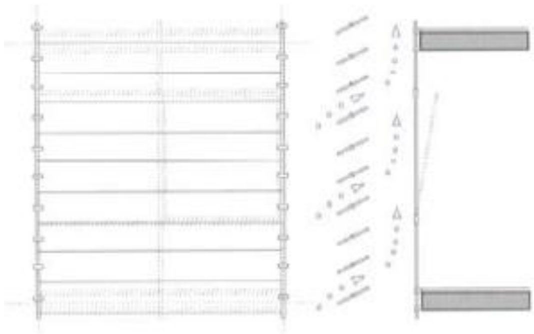

Figure 15: Controllable double skin façade system (5)

➢ ***Mono skin and double skin windows system***

- Percussion façade
- Percussion pane
- Box type Window
- Alternating façade

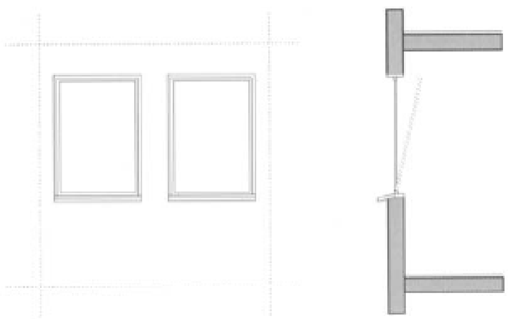

Figure 16: Percussion façade (5)

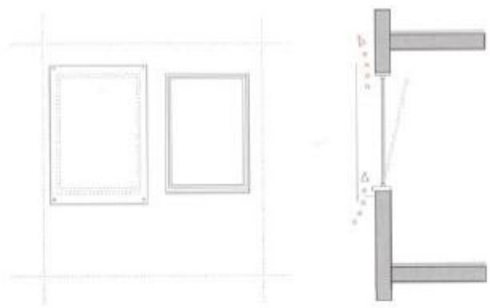

Figure 17: Percussion pane (5)

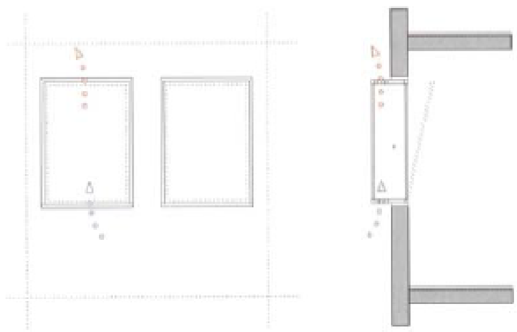

Figure 18: Box type window (5)

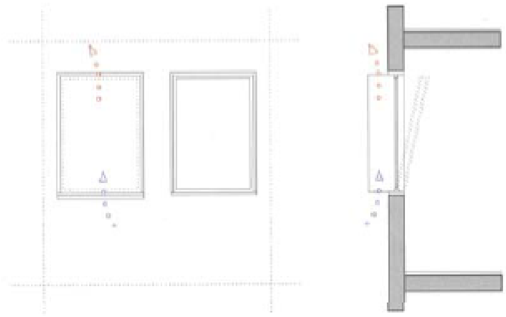

Figure 19: Alternating façade (5)

4.3.3.2 Performance indicators

The facade technology performance indicator is not related to geo-descriptors and descriptors. It is simply related to product / system characteristics. Two performance indicators are used to describe the different façade technologies.

Façade performance indicators	$T_{vis\text{-}glass}$
	U-Value$_{Total}$

Where:

- $T_{vis\text{-}glass}$: Daylight transmission [-]
- U-Value$_{Total}$: Thermal transmittance of the façade [W/m²K]

This second performance indicator is defined through the following relation:

$$U - Value_{Total} = \frac{\tau_g \times U - Value_{glazing} + (100 - \tau_g) \times U - Value_{Opaque}}{100}$$

4.3.3.3 Database

Facade performance indicators are only related to systems characteristics. Performance indicator ranges associated to each category of product are presented in the next sections.

➢ ***Mono skin façade system***

Product system	Performance indicators			
	Daylight transmission [-]		**U-Value total [W/m²K]**	
	Min	Max	Min	Max
Element façade	0.4	0.8	0.5	1.3

Table 15 : Mono skin facade system performance indicators (6) (5)

➢ ***Double skin façade system***

Product system	Performance indicators			
	Daylight transmission [-]		U-Value total [W/m²K]	
	Min	Max	Min	Max
Corridor façade	0.4	0.7	0.4	1.3
Non segmented double skin façade	0.4	0.7	0.4	1.3
Controllable double skin facade	0.3	0.6	0.4	1.3

Table 16 : Double skin facade system performance indicators (6) (5)

➢ ***Mono skin and double windows system***

Product system	Performance indicators			
	Daylight transmission [-]		U-Value total [W/m²K]	
	Min	Max	Min	Max
Perforated façade	0.4	0.8	0.3	1
Percussion pane	0.4	0.7	0.3	1.3
Box type window	0.4	0.7	0.3	1.2
Alternating facade	0.4	0.8	0.4	1.2

Table 17 : Mono skin and double skin window system performance indicators (6) (5)

4.3.4 Heat / cool storage

The main objective of a thermal storage in the building sector is to provide a buffer, in order to balance fluctuations in supply and demand of low temperature thermal energy for space heating and cooling. The demand can fluctuate in cycles of 24 hour periods (day and night), intermediate periods (a week for example) and according to seasons (spring, summer, autumn, winter). Systems for storing thermal energy (heat/cold) should therefore reflect these cycles, with either short-term, medium term or long-term (seasonal) storage capacity.

The main advantage of thermal energy storage is that heat and cold can be moved in space and time to allow utilization of energy that would otherwise be lost because not available when required.

4.3.4.1 Description

Only Phase change Materials (PCM) for the thermal applications have been considered in this report.

- ***Phase change materials***

A phase change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage (LHS) units (Wikipedia).

PCMs for building application have often the objective to use solar energy or other heat with renewable sources for heating and cooling. In this case, energy storage is necessary to match availability and demand with respect to time and also with respect to power. Two different ways to use PCMs for heating and cooling of buildings are:

- Passive systems where the heat or cold stored is automatically released when indoor or outdoor temperature rises or falls beyond the melting point (PCM in building walls and in other building components such as in **Figure 20** and **Figure 21**.

- Active systems where the stored heat or cold is in containment thermally separated from the building by insulation (PCM in heat and cold storage units – see example **Figure 22**)

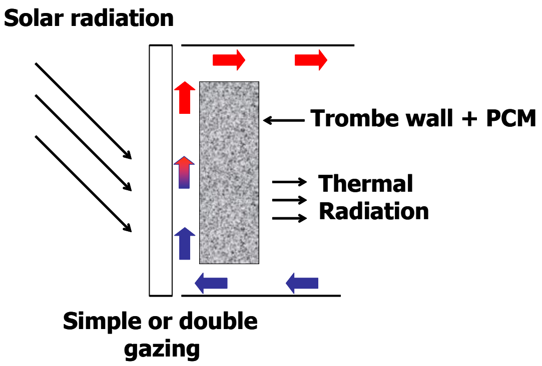

Figure 20: Optimized Trombe wall

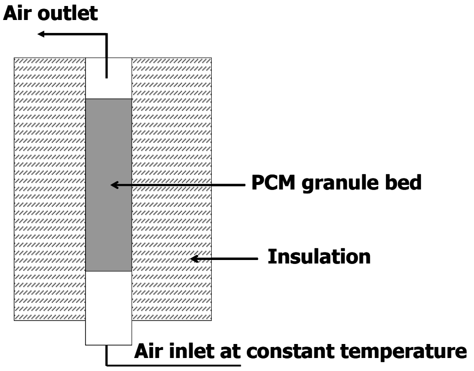

Figure 21: Ventilation system

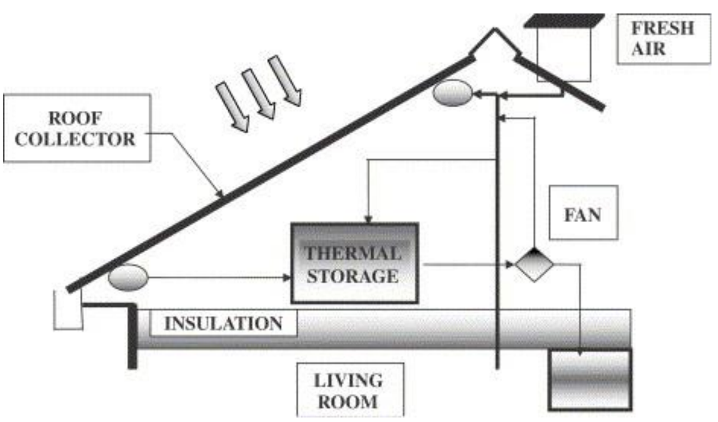

Figure 22: Solar heating system with PCM storage

4.3.4.2 Performance indicators

Heat and cool storage technology performance indicators take into account the main physical properties of products systems. The performance indicators are therefore the same for the different phase change materials products / systems.

Phase change materials performance indicators	**T_{mp}**
	L_{mp}
	c_P

Where:

- T_{mp}: Melting point temperature [°C]
- L_{mp}: Latent heat (melting) [kJ/kg]
- c_P: Specific heat capacity [kJ/kg]

4.3.4.3 Database

Heat and cool storage performance indicators are only related to systems characteristics. The following text provides the description and some range (Table 18) to identify well the performance indicator. In order to identify well the energy performance of PCM, thermal conductivity of the different phase (liquid, solid) is available as a product / system characteristic.

Material	Formula	Melting Point (°C)	Latent Heat (kJ/kg)	Density kg/m^3	Thermal conductivity (W/m.K)	Heat capacity kJ/kg.K
Water	*H2O*	*0*	*333.6*	*917(s)* *998(l)*	*0.612(l)*	*2.05(s)* *4.18 (l)*
Aluminium	*Al*			*2700s)*	*250*	*0.91*
Argon	*Ar*			*1.8(g)*	*0.016*	
Concrete				*500 to 2360*	*0.1 (lightweight) to 1.8(dense)*	*0.88(s)*
Gypsum (plasterboard)	*$CaSO_4.2H_2O$*			*2320(s)*	*0.17*	*1.09(s)*
Wood				*630(s) Average*	*0.07 to 0.15*	*1.2 to 2.3(s)*
Hexadecane	$C_{16}H_{34}$	16.7	237	773(s)	0.21	
Octadecane	$C_{18}H_{38}$	28	244	814(s) 777(l)	0.21 0.21	1.712(s)
Icosane	$C_{20}H_{42}$	36.7	246	910(s) 790(l)	0.21	n.a
Glycerol	$CH_2OHCHOHCH_2OH$	18	199	1,261(s)	0.29	2.42(l)
Polyethylene glycol E600	$H(OC_2H_2)_nOH$	22	127	1,126 (s) 1,232 (l)	0.189 (l)	n.a
n-decanoic acid (Capric acid)	$CH_3(CH_2)_8CO_2H$	31-32	152	1004(s) 893(l)	0.153(l)	n.a
n-dodecanoic acid (Lauric acid)	$CH_3(CH_2)_{10}CO_2H$	43	178	1007(s) 870l)	0.147(l)	1.76
n-tetradecanoic acid (Myristic acid)	$CH_3(CH_2)_{12}CO_2H$	54	199	990(s) 862(l)	n.a.	n.a
Methyl hexadecanoate	$C_{16}H_{31}CO_2CH3$	29.9	205	880(l)	n.a.	n.a
2-heptadecanone	$C_{16}H_{31}COCH3$	48	218	830(l)	n.a.	n.a
	$CaCl_2.6H_2O$	29.8	191	1,562(l)	1.088(s) 0.54(l)	n.a
	$Li(NO_3).2H_2O$	30.0	296	n.a.	n.a.	n.a
	$Li(NO_3).3H_2O$	30.0	189	n.a.	n.a.	n.a
	$Na_2(SO_4).10H_2O$	32	254	1485(s)	0.544(l)	n.a
	$LiBr_2.2H_2O$	*34*	*124*	n.a.	n.a.	n.a
	$FeCl_3.6H_2O$	*37.0*	*223*	n.a.	n.a.	n.a
Gallium	Ga	30.0	80.3	5,910(s)	29	0.371
Sodium acetate trihydrate + urea	$CH_3CO_2Na.3H_2O$ + NH_2CONH_2 (40:60)	30	200.5	n.a.	n.a.	n.a
Magnesium nitrate + Ammonium nitrate	$Mg(NO_3)_2.6H_2O$+ NH_4NO_3 (61.5:38.)	52	126	1596(s) 1515(l)	552(s) 494(l)	n.a

Table 18 : Phase change materials product /system characteristics (7) (8)

4.4. Active demand reduction

Active demand reduction category is composed of three main applications: artificial lighting, heat recovery ventilation, and control and monitoring system.

4.4.1. Artificial lighting

Lighting includes the use of both artificial light sources like lamps and light fixtures, as well as natural illumination by capturing daylight. Day lighting (using windows, skylights, or light shelves) is sometimes used as the main source of light during daytime in buildings. This is a solution for saving energy in place of using artificial lighting, which represents a major component of energy consumption in buildings. This action has to be included during the building design phase. Nevertheless, lamps are necessary because natural light is not always sufficient.

4.4.1.1 Description

This chapter presents different lighting technologies. Fluorescent lamps and Solid state lamps are studied in this work.

➢ ***Fluorescent lamps***

Fluorescent lamps include tubular lamps and compact lamps.

- Tubular lamps

This lighting technology is the most widely used method of lighting. Tubular lamps are mostly found in kitchens, basements, or garages. Residential use of tubular lighting varies depending on the price of energy, financial and environmental concerns of the local population, and acceptability of the light output. In order to compare tubular lamps with other technologies, the advantages and disadvantages are analyzed:

- Advantages
  - Luminous efficacy
  - Life
  - Lower luminance
  - Lower heat
- Disadvantages
  - Frequent switching
  - Health and safety issues
  - Ultraviolet emission
  - Ballast
  - Power quality and radio interference
  - Operating temperature
  - Lamp shape
  - Flicker problems
  - Dimming
  - Disposal and recycling

Figure 23 shows a short schematic representation of the tubular lamp technology. The different components are detailed.

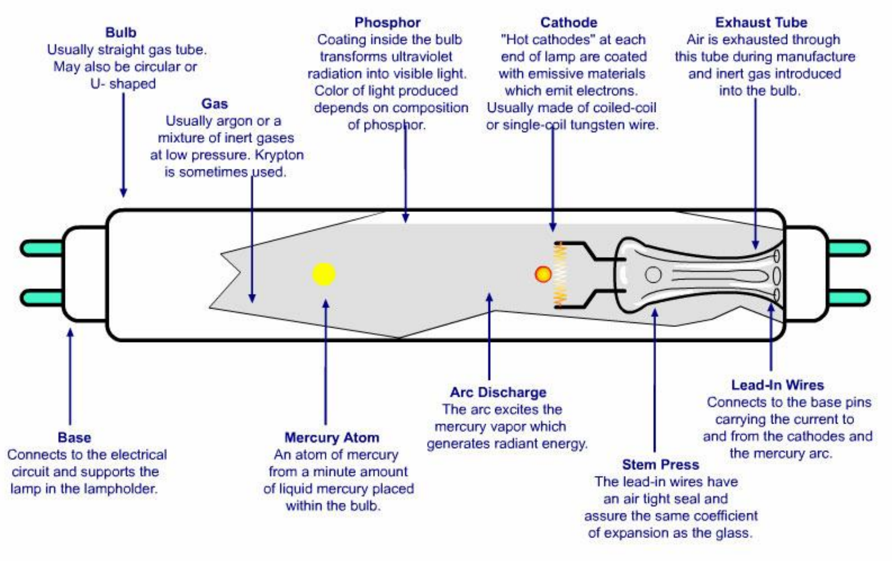

Figure 23 : Tubular lamps schematic representation

- Compact lamps

The primary objectives of CFL design are high luminous efficacy and durability. As to the design, compact lamps are often larger than their incandescent equivalents. In order to compare compact lamps with other technologies, the advantages and disadvantages are analyzed:

- Advantages
  - Less energy usage
  - Longer life
  - Money savings
  - Less heat production
  - More natural lighting
- Disadvantages
  - Starting time
  - Human health
  - Mercury content
  - Size
  - End of life
  - Recycling
  - Greenhouse gases

Figure 24 provides a short schematic representation of the compact lamp technology. The different components are detailed.

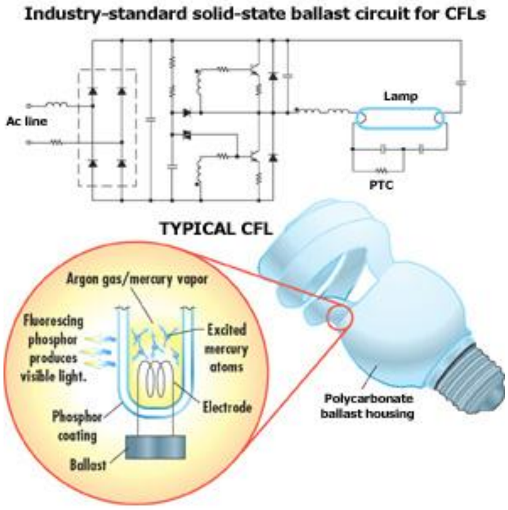

Figure 24 : Compact Lamps schematic representation

➢ ***Solid-state lamps***

Solid-state lamps are essentially composed of LED lamps technology. So LED lamp is a solid-state lamp that uses light-emitting diodes (LEDs) as the source of light. LED application domains are numerous. For example, we can found LED for automotive lighting, bicycle lighting, billboard displays, display lighting in art galleries to reduce heating on work to low values, domestic lighting, emergency lighting, flashlight, floodlighting of buildings, grow lights for plants, public transit vehicle route and destination signs, railway signals, stage lighting, traffic lights, train light, and the likes. In order to compare LED lamps with other technologies, the advantages and disadvantages have been analyzed:

- Advantages
  - Saving energy up to 90%
  - Up to 50 000 burning hours
  - Hardly heat development
  - Easily dimmable
  - Resistant against on and off switching
  - Fits standard fittings
  - Virtually unbreakable when dropped
  - No infrared and UV radiation
  - No toxic substances such as mercury
  - Completely recyclable
- Disadvantages
  - A very limited variety and selection for your home compared to other types of lighting
  - Hard to find in smaller towns where consumers may have a smaller interest in this lighting alternative
  - Significantly more expensive than regular lighting and not budget conscious
  - Not good for residential flood lighting
  - Although they are available in many color, the quality of the colors is not quite as good as with regular lighting

Figure 25 gives a short schematic representation of the LED lamp technology. The different components are detailed.

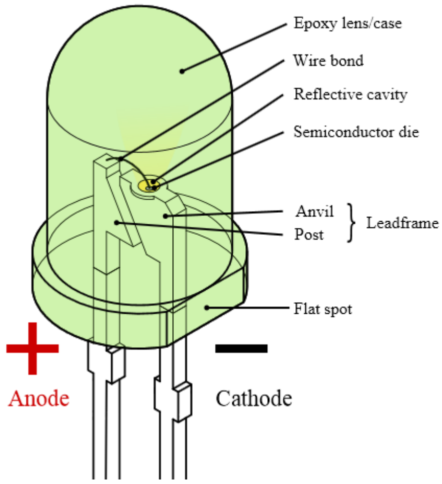

Figure 25 : LED schematic representation

4.4.1.2 Performance indicators

The artificial lighting technology performance indicator is not related to climate and building typology. However the performance of this technology is directly linked to the system characteristics of this technology. The definition of this indicator is the same as for the different artificial lighting technology (Fluorescent lamps, and Solid state lamps). This performance indicator is luminous efficiency of radiation (η_{CL}). It measures the fraction of electromagnetic power which is useful for lighting. It is obtained by dividing the luminous flux by the radiant flux. Light with wavelengths outside the visible spectrum reduces luminous efficacy, as it contributes to the radiant flux while the luminous flux of light is zero.

Artificial lighting performance indicator	η_{CL}

Where:

- η_{CL} : luminous efficiency [lm/W]

4.4.1.3 Database

Artificial lamps performance indicator doesn't depend on the geographic context. The Table 19 gives the artificial lighting performance indicators of different lighting technologies.

Technology	**Products / systems**	η_{CL} **MIN** **[lm/W]**	η_{CL} **MAX** **[lm/W]**
Fluorescent lamps	**Tubular lamps**	60	104

	Compact lamps	46	60
Solid state lamps	**LED**	28	150

Table 19 : Artificial lighting technology performance indicators

4.4.2 Heat recovery ventilation

Heat recovery ventilation systems are integrated in buildings to provide high indoor air quality by changing air in any space. Heat recovery ventilation is a way to maintain proper ventilation and improve air quality while saving energy. The main idea is to use a heat exchanger between the inbound and the outbound air flow in order to recover heat at the air outlet and to transfer it in the air inlet. Figure 26 gives a schematic representation of heat recovery ventilation systems.

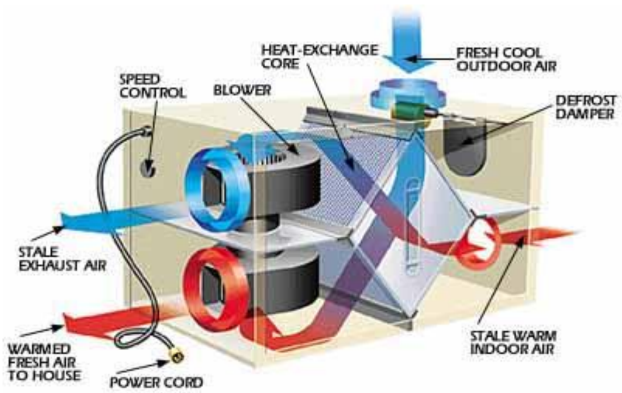

Figure 26 : Heat recovery ventilation system schematic

4.4.2.1 Description

There are three main technology systems that compose the heat recovery ventilation technology. We can distinguish air-to-air heat exchanger, rotary heat exchanger, and heat pipe exchanger. The next sub-chapters give details about these systems technology.

- ***Air to air heat exchanger***

An air-to-air heat exchanger brings two air streams of different temperatures into thermal contact, transferring heat from the exhausting inside air to incoming outside air during the heating season.

- ***Rotary heat exchanger***

The main component of the rotary wheel exchanger is the wheel. Available in various materials, this usually consists of aluminum sheet, which are alternately flat or corrugated. The result of this is that a series of passages is created through which the two air-flows move in opposite directions. In rotary heat exchanger, thermal exchange takes place through the accumulation of heat in the wheel. Thus, while the rotor rotates slowly, the exhaust air moves across half of the unit and transfers heat to the matrix of the wheel, which accumulate it. Supply air crossing the other half absorbs the heat accumulated.

➢ ***Heat pipe heat exchanger***

Heat pipe heat exchanger consists of three elements: a sealed container, a capillary wick structure and sufficient working fluid to saturate the wick structure. Because the container is vacuum sealed, the working fluid is in equilibrium with its own vapor. Heating any part of the external surface, causes instantaneous evaporation of the working fluid near that surface (the evaporation region) with the latent heat of vaporization absorbed by the vapor formed. The rapid generation of vapor at any point on the tube wall area creates a pressure gradient within the heat pipe which forces the excess vapor to a remote area of the pipe having a lower pressure and temperature. Here the vapor condenses on the tube wall and latent heat of vaporization is transferred (the condenser region).

4.4.2.2 Performance indicators

The heat recovery ventilation technology performance indicator related to climate, building typology and technology parameters is defined by the thermal annual energy loss due to ventilation per m² of building area.

Heat recovery performance indicator	$\boldsymbol{E_{vloss}}$

Where, the following formula details the heat recovery ventilation systems technology indicator. This technology indicator is correlated to technology parameters, building typology and geo-parameters.

$$E_{vloss} = (1-\tau_{hr}) \cdot V_b \cdot \rho_{air} \cdot c_{Pair} \cdot \tau_{air} \cdot \left(T_c - T_{air,h,s}\right) \cdot \frac{8760}{3600 \times 1000 \times A_l} + P_{aux} \cdot \frac{8760}{1000 \cdot A_l}$$

Where the individual elements of this formula are defined as follows:

- $T_{air,\,h,\,s}$: Average ambient temperature over heating season [°C]
- T_c: Indoor air temperature [°C]
- τ_{air}: Air change rate [Vol/h]
- C_{fr}: Flow reduction factor [-]
- τ_{hr}: Heat recovery rate [-]
- P_{aux}: Auxiliaires power (fan, …) [W]
- V_b: Heated volume [m^3]
- A_l: Heated area [m²]
- ρ_{air}: Air density [kg/m^3]
- c_{Pair}: Air heat capacity [J.kg^{-1}.K^{-1}]

4.4.2.3 Database

Heat recovery ventilation systems performance indicator is related to climate, systems characteristics, and descriptors. The following sections give the description and some range to assess the performance indicator.

➢ ***Geo-descriptors***

Heat recovery ventilation technologies are related to a unique climate descriptor; the average external air temperature over the heating seasonal: $T_{air,\,h,\,s}$ [°C].

- ***Products / system characteristics***

Heat recovery ventilation systems are characterized by two main characteristics. Table 20 describes the value of these parameters for different heat recovery ventilation systems.

Products / systems	τ_{hr} [-]	P_{aux} [W]
Air-to-air heat exchanger	0.7	100 – 1500
Rotary heat exchanger	0.8	100 – 1500
Heat pipe exchanger	0.9	100 – 1500

Table 20 : Heat recovery ventilation system characteristics

- ***Descriptors***

Energy performance of ventilation systems relies on different descriptors. These descriptors are correlated to the building typology and national regulation. Two building types have been defined, house and apartment. A building type is defined by its heated gross area, heated volume and its hourly air change rate. Most of the time this last parameter is fixed by sanitary national regulation (see Table 21)

	Building typology	
Building parameters	**House**	**Apartment**
A_l : Heated area [m²]	100	60
V_b: Heated volume [m³]	250	150
T_{air} : Air change rate [Vol/h]	0.55	0.45

Table 21 : Heat recovery ventilation descriptors

Example

Heat recovery ventilation performance indicators depend on the context (climate, building typology and regulation). Figure 27 gives the superposition of administrative zones and climatic zones for France. Geo-descriptors corresponding to these zones are detailed in Table 22.

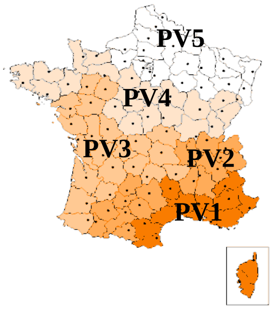

Figure 27 : French climatic zoning

Climatic zone	PV1	PV2	PV3	PV4	PV5
$T_{air, h, s}$ [°C]	9.9	10.2	10.1	9.1	8.7

Table 22 : Heat recovery ventilation geo-parameters for 5 French climatic zones

The thermal annual energy loss due to ventilation per m² of building area has been calculated for different heat recovery ventilation systems and for the PV5 climatic zone. Results are given in Table 23. Calculations have been done with an auxiliary power of 100 W.

System \ Building typology	E_{vloss} [kWh/m².year]			
	House		Apartment	
	Min	Max	Min	Max
Air-to-air heat exchanger	16.9	27.5	19.8	32.2
Rotary heat exchanger	13.6	22.1	17.1	27.8
Heat pipe exchanger	10.3	16.8	14.4	23.4

Table 23 : Heat recovery ventilation indicator for PV5 French climatic zone and P_{aux}=100W

In order to further reduce energy consumption of ventilation systems, heat recovery ventilation systems can be matched with demand controlled systems.

4.4.3 Building automation control system

Building automation describes the advanced functionality provided by the control system of a building. A Building Automation Control (BAC) system is computerized and based on an intelligent network of electronic devices designed to monitor and control the mechanical, electronics, and lighting systems in a building.

4.4.3.1 Description

BAC core functionality keeps the building climate within a specific range, provides lighting, and monitors system performance and devices failures. The BAC functionality reduces building energy and maintenance costs when compared to a non-controlled building. A building controlled by BAC system is often referred to an intelligent building system. In this report, four main application domains have been identified: Heating / cooling control, lighting control, ventilation control, and blind control.

➢ ***Heating / cooling control***

Heating and cooling control systems are used to improve the efficiency of heating and cooling systems. The objective is to incorporate control strategies that ensure systems are used only when necessary. In this report, four main heating / cooling control strategies have been identified:

- No automatic control
- Individual room automatic control + Intermittent control with fixed time program
- Sequencing of different generators based on load and generators capacities
- Intermittent control with optimum start / stop

➢ ***Lighting control***

A lighting control system consists of a device that controls electric lighting and devices, alone or as part of a daylight harvesting system, for a public, commercial, or residential building or property. Lighting control systems are used for working, aesthetic, and security illumination for interior, exterior, and landscape lighting. So, in this work, three main lighting control systems have been identified:

- Manual on / off switch
- Manual on / off switch + additional sweeping extinction signal
- Automatic detection (occupancy & daylight)

Figure 28 gives a schematic representation of a lighting control system based on automatic detection.

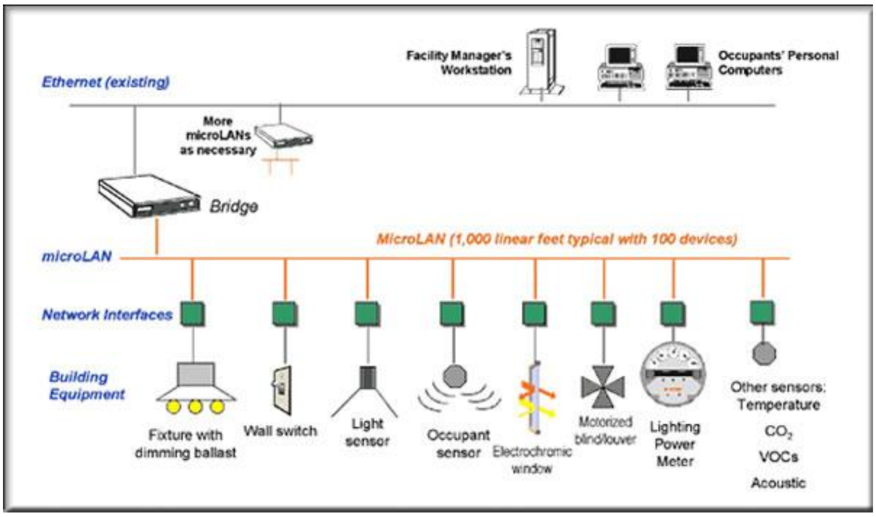

Figure 28 : Schematic representation of a lighting control system

➢ ***Ventilation control***

Controlled ventilation is a way to maintain proper ventilation and improve air quality while saving energy. The main idea is to reduce the total outdoor air supply during periods of less occupancy. So, in this work, four main ventilation control systems have been identified:

- Manual air flow control
- On / off time air flow control
- Presence air flow control
- Demand air flow control

Figure 29 gives a schematic representation of a ventilation control system based on presence air flow control.

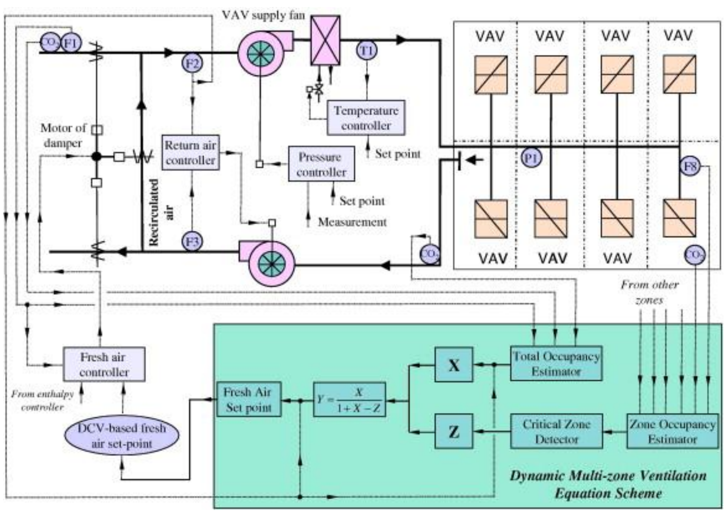

Figure 29: Schematic representation of a ventilation control system

- ***Blind control***

Blind control systems are used in building to improve lighting, and thermal comfort. In order to improve building energy efficiency, blind control strategies can also be related to other building automation controls. In this work three main blind control systems have been identified:

- Manual operation / Motorized operation with manual control
- Automatic control
- Combined light / blind / HVAC control

Figure 30 provides a schematic of blind control system.

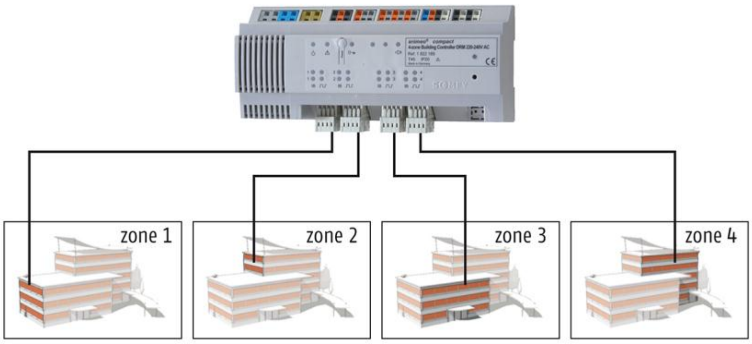

Figure 30 : Schematic representation of a blind control system

4.4.3.2 Performance indicators

Building Automation Control technology performance indicator is defined as a percentage of energy saving that could be achieved by implementing an advanced automation system compared with a reference system. Reference system corresponds to traditional and technical systems that provide no automation or energy-efficiency.

Building automation control system performance indicator	E_{BAC}

The BAC performance indicator is given by the following expression:

$$E_{BAC} = 100 \cdot \left(1 - \frac{f_{BAC}}{f_{BACref}}\right)$$

Where:

- E_{BAC}: Percentage of energy saving [%]
- f_{BAC}: Building Automation Control factor [-]
- f_{BACref}: Building Automation Control factor for the reference system [-]

4.4.3.3 Database

Building Automation Control system performance indicator is based on EN 15232 standard (10). The different systems characteristics are related to the building typology.

- ***Products / systems characteristics***

Tables 22 to 25 give the BAC energy efficiency factors for the different Building Automation Control technologies. The first line of each table (colored in yellow) corresponds to the reference system.

- *Heating / cooling control*

System \ Building typology	Single family house	Multi-family house	Office	Commercial	Health & welfare	Educational	Restaurants	Hotels
No automatic control	1.1	1.1	1.51	1.56	1.31	1.20	1.23	1.31
Individual room automatic control + Intermittent control with fixed time	1	1	1	1	1	1	1	1
Sequencing of different generators based on load and generator capacities	0.88	0.88	0.80	0.73	0.91	0.88	0.77	0.85
Intermittent control with optimum start / stop	0.81	0.81	0.70	0.60	0.86	0.80	0.68	0.68

Table 24: BAC thermal energy efficiency factors for heating / cooling control (10)

- *Lighting control*

System \ Building typology	Single family house	Multi-family house	Office	Commercial	Health & welfare	Educational	Restaurants	Hotels
Manual on / off switch	1	1	1.1	1.08	1.05	1.07	1.04	1.07
Manual on / off switch + additional sweeping extinction signal	1	1	1	1	1	1	1	1
Automatic detection (occupancy & daylight)	0.92	0.92	0.87	0.91	0.96	0.86	0.92	0.90

Table 25: BAC electrical energy efficiency factors for lighting control (10)

- *Ventilation control*

System \ Building typology	Single family house	Multi-family house	Office	Commercial	Health & welfare	Educational	Restaurants	Hotels
Manual air flow control	1.08	1.08	1.1	1.08	1.05	1.07	1.04	1.07
On / off time air flow control	0.93	0.93	1	1	1	1	1	1
Presence air flow control	0.92	0.92	0.93	0.95	0.98	0.93	0.96	0.95
Demand air flow control	0.92	0.92	0.87	0.91	0.96	0.86	0.92	0.90

Table 26: BAC thermal and electrical energy efficiency factors for Ventilation control (10)

- *Blind control*

System \ Building typology	Single family house	Multi-family house	Office	Commercial	Health & welfare	Educational	Restaurants	Hotels
Manual operation / motorized operation with manual control	1	1	1	1	1	1	1	1
Automatic control	0.93	0.93	0.93	0.95	0.98	0.93	0.96	0.95
Combined light / blind / HVAC control	0.92	0.92	0.87	0.91	0.96	0.86	0.92	0.90

Table 27: BAC electrical energy efficiency factors for blind control (10)

4.4.3.4 Example

Example 1: heating / cooling control

Advanced automation system: Individual room automatic control + Intermittent control with fixed time program implemented in a school.
In this case, f_{BACref}=1.2 and f_{BAC}=1, the energy saving for heating/cooling control is equal to 17% through the performance indicator formula.

Example 2: lighting control

Advanced automation system: Lighting control with automatic detection (occupancy & daylight) implemented in a single family house.

In this case, f_{BACref}=1 and f_{BAC}=0.92, the energy saving for lighting control is equal to 8% through the performance indicator expression.

4.5. Active demand generation and storage

Active demand generation and storage category have three main applications: cooling, heating and DHW and electricity production systems.

4.5.1. Cooling

Cooling application is used in building in order to decrease the indoor air temperature, mostly during summer, in order to improve the thermal comfort. Technology performance indicators will be used here to identify the most energy-efficient technologies in a given context. With that in mind, a special focus is given to solar cooling technologies.

4.5.1.1. Description

Solar cooling technologies can be classified into passive systems and active systems. Passive systems rely on daily changes in temperature and relative humidity. The key technology considered in this project for passive systems is the evaporative cooling. Active systems require refrigeration systems. The three main key technologies considered in this project for active systems are desiccant cooling, adsorption cooling and absorption cooling.

- ***Evaporative cooling***

Evaporative cooling system is device that cools air through the evaporation of water. Evaporative cooling works by employing water's large enthalpy of vaporization. The temperature of dry air can drop significantly through the phase transition of liquid water to water vapor (evaporation), which can cool air using much less energy than refrigeration. In extremely dry climates, evaporative cooling of air has the added benefit of conditioning the air with more moisture for the comfort of building occupants. Unlike closed-cycle refrigeration, evaporative cooling requires a water source, and must continually consume water to operate. Figure 31 gives a schematic representation of an evaporative cooling system.

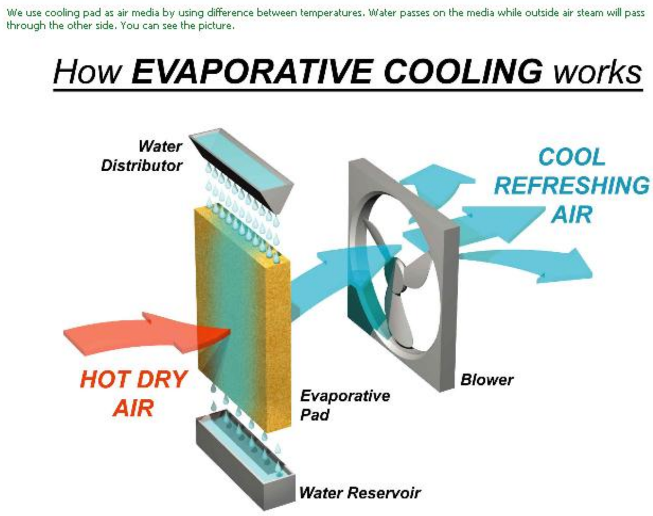

Figure 31 : Schematic representation of an evaporative cooling system

- ***Desiccant cooling***

Desiccant cooling is effective in warm and humid climate. Natural cooling of human through sweating does not occur in highly humid conditions. Therefore, a person's tolerance to high temperature is reduced and it becomes desirable to decrease the humidity level. In desiccant cooling method, desiccant salt or mechanical dehumidifiers are used to reduce humidity in the atmosphere. Materials having high affinity for water are used for dehumidification. They can be solid like silica gel, alumina gel and activated alumina, or liquids like triethylene glycol. Air from the outside enters the unit containing desiccants and is dried adiabatically before entering the living space. **Figure 32** gives a schematic representation of a desiccant cooling system.

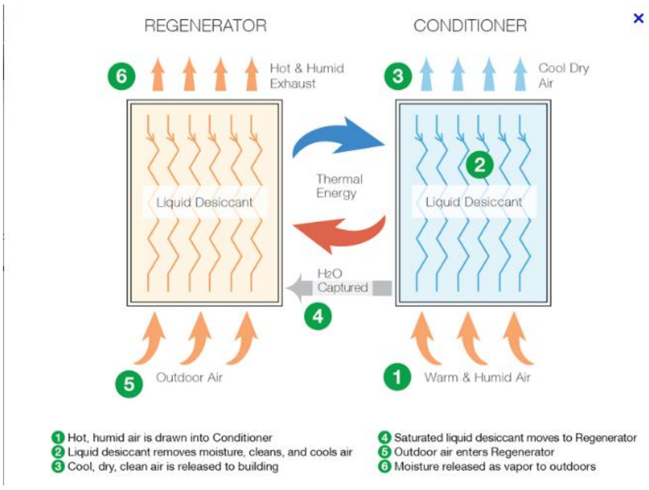

Figure 32 : Schematic representation of a desiccant cooling system

- ***Solar absorption / adsorption cooling***

Solar absorption / adsorption cooling use thermal collector to provide solar energy thermally driven chillers. The solar energy heats a fluid that provides heat to the generator of an absorption / adsorption chiller and is recirculated back to the collectors. The heat provided to the generator drives a cooling cycle that produces chilled water. The chilled water produced is used for large commercial and industrial cooling. Solar thermal energy can be used to efficiently cool in summer, and also heat domestic hot water and buildings in winter. The difference between absorption and adsorption system is due to the physical phenomena used for cooling. For absorption systems, the absorbed molecules come inside the solid. For adsorption systems, the adsorbed molecules are fixed on the surface of the solid. Absorption / adsorption chillers operate with less noise and vibration than compressor-based chillers. **Figure 33** gives a schematic representation of a solar absorption cooling system.

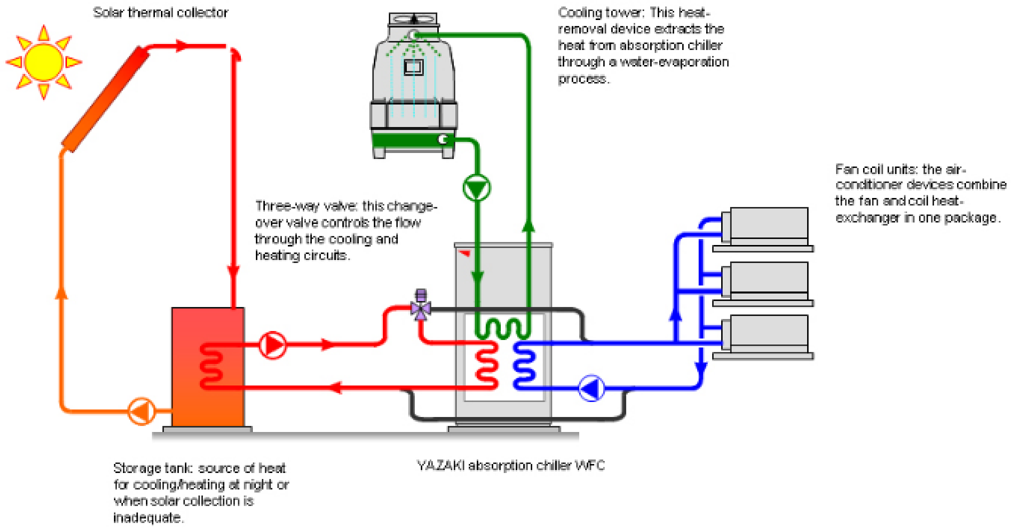

Figure 33 : Schematic representation of a solar absorption cooling system

4.5.1.2. Performance indicators

➢ ***Evaporative cooling***

Evaporative cooling performance indicator is characterized by the Cooling Seasonal Performance Factor.

Evaporative cooling performance indicator	***CSPF***

The definition of the CSPF for evaporative cooling is detailed by the following formula.

$$CSPF = \frac{\dot{m}_{Air} \cdot c_P \cdot \left(T_c - T_{air,c,s} + \left(T_{air,c,s} - T_{air,WB,c,s}\right) \cdot \varepsilon\right)}{P_{fan}}$$

$$\dot{m}_{Air} = \frac{Q_R}{c_P \cdot \left(T_{air,c,s} - T_{air,WB,c,s}\right) \cdot \varepsilon_m}$$

Where:

- Q_R: Cooling capacity [W]
- $\dot{m}_{air}$: air mass flow [kg/s]
- Cp : air specific energy [J/kg K]
- T_c : indoor air temperature [°C]
- $T_{air,\,c,\,s}$: Average ambient temperature over cooling season[°C]
- $T_{air,\,WB,\,c,\,s}$: Average ambient wet bulb temperature over cooling season [°C]
- $\boldsymbol{\varepsilon}$: evaporative media efficiency [%]
- ε_m : electromotor efficiency (%)
- P_{fan} : fan power [W]

- ***Desiccant cooling***

Desiccant cooling performance indicator is characterized by the coefficient of performance of the systems.

Desiccant cooling performance indicator	***COP***

The definition of the COP for evaporative cooling is detailed by the following formula.

$$COP = \frac{\dot{Q}_{DES}}{P_{losses}} = \frac{\dot{m}_P \cdot c_P \cdot (T_i - T_4)}{P_{fan} + \dot{Q}_R}$$

Figure 34 and Figure 35 describe the system and the thermodynamic cycle for desiccant cooling cycle.

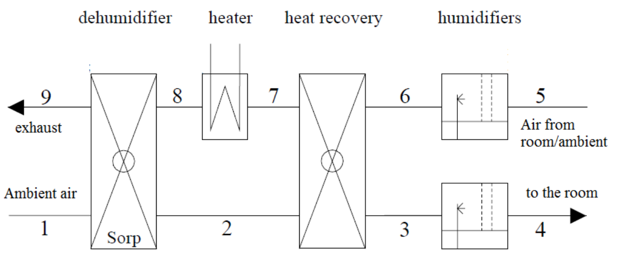

Figure 34 : Evaporative and desiccant cooling system description

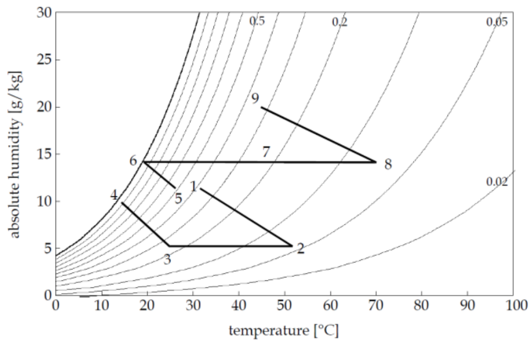

Figure 35 : Evaporative, desiccant cooling thermodynamic cycle

The thermodynamics equations for desiccant cooling are given below (according to pictures above):

$$x_2 = x_1 - (x_9 - x_8)\, R/P \qquad T_2 = T_1 + (T_8 - T_9)\, R/P \qquad T_3 = T_2 - \varepsilon_{cw}\,(T_2 - T_6)$$

$$x_3 = x_2$$

$$T_4 = T_3 - \varepsilon_d\,(T_3 - T_{3w}) \qquad T_{4w} = T_{3w}$$

$$x_7 = x_6$$

$$T_6 = T_5 - \varepsilon_d\,(T_5 - T_{5w}) \qquad T_{6w} = T_{5w} \qquad T_7 = T_6 + \frac{(T_2 - T_3)}{R/P}$$

$$T_9 = T_8 - \frac{(T_2 - T_1)}{R/P} \qquad x_9 = x_8 - \frac{(x_2 - x_1)}{R/P} \qquad T_8 = T_7 + \frac{Q_R}{\dot{m}_P\, C_P}$$

$$\dot{m}_{Air} = \frac{Q_R}{h_5 - h_4}$$

$$\dot{m}_P = \frac{\dot{m}_{Air}}{R/P}$$

Where:

- Q_R: Cooling capacity

- $\dot{m}_P$: process mass flow [kg/s]
- $\dot{m}_{Air}$: air mass flow (kg/s) – defined by fan
- R/P : reactivation air flow/process air flow [-]
- P : power consumption [W]
- T : temperature, [°C]
- T_i : room temperature [°C]
- C_p : specific heat of moist air at constant pressure [kJ/kg°C]
- x : specific humidity [g_{water} / kg] dry air
- $h_4(t_4,x_4)$ – air enthalpy on the entrance of room [kJ/kg]
- $h_5(t_5,x_5)$ – air enthalpy on the exit of room [kJ/kg]

Greek Symbols

- ε_d : direct evaporative cooling effectiveness [-]
- ε_{CW} : energy conservation wheel effectiveness [-]

Subscripts

- numbers correspond to points in Figure above
- i : inside room
- w : corresponds to wet bulb temperature; water
- R : regeneration
- fan : ventilator, fan

➢ ***Solar absorption / adsorption cooling***

Solar absorption/adsorption cooling performance indicator is characterized by the Cooling Season Performance Factor.

Solar absorption / adsorption cooling performance indicator	$CSPF$

The solar Absorption / Adsorption cooling performance indicator (CSPF) is defined has the ratio of cooling power to heating power over the cooling season. The following equation gives the definition of Solar Ab / Ad cooling CSPF:

$$CSPF = \frac{P_c}{P_H}$$

Where:

- P_c : Average cooling power produced by the cooling system (Absorption / Adsorption) during daylight over cooling season per square meter of solar collectors [W/m²]
- P_H: Average heating power produced by the solar collectors during daylight over cooling season per square meter of solar collectors [W/m²]

P_H is calculated as follows:

$$P_H = \eta \cdot G_{south,45°} = \eta_0 \cdot G_{south,45°} \cdot K_\theta - a_1 \cdot (T_H - T_{air,cool,day}) - a_2 \cdot (T_H - T_{air,cool,day})^2$$

Where:

T_H : Average hot water temperature of solar collectors during daylight over cooling season [°C]

This nonlinear equations system is resolved using the algorithm detailed in Figure 36.

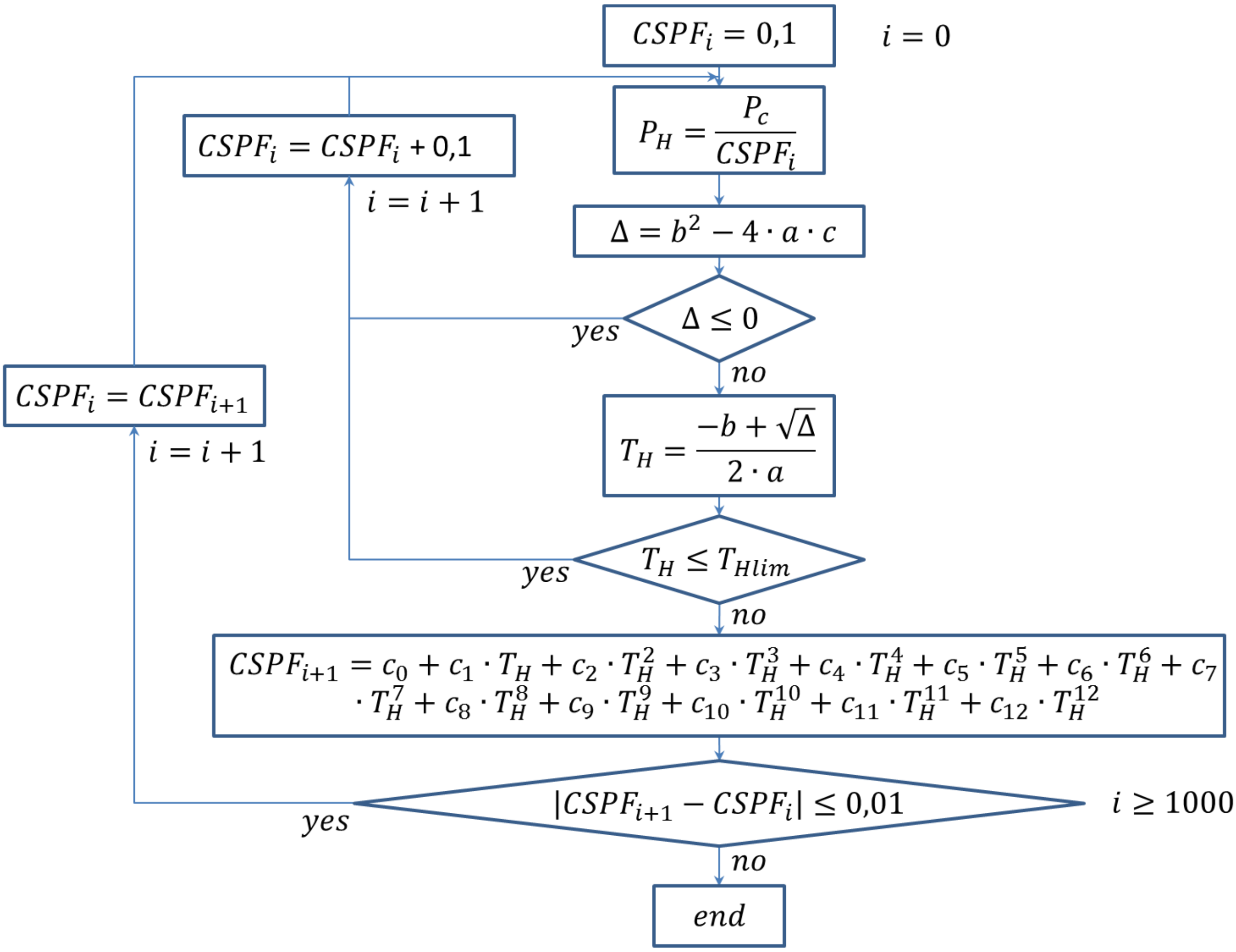

Figure 36: Algorithm used to compute the solar Absorption / Adsorption cooling CSPF

Where:

$$a = a_2$$

$$b = (a_1 - 2 \cdot a_2 \cdot T_{air,cool,day})$$

$$c = a_2 \cdot T_{air,cool,day}^2 - a_1 \cdot T_{ext} - \eta_0 \cdot G_{south,45°} \cdot K_\theta + P_H$$

- η_0: Collector optical efficiency [-]

- a1: Collector thermal convection and conduction losses [W/K/m²]
- a2: Collector radiative losses [W/K²/m²]
- K_θ: Beam radiation incidence angle modifier [-]
- $T_{air, cool, day}$: Average ambient temperature during daylight over the cooling period [K]
- $G_{south, 45°}$: Average solar irradiation during daylight over the cooling season on a south oriented plane with a 45° slope [W/m²]

4.5.1.3. *Database*

For cooling technology, performance indicators are linked to geo-descriptors, product/systems characteristics and descriptors.

- ***Geo-descriptors***

Cooling technology is related to four climatic parameters:

- $T_{air, a}$: Annual average External air temperature [°C]
- $T_{air, max}$: Maximum annual external temperature [°C]
- $T_{air, c, s}$: Average ambient dry bulb temperature over cooling season [°C]
- $T_{air, WB, c, s}$: Average ambient wet bulb temperature over cooling season [°C]
- $T_{air, cool, day}$: Average ambient temperature during daylight over cooling season [°C]
- $G_{south, 45°}$: Average solar irradiation during daylight over cooling season on a south oriented plane with a 45° slope [W/m²]

- ***Products / systems characteristics***

- Evaporative cooling

Evaporative cooling technology is characterized by the evaporative media efficiency. Table 26 gives this efficiency for different systems.

Systems	ε: Evaporative media efficiency [%]
Single Stage	80
Two stage Indirect Section	60
Two stage Direct Section	90

Table 28 : Evaporative cooling - System characteristic

- Desiccant cooling

Desiccant cooling technology is characterized by six main system characteristics:

- $\dot{m}_P$: process mass flow [kg/s]
- $\dot{Q}_R$: Cooling capacity
- R/P : reactivation air flow/process air flow [-]

- P_{fan} : fan power consumption (W)
- ε_d : direct evaporative cooling effectiveness [-]
- ε_{CW} : energy conservation wheel effectiveness [-]

Table 29 gives ranges of variation of these system characteristics.

	ε_d	ε_{CW}	R/P	P_{fan} (kW)	Building typology
Desiccant cooling	0,5 – 0,9	0,6 – 0,9	0,3 – 1,0	1- 10	House
	0,5 – 0,9	0,6 – 0,9	0,3 – 1,0	3 - 50	Apartment building

Table 29 : Desiccant cooling - System characteristics

- Solar absorption / adsorption cooling

Solar absorption / adsorption cooling technologies are featured by eighteen main system characteristics. Fourteen system characteristics are used for cooling system. Table 30 and Table 31 give the values of these characteristics for different cooling systems.

The CSPF expression has been established by fitting the evolution of the COP of different cooling systems influenced by the hot water temperature. Figure 37 gives a representation of these different COP. A twelve degree polynomial has been defined to fit the CSPF as a function of the average hot water temperature of solar collectors during daylight over cooling season. The following equation details the polynomial expression:

$$CSPF = c_0 + c_1 \cdot T_H + c_2 \cdot T_H^2 + c_3 \cdot T_H^3 + c_4 \cdot T_H^4 + c_5 \cdot T_H^5 + c_6 \cdot T_H^6 + c_7 \cdot T_H^7 + c_8 \cdot T_H^8 + c_9 \cdot T_H^9 + c_{10} \cdot T_H^{10} + c_{11} \cdot T_H^{11} + c_{12} \cdot T_H^{12}$$

The fitting coefficients are detailed in the Table 30.

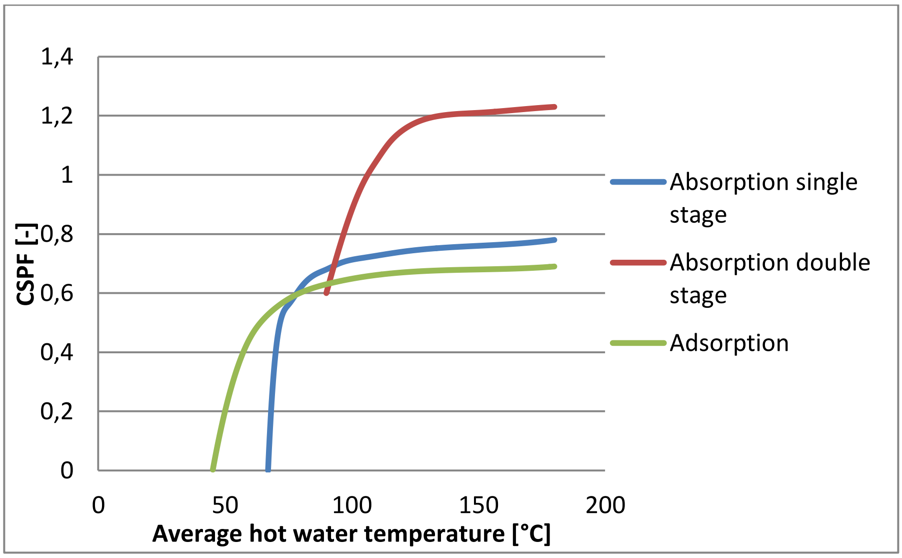

Figure 37: Performance of Absorption / Adsorption cooling systems – Influence of the average hot water temperature

	Systems characteristics												
Chiller	C_{12}	C_{11}	C_{10}	C_9	C_8	C_7	C_6	C_5	C_4	C_3	C_2	C_1	C_0
Absorption single stage	-8,44E-21	1,29E-17	-8,94E-15	3,73E-12	-1,04E-09	2,05E-07	-2,92E-05	0,00302748	-0,22690486	11,9849464	-423,423465	8983,31347	-86549,3652
Absorption double stage	-1,31E-20	2,10E-17	-1,53E-14	6,72E-12	-1,98E-09	4,13E-07	-6,24E-05	0,00686584	-0,54736361	30,8062938	-1161,62261	26343,8304	-271682,275
Adsorption	4,21E-23	-6,25E-20	4,18E-17	-1,67E-14	4,41E-12	-8,15E-10	1,08E-07	-1,02E-05	0,00069389	-0,03258337	1,00211711	-17,984971	140,823316

Table 30: Cooling systems – systems characteristics

Chiller	T_{Hmin} [°C]
Absorption single stage	67
Absorption double stage	90
Adsorption	43

Table 31: Cooling systems – systems characteristics

Four others system characteristics are used to describe the solar collector (Table 32):

	Systems characteristics			
Solar collectors	η_0	a_1	a_2	K_θ
Flat plate collectors	0.8	4	0.008	0.94
Vacuum tube collectors	0.7	1.3	0.008	0.97

Table 32 : Solar collectors – system characteristics

- ***Descriptors***
  - Evaporative cooling

To assess the annual energy performance of evaporative cooling technology, some parameters related to the building typology must be defined (see **Table 33**).

	Building Typology	
	House	Apartment building
Q_R: Cooling capacity [kW]	3	50
P_{fan} : Fan Power [kW]	2	30

Table 33 : Evaporative cooling – Descriptors

4.5.1.4. Example

In this example, performance indicators have been calculated for one cooling technology (evaporative cooling), one country (Slovenia) and two building typologies (house and apartment building). **Figure 38** gives the superposition of administrative zones and climate zones for Slovenia. Geo-descriptors corresponding to these zones are detailed in **Table 34**. In WP3 more examples will be developed and analyzed, since solar cooling is selected as one of the key technologies to be studied. In the following paragraphs basic examples are given. The examples describe cooling technologies as standalone technologies. In WP3, connection with heat source (e.g. solar collector) which is another technology will be established.

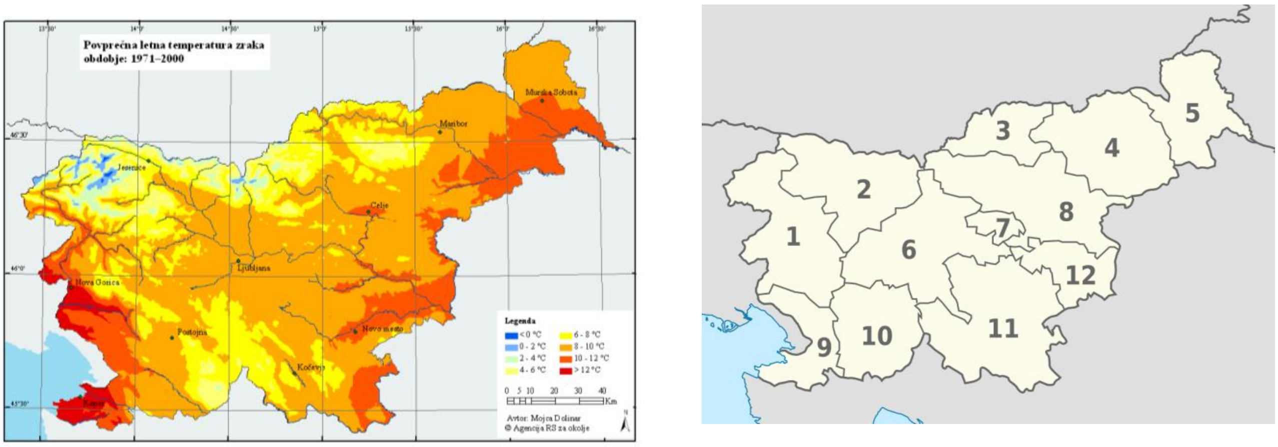

Figure 38 : Slovenia climate zoning: temperature (left), administrative zones (right)

Climatic zone	1	2	3	4	5	6	7	8	9	10	11	12
$T_{air, a}$	12	8.2	8.1	10.1	9.6	10.2	9.1	9.6	12.8	7.2	8	10
$T_{air, max}$	37.5	36.3	34.5	36.8	37.9	37.1	33.6	36.8	36.3	34	35.6	37.4
$T_{air, c, s}$	18.9	16.8	16.6	18.1	17.7	18.2	16.6	17.6	19.1	15.8	16.5	17.9
$T_{air, WB, c, s}$	11.6	11.2	12,2	13.9	11.5	13.6	10.4	11.8	12.0	10.3	13.2	13.3

Table 34 : Geo-descriptors for Slovenian climatic zones

Some parameters have been fixed in the calculations:

- C_p = 1005 J/kg K
- T_i = 25 °C
- $T_{air, c, s}$ = 18.2 °C (zone 6)
- $T_{air, WB, c, s}$ = 13.6 °C (zone 6)
- ε_m = 80%

Characteristics and descriptors are given in Tables 26 and 29 for different systems and building typologies. Performance indicators are calculated according to equations given in section "Evaporative cooling ".
Results are given in Table 31.

		Performance indicators	
Building Typology	**Systems**	**CSPF Min [-]**	**CSPF MAX [-]**
House	**Single stage**	3.4	5.1
	Two stage indirect section	3.1	4.6
	Two stage direct section	3.5	5.3
Apartment building	**Single stage**	n.a.	n.a.
	Two stage indirect section	3.4	5.2
	Two stage direct section	3.9	5.9

Table 35: Evaporative cooling – Performance indicators for Slovenian climatic zone 6

4.5.2 Heating and DHW

4.5.2.1 Description

In this report, four technologies for heating and DHW applications have been analyzed: solar thermal water heaters, ground/air/water source heat pumps, high efficiency boilers and district heating.

➢ ***Solar water heaters***

Solar thermal collectors capture and retain heat from the sun and transfer this heat to a liquid. Figure 39 gives an example of a solar water collector. Three main systems are representative of the solar water heater technology: flat plate collectors, vacuum tube collectors and unglazed collectors. The following sections give details about these systems.

Figure 39 : Vacuum tube solar water collector

- Flat plate collector

Flat plate collectors present an extension of the basic idea to place a collector in an 'oven' like box in the direction of the sun. Most flat plate collectors have horizontal pipes at the top and bottom, called headers, and many smaller vertical pipes connecting them, called risers. The risers are welded (or similarly connected) to thin absorber fins. Heat-transfer fluid (water or water/antifreeze mix) is pumped from the hot water storage tank (direct system) or a heat exchanger (indirect system) into the collector's bottom header, and it travels up the risers, collecting.

- Vacuum tube collector

Vacuum tubes are solar panels built to reduce convective and heat conduction loss. Glass evacuated tubes are the key components of this system. Each evacuated tube consists most often of two glass tubes. The double wall glass tubes have a space in the center which contains a heat pipe or a copper U-tube (direct flow). The solar radiation is absorbed by the selective coating on the inner glass surface, but prevented from re-radiating out by the silver-coated innermost lining which has been optimized for infrared radiation. In case of a heat pipe, the heat transferred to the tip of the heat pipe is in turn transferred to a copper manifold in which water circulates to heat the domestic hot water tank. Some evacuated tubes (glass-metal) are made with one layer of glass that fuses to the heat pipe at the upper end.

- Unglazed collector

Unglazed collector is a simple form of flat-plate collector without transparent cover. Used for pool heating it can work quite well when the desired temperature is near the ambient temperature.

- ***Ground, air, water heat pumps***

Ground, air, water source heat pumps capture heat from the ground, air, or water and transfer this heat to the building. Heat pumps systems are used to transfer heat from a source to a sink. For heat pumps integrated in building, the source can be ground, air, or water. Concerning the sink, the emission of the systems can do through air, floor, or radiator. The thermal context of the heat pump will influence a lot its performance. **Figure 40** gives an example of ground source heat pump system.

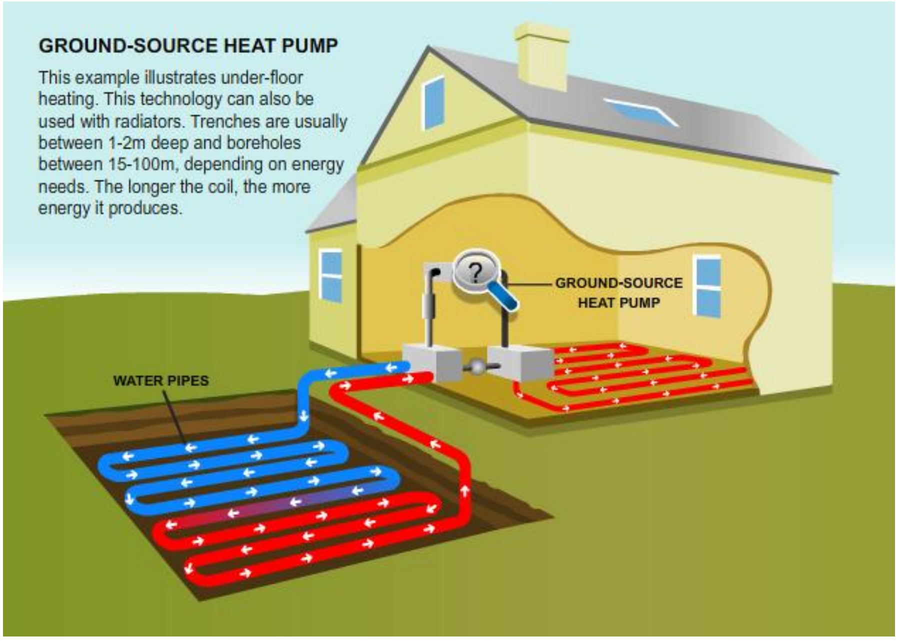

Figure 40 : Ground source heat pump system

- ***High efficiency boilers***

A boiler is a closed vessel in which water or other fluid is heated. The source of heat for a boiler is combustion of a fuel, or Joules effect.

Eight main technology systems are composing the high efficiency boilers technology. We can distinguish these systems by the nature of fuel fired, the heat exchanger technology used, and through the way of fuel supply. So the next parts give details about these systems technologies.

A distinction can be made between the different kinds of high efficiency boiler fuel supply. Gas, oil and wood are the three main fuel supplies studied in this work. As to the gas and oil fired boilers, two heat exchanger systems technology are treated separately. On one hand we have low temperature boiler, on the other hand, we have condensation boiler. Concerning wood fired boilers, two air supplies are possible. The first one is natural draft, and the second one is forced air. At the same time, two wood supplies are also possible. The wood supply can be manual or automatic. This gives us four possibilities for wood boilers. So the **Figure 41** gives a schematic representation of a wood, natural draft, automatic supply high efficient boiler.

Figure 41 : Wood, natural draft, automatic supply high efficient boiler

- ***District heating***

District heating is a system for distributing heat generated in a centralized location for residential and commercial heating requirements such as space heating and water heating. The heat is often obtained from a cogeneration plant burning fossil fuels but increasingly biomass, although heat-only boiler station, geothermal heating and central solar heating are also used. District heating plants can provide higher efficiencies and better pollution control than localized boilers. According to some research, district heating with combined heat and power is the cheapest method of cutting carbon, and has one of the lowest carbon footprints of all fossil generation plants. The Figure 42 gives an example of district heating installation.

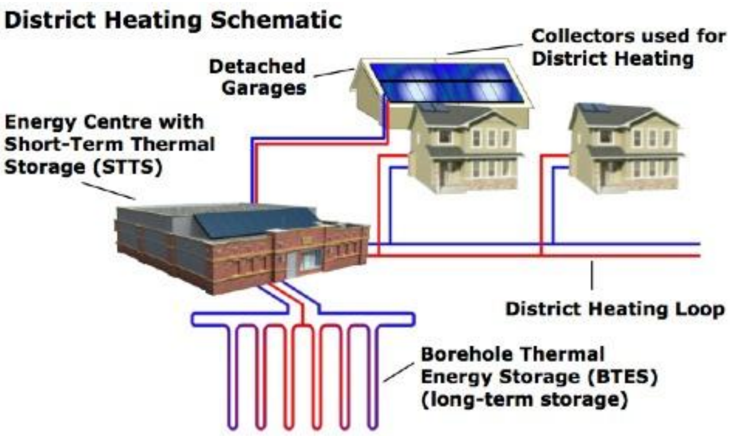

Figure 42 : Schematic representation of a district heating installation

4.5.2.2 Performance indicators

The Heating and DHW technology indicators related to climate, building typology and technology parameters are defined in different ways. The definition of these indicators differs for the solar water heaters, ground, air, water source heat pumps, high efficiency boilers and district heating systems.

- ***Solar water heater***

The solar water heater performance indicator related to climate can be defined by the annual solar thermal energy delivered by the unit area of the collector. This annual energy is given for a south oriented collector with a 45° slope. The following expression details the way to correlate technology parameters to geo-parameters.

- Annual heat delivered by the thermal solar system to DHW.

Solar water heater performance indicator	$\boldsymbol{Q_{DHW}}$

Where DHW performance indicator is given by following expression:

$$Q_{DHW} = \frac{B_a}{\frac{1}{1 - e^{-1.2 \times X}} + 0.13 \times Z}$$

Where the different terms of the equation (B_a, X, Z) are defined in the following equations:

$$B_a = 15 \times (45 - T_{gw,a})$$

$$X = \frac{A_S \times C_P}{B_a + 210}$$

Where A_S represents the collector solar input. This annual energy is defined by the following equation:

$$A_S = 0.8 \times \eta_0 \times H_{south,45°,zone}$$

$$C_P = 1 - \frac{P_C}{\sqrt{A_S \times (B_a + 210)}}$$

Where P_C represents the thermal losses of the collector. These losses are defined by the following equation:

$$P_C = 48 \times (a1 + 40 \times a2 + 1.75)$$

$$Z = \frac{B_a + 210}{1270}$$

- ***Ground, air, water source heat pumps***

Ground, air, water heat pump indicators related to the climate, and working conditions are defined through the Seasonal Performance Factor (SPF).

Ground, air, water heat pump performance indicator	$\boldsymbol{SPF}$

Where ground, air, water heat pump performance indicator is given by the following expression:

$$SPF = 0.33 \times \frac{T_{e,i} + 273}{T_{e,i} - T_{s,i}}$$

Where, ground, air, water heat pumps performance indicator is defined through inlet and outlet temperature of the system. So the inlet temperature of the source is defined as follows:

$$T_s = T_{s,i} + Delta$$

Where temperature $T_{s,i}$ represents the average heating seasonal air or ground temperature. Outlet temperatures (emission) are directly fixed by the heat emission system. The outlet temperature of the emission is defined as follows;

$$T_e = T_c + Delta$$

Where, temperature T_c represents the building comfort temperature.

- ***High efficiency boilers***

The high efficiency boiler performance indicators are not related to climate because of the non-dependence of climate parameters of the technology.

High efficiency boilers performance indicator	$\boldsymbol{\eta_{Pn}}$
	$\boldsymbol{P_{aux}}$

Where, the first indicator is the boiler efficiency at 100% of load. The relations are detailed in the following parts. The relationship between parameters and indicators change with the different systems technologies.

- Boiler efficiency at 100% Load
  - Low temperature

$$\eta_{P_n} = 87.5 + 1.5 \times \log(P_n)$$

  - Condensation

$$\eta_{P_n} = 91 + \log(P_n)$$

- Wood

$$\eta_{P_n} = 67 + 6 \times \log(P_n)$$

The second indicator is also related to the nominal power of the boiler. The following parts give the relation between the parameter and the indicator.

- Auxiliary electrical power [W]
  - Oil and gas fired

$$P_{aux} = 20 + 1.8 \times P_n$$

  - Natural draft, manual supply

$$P_{aux} = 0$$

  - Forced air, manual supply

$$P_{aux} = 73 + 0.52 \times P_n$$

  - Natural draft, automatic supply

$$P_{aux} = 10 \times P_n$$

  - Forced air, automatic supply

$$P_{aux} = 73.3 + 10.52 \times P_n$$

- ***District heating***

The performance indicator for estimating the efficiency of a DH network is heat loss factor q_{hlf}. The heat loss factor is a ratio of the heat loss to the quantity of heat supplied to the DH network. The heat loss does depend only on the efficiency of pipe insulation. In the present work the overall heat transfer coefficient is calculated on the basis of the annual heat losses. The annual heat losses are calculated as the difference between the heat supplied to the DH network and the heat measured at the consumers.

District heating performance indicator	$\boldsymbol{q_{hlf}}$

Where the heat loss factor is calculated as:

$$q_{hlf} = \frac{Q_{hlf}}{Q} = \frac{K_o \cdot A \cdot \int \Theta d\tau}{Q} = K_o \cdot \frac{(A/L) \cdot \int \Theta d\tau}{(Q/L)}$$

Where:

A: surface area of the distribution pipes [m^2]

L: pipes' length [m]

Θ : difference between water average temperature and outdoor temperature [°C]

τ: duration of difference between average and outdoor temperatures of water [h]

Q: annual quantity of the heat supplied to the district-heating network [MWh]

4.5.2.3 Database

Heating and DHW systems performance indicator is related to climate, systems characteristics, and descriptors.

- ***Geo-descriptors***

Solar water heaters, ground, air, water source heat pump, and district heating systems are related to geo-descriptors. These geo-descriptors are as follows:

- $H_{south,45°,zone}$: Annual incident energy on a south oriented plane with a 45° slope [kWh/m².years]
- $T_{gw,a}$: Average ground / water temperature over year [°C]
- $T_{air,h,s}$: Average ambient temperature over heating season [°C]
- $T_{gw,h,s}$: Average ground / water temperature over heating season [°C]
- HDD: Heating degree days [-]

- ***Products systems characteristics***

Solar water heaters, ground, air, water source heat pumps, high efficiency boilers and district heating are treated separately to identify their characteristics.

- Solar water heaters

Solar Water Heater systems are characterized by three main characteristics:

- η_0: Collector optical efficiency [-]
- a1: Collector thermal convection and conduction losses [W/K/m²]
- a2: Collector radiative losses [W/K²/m²]

Solar collectors used for Solar water Heater systems are the same as solar collector used for solar cooling. So, the Table 36 details the value of these parameters for the different solar collector systems.

	Systems characteristics		
Collector technology	**η_0**	**a_1**	**a_2**
Flat plate collectors	0.8	4	0.008
Vacuum tube collectors	0.7	1.3	0.008
Unglazed collectors	0.9	10	0.03

Table 36 : Solar collectors – system characteristics

- Ground, air, water source heat pumps

Ground, air, water source heat pump technology systems are characterized by two temperatures: the heat pump source temperature and the heat pump emission temperature.

The heat pump source temperature is linked to the nature of the source (ground, air, and water) and linked to the heat exchange quality of the exchanger between the source and the heat pump. The definition of the source temperature is detailed in the geo-parameter part. The exchanger characterization is treated trough the temperature difference between the source temperature (T_s) and the heat pump source temperature ($T_{s,i}$). This parameter (Delta) is defined for the different type of sources.

The heat pump emission temperature is defined in the same way as the source temperature. In this case, the nature of the emission can be (air, radiator, and floor). Table 37 gives the range of temperature difference in the source and emission exchangers.

		Delta $_{Min}$	**Delta $_{MAX}$**
Source	**Air**	-5	-8
	Water	0	0
	Ground	-3	-5
Emission	**Air**	3	7
	Radiator	20	45
	Floor	7	15

Table 37 : Ground, air, water source heat pump exchanger parameters table (11)

- High efficiency boilers

High efficiency boiler systems are characterized by one main parameter:

P_n: Boiler nominal power [kW]

Table 38 details the value of this characteristic for the different high efficiency boiler systems.

	P_n: Nominal power [kW]
Gas-fired, Low temperature	21 – 100
Oil-fired, Low temperature	30 – 100
Gas-fired, Condensation	18 – 130
Oil-fired, Condensation	25 – 210

Wood, natural draft, manual supply	20 – 80
Wood, forced air, manual supply	36 – 120
Wood, natural draft, automatic supply	40 – 450
Wood, forced air, automatic supply	200 – 800

Table 38 : High efficiency boiler technology parameters table (11)

- District heating

District heating systems are characterized by two main characteristics, linked to physicalphenomenon:

- K0: The overall heat transfer coefficient, which characterizes the efficiency of the pipe insulation [W/m².K]
- A/L: the specific surface area of the distribution pipe, which characterizes the average size of the district heating pipes [m²/m]

A table with ranges of variation for these two characteristics is still under construction.

- ***Descriptors***

Energy performance of heating and DHW technologies depends on various descriptors. These descriptors are correlated to the building typology. Two building types have been defined, house and apartment. A building type is defined by the thermal power needed for heating the building volume. For example, Table 39 gives value of this parameter.

	Building typology	
Building parameters	**House**	**Apartment**
P_n: Nominal power [kW]	<60	>60

Table 39 : Heating descriptor table

Also, the distinction between existing and new building is approached. Existing buildings are related to the use of radiators for heating, and the new buildings are related to the heated floor. This approach is realized for heat pumps systems.

Concerning the district heating, the performance indicator is also linked to neighborhood typology. So the Table 40 gives ranges associated to the concentration of the district heating demand depending of the building and neighborhood typology.

	Q/L [MWh/m.year]	
Neighborhood / Building typology	**Existing**	**New**
High density	8 – 20	3 – 6
Medium density	4 – 8	1.5 – 3
Low density	2 – 4	1 – 1.5

Table 40 : District heating descriptor table

4.5.2.4 Example

Heating and DHW technology performance indicators depend on the technology applied context. So in order to understand well the data base collection, heating and DHW are treated through examples in a climate, building typology and well defined regulation context. The Figure 43 : Italy climate zoning gives the superposition of administrative zones and climate zones for Italy. Geo-descriptors corresponding for these zones are detailed in Table 41.

Figure 43 : Italy climate zoning

Climate zone	B	C	D	E	F
$H_{south,45°,zone}$	1742	1701	1700	1605	1528
$T_{gw,a}$	18	18.2	16.3	13.7	11.2
$T_{air,h,s}$	12.1	12.4	10.7	7.7	8
$T_{gw,h,s}$	12.1	12.4	10.7	7.7	8
HDD	787	1159	1641	2430	3019

Table 41 : Solar water heaters, ground, air, water heat pump and district heating geo-descriptors for Italian climatic zoning

- ***Solar water heaters***

The solar thermal annual energy delivered by the unit area of the panel south oriented with 45° slope is given in the following Table 42. This table is an example for Italy climate zone B.

	Performance indicators	
Technologies	Q_{min} [kWh/m².year]	Q_{max} [kWh/m².year]
Flat plate collector	234	380
Vacuum tube collector	222	361
Unglazed collector	160	261

Table 42 : Solar Water Heater technology indicator table for B Italian climatic zone

- ***Ground, air, water source heat pumps***

The SPF factor identified for different ground, air, water source heat pump systems are given in Table 43. This table is an example for Italy climate zone D.

		Indicator	
Building typology	**Technology**	SPF_{Min}	SPF_{Max}
	Air /Air	4.2	6.0
Existing building	**Air / water**	1.8	3.1

(Radiators)	Water / Water	2.1	3.6
	Brine Water	1.9	3.3
New buildings (Floor)	Air / Water	3.2	4.9
	Water / Water	4.3	6.4
	Brine / Water	3.6	5.4

Table 43 : Ground, air, water source heat pumps indicator table for D Italian climatic zone

- ***High efficiency boilers***

The high efficiency boiler technology indicators are dependent on the building typology. The defined indicators are the boiler efficiency at 100 % load, and the electrical power of the auxiliaries. Table 44 gives high efficiency boilers indicators calculated.

	η_{Pn} : Boiler efficiency at 100% Load [%]		P_{aux} : Auxiliary electrical power [W]	
Building typology	**House**	**Apartment building**	**House**	**Apartment building**
Gas-fired, Low temperature	89.5	90.5	58	200
Oil-fired, Low temperature	89.7	90.5	74	200
Gas-fired, Condensation	92.3	93.1	52	254
Oil-fired, Condensation	92.4	93.3	65	398
Wood, natural draft, manual supply	74.8	78.4	0	0
Wood, forced air, manual supply	76.3	79.5	92	135
Wood, natural draft, automatic supply	76.6	82.9	400	4500
Wood, forced air, automatic supply		84.4		8489

Table 44 : High efficiency boiler technology indicators table

4.5.3 Electricity production system

4.5.3.1 Description

In this report, two main technologies for electricity production have been analyzed: Photovoltaic (PV) panels and Combined Heat and power (CHP).

- ***PV Panels***

A solar PV panel is packaged, connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity. Figure 44 gives an example of a roof integrated PV panel installation.

Four main PV technologies have been considered in this report: mono-crystalline silicon, poly-crystalline silicon, amorphous silicon and thin layers. The next parts give details about these systems technologies.

- Mono-crystalline silicon

Mono-crystalline modules are composed of cells cut from a piece of continuous crystal. The material forms a cylinder which is sliced into thin circular wafers. The cells may be fully round or they may be trimmed into other shapes, retaining more or less of the original circle. Because each cell is cut from a single crystal, it has a uniform color which is dark blue.

- Poly-crystalline silicon

Poly-crystalline cells are made from similar silicon material. Instead of being grown into a single crystal, they are melted and poured into a mold. This forms a square that is cut into square wafers. As the material cools, it crystallizes in an imperfect manner, forming random crystal boundaries. The surface has a jumbled look with many variations of a blue color.

- Amorphous silicon

Amorphous silicon is the non-crystalline allotropic form of silicon. It is deposited in thin films at low temperatures onto a variety of substrates. Amorphous silicon solar cell has an inherent lower efficiency compared to mono or poly-crystalline solar cells. However, higher efficiency can be reached by stacking several thin film cells on a top of each other, each one tuned to work well at a specific frequency light.

- Thin layers

A thin layer solar cell is a solar cell that is made by depositing one or more thin layers of photovoltaic material on a substrate. The thickness range of such a layer is wide and varies from a few nanometers to tens of micrometers.

Figure 44 : Example of a PV Panel installation

- ***CHP***

Cogeneration, also called CHP (Combined Heat and Power), is the use of a power station in order to generate simultaneously electricity and useful heat. During the electricity generation, all thermal power plants emit an amount of heat. In many cases, this amount of heat is released into the natural environment through cooling towers, flue gas or other means. So the objective of cogeneration is to capture some or all by-product heat for heating applications. This can be done either through district heating for macro-cogeneration, or the power station can be directly integrated into the building for cogeneration and micro-cogeneration.

Figure 45 : Stirling engine micro combined heat and power system

Five main CHP systems have been considered in this report. Most of them are designed for a natural gas alimentation system.

- Solid Oxide Fuel Cell

Solid Oxide Fuel Cell (SOFC) is an electrochemical conversion device that produces electricity directly from oxidizing a fuel. Fuel cells are characterized by their electrolyte materials. The SOFC has a solid oxide or ceramic electrolyte. The advantages of this class of fuel cells include high efficiency, long term stability, fuel flexibility, low emission, and relatively low cost. The largest disadvantage is the high operating temperature (750 – 900 °C) which results in longer start-up times, mechanical and chemical compatibility issues.

- PEM Fuel Cell

Proton Exchange Membrane Fuel Cell (PEMFC), also known as Polymer Electrolyte Membrane, is a type of fuel cell being developed for transport application as well as for stationary fuel cell application and portable fuel cell applications. Their distinguishing features include lower temperature / pressure ranges (50 to 100°C) and a special polymer electrolyte membrane.

- Stirling Engine

Stirling engine is a heat engine operating by cyclic compression and expansion of air or other gas, the working fluid, at different temperature levels so that there is a net conversion of heat energy to mechanical work. Typical of heat engines, the general cycle consist of compressing cool gas, heating the gas, expanding the hot gas, and finally cooling the gas before repeating the cycle. The efficiency of the process has an upper limit set by the efficiency of the equivalent Carnot cycle operating between the same hot and cold temperature. The Stirling engine is noted for its high efficiency compared to steam engines, quiet operation, and the ease with which it can use almost any heat source.

- Steam Engine

Steam engine converts heat into work. The Rankine cycle describes the process by which steam operated in heat engines generate power. This cycle is mainly used in the world to generate electric power. 90 % of the world electric production is generated through the Rankine cycle. The main heating processes used in power generation are nuclear fission and fossil fuel (coal, natural gas, and oil) combustion.

- Internal Combustion Engine

In internal combustion engine, combustion of the fuel occurs with an oxidizer in a combustion chamber. The expansion of the high-temperature and pressure gases produced by the combustion applies a direct force to components (pistons, turbine blades, nozzle…) of the engine. This force moves the components over a distance, transforming chemical energy into useful mechanical energy. Internal combustion engines are most commonly used for mobile propulsion in vehicles and portable machinery. In mobile equipment, internal combustion is advantageous since it can provide high power-to-weight ratios together with excellent fuel energy density.

For combined heat and power technology, technology indicators are not correlated to geo-parameters. Thereby, next parts contain parameters and indicators technology description.

4.5.3.2 Performance indicators

The electricity production technology indicators related to climate, building typology and technology parameters are defined in different ways. The definition of these indicators differs between the PV panels and CHP systems.

- ***PV Panels***

The PV panel indicator related to climate can be defined by the annual electrical PV production delivered by the unit area of the panel. This annual energy is given for a south oriented panel with a 45° slope. So the following expression details the way to correlate performance indicator to geo-descriptors, and system characteristics.

PV Panels performance indicator	$\boldsymbol{E_{aepp}}$

Where the PV panel performance indicators is given by the following expression:

$$E_{aepp} = H_{south,45°,zone} \times R_S \times 0.75$$

Where:

- $H_{south,\,45°,\,zone}$: Solar annual energy on a south oriented area with a 45° slope [kWh/m².years]
- R_S: : Peak Power Ratio [Wc/m²]

4.5.3.3 CHP

Combined heat and power performance indicator is related to the system characteristics. Also, this indicator can be related to building typology.

Combined heat and power performance indicator	$\boldsymbol{R_{cogen}}$

Where the combined heat and power performance indicator is given by the following expression:

$$R_{cogen} = \frac{\eta_E}{100 - \eta_E}$$

Where:

- η_E: combined heat and power Electrical efficiency [%]

4.5.3.4 Database

Electricity production systems performance indicators are related to climate, systems characteristics, and descriptors. The following parts give the description and some range to identify well the performance indicator.

- ***Geo-descriptors***

PV panel technology is related to one climate parameter. This is the annual incident energy collected by the panel. The orientation has been chosen as the south oriented plane with a 45° slope:

$H_{south, 45°, zone}$ [kWh/m².years]

- ***Product / system characteristics***

PV Panels, and Combined Heat and Power are treated separately to identify their characteristics.

- PV Panels

PV panels technology is characterized by one main characteristic, linked to physicalphenomenon:

- R_s: : Peak Power Ratio [Wc/m²]

This peak power ratio is used to model the internal losses to current flow and the connection between cells. The following table (Table 45) details the value of this parameter for the different systems of PV panel technology.

	System characteristics
Systems	**R_S: [Wc/m²]**
Mono-crystalline Silicon	125
Poly-crystalline silicon	115
Amorphous Silicon	55
Thin layers	35

Table 45 : Technology parameters for different PV systems (11)

- CHP

In this part, the goal of the study is to identify Combined Heat and Power characteristics that will enable to compare the different systems of this technology. Thus, Combined Heat and Power Technology characteristic chosen is the electrical efficiency of the system. Also, this characteristic is dependent on the system used and on the building typology through the electrical power of the system. Indeed, the size of these systems has a significant influence on the electrical efficiency of the different systems. The decision to separate houses and apartment building is linked to electrical power: from 1 to 10 kW for houses, and over than 10 kW for apartment building. Table 46 indicates the different electrical efficiency values of combined Heat and Power systems. These values are presented below for two building types (House and apartment building).

Systems Power Station	Technology parameter	
	η_E : Electrical efficiency [%]	
	House (micro CHP) 1 – 10 kW	Apartment building (CHP) PE > 10 kW
Solid Oxide Fuel Cell	40	55
PEM Fuel Cell	35	40
Stirling Engine	10	20
Rankine Cycle Engine	10	20
Internal Combustion Engine	20	30

Table 46 : Combined Heat and Power technology parameter table (11)

4.5.3.5 Example

Electricity production technology performance indicators depend on the context. To complete the electricity production systems data base, an example is given for a climate, building typology and well defined regulation context. Figure 44 gives the solar distribution of different climate zone for Belgium. Geo-parameters corresponding for these zones are detailed in Table 47.

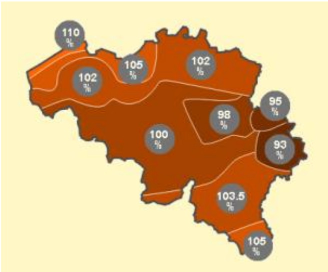

Figure 46 : Belgium climatic zoning

Geographic zone	North	Center	South
$H_{south,45°,zone}$	1144	979	993

Table 47 : PV Panel technology Geo-parameters for Belgium climate zoning

➢ ***PV Panels***

The annual electrical PV production delivered by the unit area of the panel south oriented with 45° slope is given in Table 48. This table provides an example for North Belgium climate zone.

Systems	Technology indicator	
	$E_{aepp,min}$ [kWh/m².year]	$E_{aepp,max}$ [kWh/m².year]
Monocristalline Silicon	86	139
Polycrystalline silicon	79	128
Amorphous Silicon	38	61
Thin layers	24	39

Table 48 : PV panel indicator for North Belgium climatic zone

➢ ***CHP***

The Power to heat ratio produced by the different power station systems are given in Table 49. This performance indicator is essentially related to the building typology.

Systems Power Station	Indicators: R_{cogen} : Power to Heat ratio [-]		Building typology
	House (micro CHP) 1 – 10 kW	Apartment building (CHP) PE > 10 kW	
Solid Oxide Fuel Cell	0.7	1.2	New building (low thermal consumption[4])
PEM Fuel Cell	0.5	0.7	
Stirling Engine	0.1	0.3	Existing building (high thermal consumption[5])
Rankine Cycle Engine	0.1	0.3	
Internal Combustion Engine	0.3	0.4	

Table 49 : Combined Heat and Power technology indicators for different building typology

[4] For this hypothesis, Power to heat ratio is higher than 0.5

[5] For this hypothesis, Power to heat ratio is lower than 0.5

5. IDENTIFICATION OF DESCRIPTORS – NON-TECHNOLOGICAL LAYERS

5.1. Introduction

As reported within the introduction of the present document the proposed geo cluster concept is built on parameters and indicators grouped within different layers and sub layers. The two main ones are the technological layers already described and the non-technological ones that will be analysed within the following sections.

The scope of the non-technological layers is multiple: on one side, it to provide feeds input information for the technological layer, for instance climatic data used to calculate the efficiency of a given technology in a given area; on the other, it provides the user with context information which may not be influencing the technical performance of a technology, but could prove determinant in the decision whether to adopt it or not in a given area, e.g. the presence of favourable social-economic conditions, the availability of subsidies etc. A further function of the non-technological layer is related to the possibility of performing comparisons and correlations between different areas.

While the technological layer is composed by both geo-referenced elements and elements which are valid "per se" (e.g. properties of a material or a product).The non-technological layers are essentially geo-based, in that descriptors are always referred to the specific geographic area they belong to.

The following list provides overview of key non-technological layers:

- Context layer, consisting of the climatic aspects (already mentioned in the Technology layer part because of their close correlation with the technologies' performance indicators) and generic descriptive information about the geographic area (type of landscape, area usage etc.);
- Socio-economic layer, consisting of a set of statistical indicators shaping the overall social and economic picture of the geographic area considered, such as population, population density, GDP, employment rate etc. When applicable, these data are also specified for the construction sector in particular, in order to describe the dynamics of the market of interest;
- Financial layer, which is closely correlated to the technology layer: in this layer price/cost values for each of the considered technologies are categorized and collected, along the four phases of a product's lifetime (Product price, Cost of installation, Cost of maintenance (if any), Cost of disposal at end-of-life).
- Building typologies layer: this layer mainly reports the distribution of buildings in the area of interest along the two axes of residential / non-residential and their sub-categories;
- Normative layer, reporting the existing norms, directives, regulations and standards at national and/or local level.

A definition of each of the layers, as well as the associated descriptors, is given in the following paragraphs.

5.2. Context layer

Context layer is one of the non-technological layers analyzed within the framework of the project.

In order to create a solid geo-clustering database, the descriptors will be gathered mainly within two families:

- Climate geo-descriptors → "technology related" influencing performance indicators of a technology;
- Climate geo-descriptors → "non technology-related" describing the geo-climatic context of the area. These for instance include parameters such as altitude, climate zone etc., which are not directly present as variables in the equations used to calculate the technical performances of materials/technologies, but nonetheless can be useful to describe a geographic area.

The climatic data available in the individual EU member states differ in granularity. For the purpose of geo-clustering data it has been agreed to describe the climatic zones at NUTS 3 level. In some cases of very fine data (e.g. Slovenia) average values are to be assigned to a NUTS 3 area. In other cases single climatic zone may comprise more than one NUTS 3 area.

The climatic parameters, necessary to determine the performance of one or more technologies, are called technology related "climate geo-descriptors" and are listed in Table 50. Please note this list is not comprehensive and has been proposed only to realize a proof of geo-cluster concept:

Geo-descriptors	**Description**	**Unit**
HDD	Heating Degree Days	DD
CDD	Cooling Degree Days	DD
$\mathbf{H_{south,\ 45°,\ zone}}$	Annual incident energy on a south oriented plane with 45° Slope	[kWh/m².years]
$\mathbf{H_0}$	Annual incident energy on a south oriented vertical surface	[kWh/m².years]
$\mathbf{T_{air,\ a}}$	Average ambient temperature over year	[°C]
$\mathbf{T_{air,\ h,\ s}}$	Average ambient temperature over heating season	[°C]
$\mathbf{T_{air,\ c,\ s}}$	Average ambient temperature over cooling season	[°C]
$\mathbf{T_{air,\ max}}$	Maximum ambient temperature over year	[°C]
$\mathbf{T_{gw,\ a}}$	Average ground / water temperature over year	[°C]
$\mathbf{T_{gw,\ h,\ s}}$	Average ground / water temperature over heating season	[°C]

$T_{gw, c, s}$	Average ground / water temperature over cooling season	[°C]
$T_{air, WB, c, s}$	Average ambient wet bulb temperature over cooling season	[°C]
$T_{air, cool, day}$	Average ambient temperature during daylight over cooling season	[°C]
$G_{south, 45°}$	Average solar irradiation during daylight over cooling season	[W/m²]

Table 50: Climate geo-descriptors (technology-related)

In addition to the purely climatic geo-descriptors, a set of complementing parameters is defined in order to better describe the geo-climatic context of the area. These are introduced in Table 51.

Geo-descriptors	**Description**	**Unit**
Climate zone	Climate zone according to Köppen	descriptive
Altitude	Altitude of the administrative capital city over sea level	m
Precipitations	Average annual millimetres of rain	mm
Rain-dry days	Average annual number of days without precipitations	days

Table 51: Climate geo-descriptors (non-technology related)

5.3. Socio-economic layer

The benefits of energy efficiency approach are influenced by different aspects that need to be analyzed in order to maximize the return from application of innovative technologies.

Social and economic aspects needs to be analyzed with reference to the specific context where the technology should be applied since they both may represent a bottleneck if not adequately considered.

The socio-economic layer is meant to provide users with additional information, with respect to the technical parameters provided by technological layer enabling the use to have a complete picture of the overall favorability of societal and economic conditions of the area for new investments and/or new products. These aspects can be determinant when deciding whether to invest in a new market (push scenario) or when comparing the feasibility of employing different technologies belonging to the same family in a given area (pull scenario).

Within this project a list of descriptors relating to combination of both, social and economic aspects, has been identified. The definitions of descriptors are a result of both, internal discussion within the consortium and the push and pull scenario exercise described in Section 2.1.

This chapter introduces the identified socio-economic indicators along with data source and resolution of available data. As clear from the table, the geographic coverage is not homogeneous, in particular regarding the granularity of data (some data are available at NUTS3 detail, while other only at NUTS2 or even NUTS0). Since the resolution chosen for the mapping tool corresponds to NUTS3, all data will be reduced (or merged) accordingly.

Geo-descriptors	Description	Unit	Source	Spatial resolution
pop	Population living in the area at last census	persons (number)	EUROSTAT demo_r_d3avg	NUTS3
pop_d	Population density	persons/km2	EUROSTAT demo_r_d3dens	NUTS3
GDP	Gross domestic product of the area at last census	€	EUROSTAT nama_gdp_c	NUTS0
GDP_c	Gross domestic product in construction	€	EUROSTAT nama_nace64_c	NUTS0
empl_%	Employment rate	percentage	EUROSTAT lfst_r_lfe2emprt	NUTS2
empl_c	Employment in construction	persons (number)	EUROSTAT lfst_r_lfe2en1	NUTS2
res_n	Number of households	number	EUROSTAT cens_01rheco	NUTS3
pov_%	People at risk of poverty or social exclusion	percentage	EUROSTAT Ilc_pnp1	NUTS2
Old_pov%	At-risk-of-poverty rate of older people by sex and selected age groups	percentage	EUROSTAT SILC ilc_pnp1	NUTS0
age_n	Population by age at regional level	number	EUROSTAT demo_r_d2jan	NUTS2
gas	Gas prices for householdconsumers	€/Gigajoule	EUROSTAT ten00113	NUTS0
electr	Electricity prices for household consumers	€ / kWh	EUROSTATten001 15	NUTS0
HICP_%	Harmonized Indices of Consumer Prices (HICPs) for energy	Index (2005 = 100) and percentage change	EUROSTAR teicp250	NUTS0

labor	Labour cost, wages andsalaries, and direct remuneration	€	EUROSTARlc_r08cost_r2	NUTS 2

Table 52: Socio-economic geo-descriptors

5.4. Financial layer

The financial layer needs to be tackled with a life cycle prospective. Financial layer is related to the price/cost parameters of the identified technologies. They are grouped along the lines of the four main stages in a product's lifetime:

- Product price;
- Cost of installation;
- Cost of maintenance (if any);
- Cost of disposal at end-of-life.

All of these parameters are related to the other layers: they depend from the specific technology; they are dependent from the geographic area; moreover, they may also depend from legislation (disposal in particular).

Two options were possible to implement this layer:

- First option (specific, open) implies taking in consideration specific products representative of each technology and collecting data directly from suppliers. In the future: suppliers would be enabled to contribute their own specs under the supervision of the project group. However, this approach is potentially exposed to the risk of introducing biased information which would be extremely difficult to filter;
- Second option (generic, closed) implies that the project group estimates ranges of costs for each technology, on the basis of experience and interviews with experts. This "closed" approach can only deliver approximate estimates, however it has the advantage of being in full control of the project group.

It has been decided to follow the second approach in the proof-of-principle demonstration of the geo-clustering mapping tool, as it enables controlling all information.

In particular since the project aims to deeply analyzed technologies, it was decided that the financial layer only include some of them, and in particular the choice has been done considering the workflow of the project and the case studies identified.

The project will lunch case studies to validate of the methodology within two pilot clusters: "Mediterranean Arc" and "Benelux cluster". For such clusters has been decided that the following applications will be tested:

- "Mediterranean arc" → solar cooling;
- "Benelux cluster"→ thermal insulation.

The following tables provide specific units relevant for individual financial descriptors of the above technologies and also for "windows and glazing" and "artificial lighting" technologies. The financial descriptors include product price, installation cost, maintenance cost, frequency of maintenance, cost of disposal and service life. Since the financial parameters are specific for each technology, they are described in more detail for each technology in Table 53 to Table 56

Table 53 : Financial layer (thermal insulation technologies)

Technology	Product / systems	Product price	Installation cost	Maintenance cost	Frequency of maintenance, if any	Cost of disposal	Service life
Panel, roll							
	Foam board	Euro/m^2, Euro/m^3, Euro/kg [1]	Euro/hour/m^2 [2]	Euro/call	times per year [3]	Euro/m^2, Euro/m^3, Euro/kg 1	Years
	Mineral wool						
	Natural						
	Aerogel						
	Vacuum insulation panels						
Foam							
	Spray foam	Euro/m^2, Euro/m^3,	Euro/hour/m^2 2	Euro/call	times per year 3	Euro/m^2,	Years

[1] conversion through density and thickness question is if conversion in this way works because price will depend strongly on the application method and used materials

[2] labour cost of skilled workers

[3] decimals possible

	Natural loose-fill	Euro/kg 1				Euro/m^3, Euro/kg 1	
Multi layers							
	Multi foil reflective	Euro/m^2, Euro/m^3, Euro/kg 1	Euro/hour/m^2 2	Euro/call	times per year 3	Euro/m^2, Euro/m^3, Euro/kg 1	Years

Table 54 : Financial layer (Windows & Glazing technologies)

Technology	**Product / systems**	**Product price**	**Installation cost**	**Maintenance cost**	**Frequency of maintenance, if any**	**Cost of disposal**	**Service life**
Double glazing							
	Air filled	Euro/m^2	Euro/hour/m^2 2	N/A	N/A	Euro/m^2	Years
	Argon filled	Euro/m^2	Euro/hour/m^2 2	N/A	N/A	Euro/m^2	Years
	Low E Glass (air filled)	Euro/m^2	Euro/hour/m^2 2	N/A	N/A	Euro/m^2	Years
	Low E glass (argon filled)	Euro/m^2	Euro/hour/m^2 2	N/A	N/A	Euro/m^2	Years
Triple glazing							
	Air filled	Euro/m^2	Euro/hour/m^2 2	N/A	N/A	Euro/m^2	Years
	Argon filled	Euro/m^2	Euro/hour/m^2 2	N/A	N/A	Euro/m^2	Years
	Low E Glass (air filled)	Euro/m^2	Euro/hour/m^2 2	N/A	N/A	Euro/m^2	Years
	Low E glass (argon filled)	Euro/m^2	Euro/hour/m^2 2	N/A	N/A	Euro/m^2	Years
Vacuum glazing							
	Vacuum	Euro/m^2	Euro/hour/m^2 2	N/A	N/A	Euro/m^2	Years

Table 55 : Financial layer (Artificial lighting technologies)

Technology	Product / systems	Product price	Installation cost	Maintenance cost	Frequency of maintenance, if any	Cost of disposal	Service life
Fluorecent lamps							
	Tubular lamps (TL)	Euro/W, Euro/piece		N/A	N/A		Years
	Compact lamps (CFL)	Euro/W, Euro/piece		N/A	N/A		Years
Solid state lamps							
	LED	Euro/W, Euro/piece		N/A	N/A		Years

Table 56 : Financial layer (Cooling technologies)

Technology	**Product price**	**Installation cost**	**Maintenance cost**	**Frequency of maintenance, if any**	**Cost of disposal**	**Service life**
Earth sheltering	Euro/m2	Euro/hour/m^2 2	N.A.	N.A.	Euro/m2	Years
Evaporative cooling	Euro/machine	Euro/machine	Euro/call	Times per year 3	Euro/machine	Years
Desiccant cooling	Euro/machine	Euro/machine	Euro/call	Times per year 3	Euro/machine	Years
Solar absorption cooling	Euro/machine	Euro/machine	Euro/call	Times per year 3	Euro/machine	Years

5.5. Normative layer

The normative situation is quite scattered across Europe and it is a complex task to extrapolate the specific values mandated for each technology. Moreover, it is often the case that application-specific parameters are involved: taking this level of detail into account would mandate additional input on the part of the user and/or introducing assumptions on the part of the programmer.

Since it is preferable to avoid such complications (and possible error sources), it has been decided that, the mapping tool will map the existence and kind of regulation/subsidy scheme applicable, rather than its precise values and limitations, at least at the proof-of-principle stage. A scale of color shades will indicate the presence and the nature of normative and subsidies on the map.

5.5.1. Type of buildings

Regulations, norms and, in general short, medium or long-term policies for energy efficiency support are in 100% of cases directly related to one (or several) type of buildings, as final target of the intervention. For this reason and to achieve the project's objective it became necessary to define a list of building types.

In the Normative Layer, the buildings can be represented by a hierarchy tree, as summarized in the table below:

I LEVEL SELECTION	II LEVEL SELECTION	III LEVEL SELECTION
New building	Residential building	Single family house
		Multi family house
		High-rise building
	Non residential building	Office
		Commercial
		Health&wellfare
		Educational
		Administrative
		Other
Existing building	Residential building	Single family house
		Multi family house
		High-rise building
	Non residential building	Office
		Commercial
		Health&wellfare
		Educational
		Administrative
		Other

Table 57 : Building typologies

The next table provides definition of each family of buildings together with a brief highlight on relevant issues, specific for each family that needs to be considered within any energy efficiency plans or project. Specific norms and directives for construction sector are described in next sub-chapter..

	BUILDING TYPE	DEFINITION	SPECIFIC ISSUES
I LEVEL SELECTION	New building	The definition of "new buildings" includes buildings not yet constructed and building in construction, with overall project documents still modifiable.	• Expected date of construction ; • Easy integration EE Technologies/structure (no retrofitting needed).
	Existing building	The type includes buildings already constructed, buildings in state of ruins to be partially rebuilt	• Year of construction : - <1900 - 1901-1945 - 1946-1960 - 1961-1980 - 1981-2000 - >2001 • Retrofitting needed; • Beaux-art competence.
II LEVEL SELECTION	Residential building	It's a structure dedicated to private use. It is generally composed by rooms of average areas. It does not host heavy machines or other kind of plants. Can include technical rooms and garages.	• Dimension and geometry of single housing units to be considered; • Presence of main supply lines (electricity, gas, water) and wastewater; • Presence of rooms and areas in common or for shared use (e.g. stairs, entrance, lifts, roof, other); • Possible presence of areas dedicated to other specific uses than housing (e.g. cellars, garages); • Potentially used 24h/24 and 7day/week.

	Non residential building	It's a structure primarily built for other use than housing. It can be composed by rooms of average areas as well as very large open spaces. It usually host light and heavy machines or other kind of fixed plants. It usually include several technical rooms and specific supply lines. It can host community of people with specific needs.	• Dimension and geometry of single housing units to be considered; • Average presence of further supply lines other than in residential buildings (e.g. high voltage line, oxygen or other specific gas supply; compressed air, process water, oil or other lubricants, refrigerators gases or liquids, dangerous lines) and waste lines; • High presence of rooms and areas in common or for shared use (e.g. stairs, entrance, lifts, roof, other); • High possible presence of technical areas and equipment dedicated to other specific uses than housing (e.g. storage, production, hazardous rooms, technical service rooms, garages, medical treatments); • It can be used (completely or partially) either 24h/24, 7day/week or subjected to specific cycles (e.g. night/day, summer/winter, working days/holydays); • In several cases there is space on the roof for implementing energy technologies (e.g. solar panels);
III LEVEL SELECTION	Single family house	Housing unit targeted on only one family. The building is typically disconnected from the other buildings in the neighborhood. Typically the building has one or two floors (in few cases three), and a technical room. The structure can be either custom designed or prefabricated.	• No areas for common or for shared use (e.g. stairs, entrance, lifts, roof, other); • Availability of roof for technical use; • Independent heating system; • HVAC system to be confirmed.
	Multi family	Housing unit targeted on few	• Possible small areas for common or for

	house	families (up to three, four). The building is bigger in volume than single family house and it is typically disconnected from the other buildings in the neighborhood. The building has more floors and technical rooms than single family one (up to three, four). The structure can be either custom designed or prefabricated.	shared use (e.g. stairs, entrance, lifts, roof, other); • Availability of shared roof for technical use; • Independent or shared heating system; • HVAC system to be confirmed.
	High-rise building	Housing unit built to host several apartments (from 15-20 up to 50 or more). The building can be integrated in the neighborhood and have common spaces, areas or walls in common with other structures. The building has several floors (typically up to 10-12), and several areas dedicated to specific uses. The structure is seldom prefabricated. Materials used (e.g. for insulation) and general technical performance can vary a lot.	• Large areas (as sum of volumes) for common or for shared use (e.g. stairs, entrance, lifts, roof, other); • Availability of roof for technical use to be confirmed; • Independent or shared heating system; • Part of common supply lines shared between different apartments; • HVAC system to be confirmed.
	Office	It's a building used to host (completely or partially) desk workers. It can be specifically designed for this purpose or it can be a residential building,	• Presence of small rooms (single offices) and large open space offices. • Large and small areas (as sum of volumes) for common or for shared use (e.g. stairs, entrance, lifts, roof, other); • Availability of roof for technical use to be

		transformed into offices. The same building ca host offices belonging to one or several companies. In most cases higher density of people (Area/people, volume/people) than residential buildings. Can be typically the target for architectural innovations.	confirmed; • Independent or shared heating system; • Technical rooms for computers and servers with specific air parameters requirements; • Short and long periods of closure, since it is typically subjected to cycles (week, season, year) and holydays; • Typically HVAC system is available or requested; • Small or no use during nights.
	Commercial	It's a building used to host (completely or partially) commercial activities. It can be specifically designed for this purpose (e.g. large shopping mall) or it can be integrated into a residential building or context (e.g. block of single shops/restaurant). The same building can host different commercial activities, with different requirements and/or manufacturing plants and equipment. In most cases there are several areas with different specific requirements of temperature and humidity.	• Large areas (as sum of volumes) for common or for shared use (e.g. stairs, entrance, lifts, roof, other); • Availability of roof for technical use; • Independent heating system; • Small or very large HVAC system; • Areas (large and small) with specific requirements (e.g. manufacturing areas, goods and fresh goods storage, freezers, large kitchens...); • Possible presence of power generation stations or rooms; • The trend is to maintain the commercial activities opened 7 days/week and to increase the daily opening time. • Small or no use during nights.
	Health&well fare	It is a building which primary function is to provide medical services to patients. The building usually hosts medical machinery, equipment and devices for diagnosis and treatment of patients. In most	• Large areas (as sum of volumes) for common or for shared use (e.g. stairs, entrance, lifts, roof, other); • Availability of roof for technical use; • Small or very large independent heating system; • Small or very large HVAC system; • Housing rooms (large and small) with specific

		cases it shall provide complete accommodation to patients for daily, short or long term treatments. The building can be small (e.g. small clinics, small laboratories) or very large (e.g. large hospital with several building blocks).	requirements (e.g. single patient rooms, large corridors, treatment rooms...); • Several technical rooms with specific requirements (e.g. surgery rooms, analysis rooms and labs…); • Possible presence of power generation stations or rooms; • The activities in the building, in particular in clinics and hospitals, are ongoing 24h/24, 7days/week, including nights.
	Educational	It is a building which function is to host lectures, studies and research, at different level from primary school to university and research centers. The dimension of the building can vary significantly (area, number of floors, number of rooms) and can be integrated in a context of building block of the same type. The building can be either designed and built for educational scope or transformed from other types (e.g. past residential villas).	• Large areas (as sum of volumes) for common or for shared use (e.g. stairs, entrance, lifts, roof, other); • Availability of roof for technical use; • Small or very large independent heating system; • HVAC system not always available; • Mix of different room size: very large rooms (e.g. for lecture) large rooms (e.g. laboratories), small rooms (e.g. professors offices); • Technical rooms for computers and servers with specific air parameters requirements; • Several technical rooms with specific requirements (e.g. analysis rooms and labs…); • Possible presence of power generation stations or rooms; • Short and long periods of closure or low workload, since it is typically subjected to cycles, in particular season cycles and holydays;
	Administrative	It's a building used to host (completely or partially) desk workers and public administration. Features are similar to Offices, the main difference is that Offices and Public administration buildings	• Presence of small rooms (single offices) and large open space offices. • Large and small areas (as sum of volumes) for common or for shared use (e.g. stairs, entrance, lifts, roof, other); • Availability of roof for technical use to be confirmed; • Independent or shared heating system;

		can be addressed by different regulations or policies for energy efficiency intervention.	• Technical rooms for computers and servers with specific air parameters requirements; • Short and long periods of closure, since it is typically subjected to cycles (week, season, year) and holydays; • Typically HVAC system is available or requested; • Small or no use during nights.
	Other	Every other building, not referable to previous types, with specific requirements.	• Specific requirements (custom.

Table 58 : Building typologies definition and key issues

BUILDING TYPE	EXAMPLE	
Single family house		
Multi family house		

High-rise building		
Office		
Commercial		

Health & wellfare		
Educational		
Administrative		
Other		

Table 59 : Building typologies examples

As obvious from the previous tables, the type of buildings is crucial to determine the real efficiency and future impact of implementation of a certain technology. Taking into account all specific features previously mentioned, the same technology for energy efficiency could be optimal in certain context and not so influential in other one.

Furthermore, before planning and evaluating a certain intervention in a certain region, we shall take into consideration the existence of energy efficiency policies, norms and even financial support, and in particular if they are addressing or not the type of building target of our intervention.

5.5.2. Norms, directives and regulations

Within the Normative Layer, the presence of norms and directives, whether it be transposed and implemented norms at large geographical scale or local specification and regulations, shall be considered.

These normative aspects shall be taken into consideration since they can:

- Define the minimum performance (e.g. energetic) of a construction;
- Define the upper or lower limits of technical parameters;
- Define other standards (e.g. aesthetic);
- Allow or ban determined technologies, materials or other;
- Define the ranking values/energetic labeling;

Level of transposition or implementation	DEFINITION
EU directives & related national transposed directives	European normative, concerning energy efficiency of buildings, and its transposition at national levels, implemented al very large scale
National regulations	Specific regulations adopted at national level, taking into account specific country’s aspects (climatic, technical and non-technical)
Regional/local regulation	Local regulations, taking into account specific features of the region (climatic, technical and non-technical)
Type-of-building-related regulations building	Specific norms addressing certain kind of building (e.g. housing normative, manufacturing plants and office building norms, public buildings..)

Table 60: Normative Layer

5.5.3. Energy efficiency support policies

Before working (and investing) in regions and clusters, it is crucial to know whether there is a support policy for energy efficiency or not, if it's already implemented or it is going to be launched.

Short, medium and long term policies for energy efficiency intervention shall be highlighted region by region.

It will be a qualitative representation in fake colors, superimposed to the geographic map, as shown in Figure 47: Example of energy efficiency intervention policy layer view (Italy, fake data).

Figure 47: Example of energy efficiency intervention policy layer view (Italy, fake data)

The categories that will be included in this layer are:

- General requirements regarding energy efficiency for the whole building;
- General subsidy schemes regarding energy-efficiency in the whole building;

- Specific requirements for the case study technologies (thermal insulation in the Benelux countries and Cooling in the Mediterranean countries);
- Specific subsidy schemes regarding the case study technologies.

For each building typology listed in one of the entries listed in Table 61 must apply.

Regulation	Subsidy
No regulation	No subsidy
Product/system performance thresholds are required	Direct grants for equipment
Use of product/system is mandatory	Grants for performance thats exceeds the standard
Use of product/system is forbidden	Tax reductions
No regulation but label	Loans at reduced rates
	Feed in tariff

Table 61 : Regulation and subsidy entries

6. PUSH AND PULL SCENARIO

6.1. Introduction

The working process in Task 2.2 begins with two scenarios Push and Pull. They are designed to identify what the users are applying for/asking for. The purpose of this exercise is to provide a complete view of all information that will be needed for this specific key technology (thermal insulation and sheep wool) and how the stakeholder may want to use this information, which is useful for making a structure of the mapping tool

The scenarios are made to identify:

- The goals of the geo-cluster mapping tool. Who are the users? What questions can be answered by the tool?
- What are the necessary steps to determine the geo-cluster mapping tool's accuracy?
- What are the limitations of the geo-cluster mapping tool (within the project).

The scenarios determine the questions a potential user of the Geo-cluster map might have at the end of the project, and the purpose of the Geo-cluster map for the specific situation.

The results of the scenario help us build a situation from end to beginning, increasing the usability of the data that appears in the 3D map.

First step: Produce a push and a pull scenario in different climate zones for the technology, Thermal insulation

6.2. Push scenario 1: "Sheep wool"

A sheep's wool insulation manufacturer in Scotland is looking to expand his market. The insulation is completely natural, has no chemical additives and has been fully tested according standards; e.g. fire resistance, thermal resistance. However, it requires a very high skill level to correctly install and to store on construction sites to avoid moisture saturation, meaning it can be expensive to install due to labour costs of the required skill. The nature of the insulation means it would be most beneficial in colder climates requiring high levels of thermally-resistive building fabric, and where there is sufficient space to install a lofting material. The material itself is fairly expensive, but has low shipping costs due to its lightweight nature, meaning it could travel a fair distance before the shipping costs become cost-prohibitive. He knows his product tends to appeal to high-value, private, residential markets. The manufacturer wants to know where in Europe he should start looking for potential clients and

purchasers, and inputs key attributes of his product into the Geo-clusters tool, to get that information.
FROM: IFS scenario's for users of the geo-cluster project

6.3. Pull scenario 2: "Improving thermal insulation"

A housing association in Prague wants to improve the thermal performance of their existing housing stock, having very cold winters. The housing stock is in historically listed buildings, with solid-brick walls. They cannot make any alterations to the external facades due to regulatory restrictions, so the only viable solution is some kind of internal insulation. However, the flats are also extremely small, so they're looking for the thinnest possible insulation solution which offers the highest thermal resistance, and which has low maintenance costs and a lifespan of at least 50 years, and which requires only basic skills to install properly as specialist installers are too expensive for their budget. They cannot find anything in the local market which meets their requirements. Their budget is limited. The housing association's specifier /designer inputs their requirements into the geoclusters system to try and identify which products might suit their requirements. (Their inputs: cost per m2 of material, skill, thermal resistance in relation to thickness, maximum available thickness, minimum lifespan, maximum maintenance costs) Their outputs: List of materials, sorted by thermal property in relation to thickness and costs per m2 product, to help him identify the most value-for-money in terms of performance).

FROM: IFS scenario's for users of the geo-cluster project

Second step: Each partner was intended to contribute to these scenarios providing relevant questions and indicators for the different non-technological categories. (Annex I (012-021_Identification of descriptors)

Goal for this step: to collect as many questions as possible that the stakeholder might have in this scenario. What are the critical input questions of the stakeholder?
Approach: each project partner defines as many relevant questions as possible for the categories:

- **GEO DESCRIPTORS**
  - Socio-economics
  - Labour Costs
  - Environment & Energy regulation
  - Financial incentives
  - Other
- **TECHNOLOGICAL APPLICABILITY**
  - Climate
  - Building typologies

- **KEY-TECHNOLOGY INDICATORS**

These categories follow the structure of the 3D-matrix. Questions were tried to make as specific as possible, as they could be converted in indicators with measurable units, even qualitative or quantitative.
In this inventory it was important to define all questions a stakeholder might have. Although in practice some questions are more important than others, or the stakeholder wants to combine the answers to some questions, we did not prioritize or combine in this exercise.

Question list for both scenarios are almost identical. In the Annex II all questions related to ***"Improving thermal insulation''***, are listed.

Within the analysis of the existing data and scenarios exercise, and apart from the data of technologies, the information on geo-descriptors was finally grouped in layers and sub layers.

Following seven layers were identified:

1. **Characterization of energy use in buildings**
1. **Characterization of buildings**
2. **Characterization of the construction sector – employment aspects**
3. **Characterization of the construction sector – dynamic aspects**
4. **Regulation**
5. **Climate**
6. **Environmental and social consideration layer**

During the working process it was decided to exclude some layers such as: Characterization of construction sector EMPLOYMENT- it is difficult to find accurate data. The data that are available is not really relevant for the geo-cluster mapping tool. Therefore it was decided to exclude this layer, keeping only the overall figure of "employment in the construction sector" as a geo-descriptor in the socio economic layer.

A similar situation exists with layers: Environmental social consideration and Characterization of energy use.

Layers (1) and (2) are sub layers of a building related properties layer. Layers (3) and (4) are sub layers of the construction sector description layer.

Accurate data are from available sources, such as EUROSTAT, ESPON indicators, TABULA project and others.

The second part of the work was to find out whether this is answerable or not. When the exercise was completed, we saw that a lot of questions were not currently answerable. The third part of the work was to take a question from the EUROSTAT database or for some other available source (ESPON indicators, TABULA project) and make a definition for the indicators category. We divided the work between the partners

Third step: Is to complete those data layer with appropriate indicators and with the data with the qualification and quantification those indicators on a geo-referenced way (trying as much as possible to applied to regional level and calling in all cases to territorial relations)

The conclusion from this work is that the Push and Pull scenario exercise helped us to make the main layers and indicators for the non-technology aspects. From this we decided that some of the layers will be put on hold temporarily, such as Characterization of energy use, Characterization of construction sector, and Environmental social considerations. The final non-technology aspects have been reported within the previous section of this report.

MAIN DATA LAYERS			
	SCOPE	**MUSTS INCLUDE**	**SOURCE: SUGGESTIONS AND LIMITS**
Characterization of buildings	Housing stock. Inform about **existing buildings** and their characteristics	Type; age and main building constructive elements and installation	EUROSTAT; TABULA PROJECT
Characterization of construction sector II DYNAMIC	Inform about **economical dynamics** of the sector	Evolution of permits for new buildings and retrofitting; inversion on technology and R&D; census of enterprises (birth and death rate); added value; prices index of buildings; prices index for materials; financial access	EUROSTAT AND OTHERS

Regulation	Inform about national regulation and UE adaptation of Directives	National building codes limits (máx/min; required skills for professionals) certification (compulsory; voluntary); standards; incentives.	RECOMENDED TO LOOK FOR EXISTING PROJECTS THAT RESUME IMPORTAN INFORMATION AS NATIONAL BUILDING CODES…
Climate	Provide data of each climatic zone mainly to answer to performance of technologies		Mainly to answer to PERFORMANCE OF TECHNOLOGIES

Table 62: Main data layers for Geo-clustering energy efficiency technological solutions form buildings 'topic

7. CONCLUSION

This deliverable summarizes the activities carried out in Task 2.2 of the project ‘’Geo-clustering to deploy the potential of Energy efficient Buildings across EU”.

As explained at the beginning of this report, the objective of the project is only to realize a proof of concept of a geocluster mapping tool. The tool should demonstrate that the geocluster approach can provide useful information to future users. It is not the objective of this project (coordination and support action) to develop a fully operational tool. Therefore, the data collection process has been limited and the focus will be on two selected technologies for the rest of the project.

The proposed geo-cluster concept is based on the possibility to locate similarities across European regions by combining single or multiple parameters and indicators organized in homogeneous layers and sub-layers. Two types of layers and sub-layers, technological and non-technological, have been selected based on the information gathered and lessons learnt in Task 2.1.

The technological layer of the knowledge repository consists of 28 different energy-efficient technologies related to the building sector. These technologies represent existing market solutions although some of them are not widely spread. Innovative solutions that are at their early stage of market development have not been considered. The energy performance of a technology is identified through one or more performance indicators. A performance indicator is defined as a function of the technology systems / products characteristics, geo-descriptors (climate) and descriptors (building typology, regulation).

Performance indicators will offer the possibility to compare different products / systems at the European level. These performance indicators will compose the pillars of the multi-dimensional geocluster maps.

Non-technological aspects can also be the determining factor when deciding what kind of product or system will be implemented. The analysis of non-technological layers has been organized within four main layers:

- Context layer, consisting of weather related data and generic descriptive information about the geographic area;
- Socio-economic layer, consisting of a set of statistical indicators shaping the overall social and economic picture of the geographic area considered;
- Financial layer, related to the price/cost parameters of the identified technologies, along the phases of a product’s lifetime;
- Normative layer, reporting the existing norms, directives, regulations, standards and energy-efficiency support policies at the national and/or local level.

Evaluation and analysis of these layers and the respective descriptors are fundamental to match the most appropriate technology with real applicability and consequent energy efficiency that could be reached in an enlarged Europe.

Data and information necessary for creating the multi-dimensional maps were collected across European regions based on EU wide data repositories and documents/reports publicly available. This information was complemented with other qualitative and quantitative data identified in Task 2.1. Further knowledge and information needed will be mobilized within the pilot clusters in WP3 and WP4.

In order to get a complete view of all information that will be needed for a specific key technology and how a given stakeholder may want to use this information, a push and pull scenarios have been defined and analysed. The scenario analysis will also be used in the upcoming WPs.

TERMINOLOGY MANUAL

CLIMATE

Degree days DD - a simplified form of historical weather data. DD are essentially a simplified representation of outside air-temperature data and they are specific to each location, regardless of their geographical location. So every city is characterized by a specific value of the degree-days. They are commonly used in monitoring and targeting to model the relationship between energy consumption and outside air temperature. Degree days can come in any timescale, but they typically come as weekly or monthly figures. There are two main types of degree days: heating degree days (HDD) and cooling degree days (CDD). Both types can be Celsius based or Fahrenheit based.

Heating degree days HDD - a measure of how much (in degrees), and for how long (in days), outside air temperature was *lower* than a specific "*base temperature*" (or "*balance point*"). They are used for calculations relating to the energy consumption required to *heat* buildings.

Cooling degree days CDD - a measure of how much (in degrees), and for how long (in days), outside air temperature was *higher* than a specific base temperature. They are used for calculations relating to the energy consumption required to *cool* buildings.

$H_{south,\ 45°,zone}$ - Annual incident energy on a south oriented plane with a 45° Slope [kWh/m².years]. Incident solar radiation (insolation – solar energy) refers to the amount of energy falling on a flat surface and it is not affected in any way by the surface properties of materials. In particular H_{south} is related to a plane south oriented with a 45°Slope referring to the annual period.

H_0 - Annual incident energy on a south oriented vertical surface [kWh/m².years]. H_0 instead of $H_{south,45°,zone}$ is referred to a vertical surface.

$T_{air,a}$ - Annual Average External air Temperature [°C]

For Italy the UNI 10349 provides the Monthly Average External Air Temperature for all the Italian provinces in the “Prospetto VI”

$T_{air,h,s}$ - Average Heating Seasonal External Air Temperature [°C]

$T_{air,c,s}$ - Average Cooling Seasonal External Air Temperature [°C]

$T_{air,max}$ - Maximum Annual External Air temperature [°C]

For Italy the UNI 10349 provides the Average Heating Seasonal External Air Temperature for all the Italian provinces in the “Prospetto XVI”

$T_{gw,a}$ - Annual Average Ground / Water Temperature [°C]

For Italy there is not a specific regulation regarding the Water Temperature, so usually for system plant calculation, both heating and cooling, that needs these values, the same referred to Air Temperature are used.

$T_{gw,h,s}$ - Average Heating Seasonal Ground / Water Temperature [°C]

$T_{gw,c,s}$ - Average Cooling Seasonal Ground / Water Temperature [°C]

GEO-DIMENSION

Unless otherwise specified the following definitions are takes from the OGC-glossary page (

GIS - Geographical information systems

OGC – Open GIS Consortium (http://www.opengeospatial.org/)

C

Coordinate reference system - A coordinate system that has a reference to the Earth. Consists of a coordinate system and a datum

Coordinates - A tuple of ordered scalar values that define the position of a single point feature in a coordinate reference system. The tuple is composed of one, two or three 'ordinates'. The ordinates must be mutually independent and their number must be equal to the dimension of the coordinate space; for example, a tuple of coordinates may not contain two heights.

D

Datum - Defines the origin, orientation and scale of the coordinate system and ties it to the earth, ensuring that the abstract mathematical concept 'coordinate system' can be applied to the practical problem of describing positions of features on or near the earth's surface by means of coordinates.

Digital Cartographic Model

(source :http://www.eurogeographics.org/Projects/GDDD/GDDD/lists/products.htm#52)

"Simple digital maps having a 'flat' data structure, e.g. digitized maps. Digital Cartographic Models (DCMs) are suitable for display and plots purposes. In the context of GIS the DCM may be used as background information. The geometric form of the DCM is vector".

Digital Elevation Model

(source http://www.eurogeographics.org/Projects/GDDD/GDDD/lists/products.htm#52)

"The Digital Elevation Model (DEM) only contains elevation data. Normally, the height data are arranged in a matrix. Also, vector based contour lines and spot elevations are considered as DEM. "

Digital Ortophoto - Orthorectified images produced using photogrammetric techniques to orthorectify scans of aerial photos and paper maps.

Digitize - The process of converting information into the digital codes stored and processed by computers. In geographic applications, digitizing usually means tracing map features into a computer using a digitizing tablet, graphics tablet, mouse, or keyboard cursor.

E

EEA - European Environment Agency

EO - Earth observation, i.e., remote sensing.

ESRI - http://www.esri.com/

G

Geospatial data – Location properties related to any terrestrial feature or phenomena. Location properties may include any information about the location or area of, and relationships among, and descriptive information about geographic features and phenomena. This includes remotely sensed data, vector map data, addresses, coordinates, etc. Note that "geospatial data" is more precise in many contexts than "geographic data," because geospatial data is often used in ways that do not involve a graphic representation, or map, created from the data.

Geospatial information - Information about entities and phenomena that includes their location with respect to the Earth`s surface. Frequently used as a synonym to geodata, but technically, geodata are "dry" digitally represented facts or recorded observations which on their own have no meaning. They become information when interpreted and put in context by humans.

Geospatial portal - A Web site that provides a view into a universe of spatial content and activity through a variety of links to other sites, communication and collaboration tools, and special features geared toward the community served by the portal. As an open Web resource, a geospatial portal should connect through open interfaces to data and services with similar interfaces. Catalogs and registries that conform to OpenGIS Specifications play an important role in geospatial portals.

GeoTIFF - Data interchange standard for raster geographic images. An extension of the TIFF format to support a geodetically sound raster data georeferencing capability. The aim of GeoTIFF is to allow a means for tying a raster image to a known model space or map projection, and for describing those projections. The geographic content supported in GeoTIFF tag structure includes its cartographic projection, datum, ground pixel dimension, and other geographic variables.

GIS application (source OpenGIS Guide) "The use of capabilities, including hardware, software and data, provided by a Geographic Information System specific to the satisfaction of a set of user requirements. Example of a GIS application: Spatial decision support system application for district planning purposes."

Geography Markup Language (GML) - OGC`s XML-based language for describing and encoding geospatial information. An application of XML, a specification developed by members of the Open GIS Consortium. http://www.opengis.org/techno/specs/00-029/GML.html ". GML is an XML encoding for spatial data. In a sense, it is a schema-writing language for spatial information.

I

Interoperability (of data), (source: OpenGIS Guide) - "Capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units ISO 2382-1. "The ability for a system or components of a system to provide information portability and interapplication, cooperative process control. Interoperability, in the context of the OpenGIS Specification, is software components operating reciprocally (working with each other) to overcome tedious batch conversion tasks, import/export obstacles, and distributed resource access barriers imposed by heterogeneous processing environments and heterogeneous data. "

ISO - International Organization for Standardization

J

JPEG - (Joint Photographic Experts Group) Image format for continuous tone pictures: JPEG makes use of continuous-tone digital images much more economical by drastically reducing the volume required for storage and the bandwidth required for transmission.

M

Map - A two-dimensional visual portrayal of geospatial data. A map is not the data itself.

Map projection - A coordinate conversion from a geodetic coordinate system to a planar surface, converting geodetic latitude and longitude to plane (map) coordinates. The result is a two-dimensional coordinate system called a projected coordinate reference system.

Map scale - The relationship between distance on a map and the corresponding distance on the earth`s surface. Map scale is often recorded as a representative fraction such as 1:1,000,000 (1 unit on the map represents a million units on the earth`s surface) or 1:24,000 (1 unit on the map represents 24,000 units on the earth`s surface). The terms `large` and `small` refer to the relative magnitude of the representative fraction. Since 1/1,000,000 is a smaller fraction than 1/24,000, the former is said to be a smaller scale. Small scales are often used to map large areas because each map unit covers a larger earth distance. Large-scale maps are employed for detailed maps of smaller areas.

Metadata (source: ISO 19115; KOGIS Switzerland; Co-ordination for GIS in the federal administration of Switzerland)

"Data about data or a service. Metadata is the documentation of data. In human-readable form, it has primarily been used as information to enable the manager or user to understand, compare and interchange the content of the described data set. In the Web Services context, XML-encoded (machine-readable and human-readable) metadata stored in catalogs and registries enables services to use those catalogs and registries to find data and services.

N

National Mapping Agencies (NMA) - National government agencies, such as the UK's Ordnance Survey, France`s Institut Geographique National (IGN) and the US's US Geological Survey and Federal Geographic Data Committee, that are chartered to provide national mapping products and services.

National Spatial Data Infrastructure (NSDI) - Information Infrastructure elements that make digital geographic information a part of everyone's digital information environment: data content and metadata standards; national Framework (base) data; metadata to help inventory, advertise, and intelligently search geographic data sets; a clearinghouse that allows for catalog searches across multiple geodata servers on the Internet; commercial geoprocessing products that interoperate through interfaces that conform to interoperability interface specifications; and partnerships to advance data sharing and NSDI development.

O

Open source - It is important not to confuse "open source" with "open standards." They are entirely different. The special licenses that govern use and sale of such software exist not to ensure profits to the software`s owner, but to ensure that the software`s source code remains in the public domain (free to all), though companies are allowed to sell products that include some or all of the source code. Open source software is usually developed not by single company but by a distributed team of developers, typically an informal ad hoc group of volunteers.

Open standard - An "open standard" is one that: 1. Is created in an open, international, participatory industry process 2. Is freely distributed and openly accessible 3. Does not discriminate against persons or groups 5. Ensures that the specification and the license must be technology neutral: Its use must not be predicated on any proprietary technology or style of interface.

P

Photogrammetry - Use of aerial photographs to produce planimetric and topographic maps of the earth`s surface and of features of the built environment. Effective photogrammetry makes use of ground control by which aerial photographs are carefully compared and registered to the locations and characteristics of features identified in ground-level surveys.

Publish - "publish" web pages contents - make them discoverable - through HTML, metadata, geodata and geoprocessing services servers publish their contents and capabilities through XML metadata contained in feature type registries, feature instance catalogs, and service registries.

R

Request - Invocation of an operation by a client

Response - Result of an operation returned from a server to a client

Raster - The representation of spatial data as a matrix of valued cells. Originally, a raster was a scan line in an electronic display such as a television or computer monitor. In geoprocessing, raster refers to a digital representation of the extent of geographic data sets using "grid cells" in a matrix. A raster display builds an image from pixels, small square picture elements of coarse or fine resolution. A raster database maintains a "picture" of reality in which each cell records some sort of information averaged over the cell`s area. The size of the grid cell may range from centimeters to kilometers. Many satellites transmit raster images of the earth`s surface. Reflectance of sunlight at a certain wavelength is measured for each cell in an image.

S

SDI (source: PreANVIL Glossary http://www.anvil.eu.com/find/Glossary-english.htm)

"(Geo)Spatial Data Infrastructure: a comprehensive package of consensus and initiatives required to enable complete provision of data, access and privacy within the territory of the designated infrastructure."

Service - A computation performed by a software entity on one side of an interface in response to a request made by a software entity on the other side of the interface. A collection of operations, accessible through an interface, that allows a user to evoke a behavior of value to the user. ISO – 19119

SHAPE – An ESRI published spatial data format.

Spatial reference system - As defined in the OpenGIS Abstract Specification Topic 2 and ISO 19111. Position on or near the Earth's surface can be described by spatial reference systems. These are of two basic types: those using coordinates; and those based on geographic identifiers (for example postal addresses, administrative areas). Spatial referencing by geographic identifiers is defined in ISO 19112, Geographic information - "Spatial referencing by geographic identifiers." The subject matter of The OpenGIS® Abstract Specification Topic 2: "Spatial Referencing by Coordinates" is spatial referencing by coordinates.

Spatial Web - The Spatial Web is the spatially enabled World Wide Web. It is also the set of Web-resident open geospatial resources -- data, schemas and services - that enable people to publish, find and use Web-resident geospatial information off all kinds.

Standard - A document that specifies a technological area with a well-defined scope, usually by a formal standardization body and process.

T

Thematic map – A map showing, by color or pattern, the distribution of a single phenomenon

Tool - A software component, sometimes called an application object, which can act as either a service provider or service requester within an application platform.

Topographic maps (source: AGI glossary. http://www.geo.ed.ac.uk/agidict/welcome.html) – "A map whose principal purpose is to portray the features of the earth`s surface. These features might include the cultural landscape, but normally refer to the terrain and its relief."

U

UTM Coordinate System (Universal Tranverse Mercator) - A planar locational reference system which provides positional descriptions accurate to 1 meter in 2,500 across the entire earth`s surface except the poles. Based on the Universal Transverse Mercator map projection. At the poles, the Universal Polar Stereographic projection is used. The UTM system divides the earth`s surface into a grid in which each cell, excluding overlap with its neighbors, is 6 degrees east to west, and 8 degrees north to south (with the exception of the row from 72-84 degrees north latitude). For any position in the UTM grid, X-Y coordinates can be determined in eastings and northings. Eastings are in meters with respect to a central meridian drawn through the center of each grid zone (and given an arbitrary easting of 500,000 meters). In the northern hemisphere, northings are read in meters from the equator (0 meters). In the southern hemisphere, the equator is given the false northing of 10 million meters.

V

Vector - A representation of the spatial extent of geographic features using geometric elements (such as point, curve, and surface) in a coordinate space.

W

Web Feature Srvice (WFS) - OpenGIS Specification that supports INSERT, UPDATE, DELETE, QUERY and DISCOVERY of geographic features. WFS delivers GML representations of simple geospatial features in response to queries from HTTP clients. Clients access geographic feature data through WFS by submitting a request for just those features that are needed for an application.

Web mapping - Dynamic query, access, processing, combination and portrayal of different types of spatial information over the Web.

Web Mapping Service (WMS) - OpenGIS Specification that standardizes the way in which Web clients request maps. Clients request maps from a WMS instance in terms of named layers and provide parameters such as the size of the returned map as well as the spatial reference system to be used in drawing the map.

Web services - "Web services are self-contained, self-describing, modular applications that can be published, located, and invoked across the Web. Web services perform functions that can be anything from simple requests to complicated business processes. Once a Web service is deployed, other applications (and other Web services) can discover and invoke the deployed service."

WWW (source: PreANVIL Glossary http://www.anvil.eu.com/find/Glossary-english.htm)

“World Wide Web: a collection of protocols, based on IP, and infrastructure that enable efficient, user-friendly publishing, discovery and access to digital information."

X

XML (source: PreANVIL Glossary http://www.anvil.eu.com/find/Glossary-english.htm)

XML (eXtensible Markup Language) is the predominant form for interoperable, self-describing data/content, in combination with XML schema definition language. See http://www.w3.org/XML/. XML has its roots in SGML, the Standard Generalized Markup Language (an ISO standard). The development of XML came about because of perceived limitations in HTML when used as a tool for publishing complex documents on the Web. http://www.w3.org.

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