Design4Energy - Building life-cycle evolutionary Design methodology able to create Energy-efficient Buildings flexibly connected with the neighborhood energy system

Co-funded by the European Commission within the 7th Framework Programme.
Grant Agreement no: 609380.
2013-10-01…2017-09-30 (48 months).

Deliverable 3.1

Current State and requirements

Revision 0

Preparation date 2013-10-31 (m01)

Due date 2014-12-30 (m15)

Lead contractor............................. SYM

Authors:

Team Symelec

Team Fraunhofer IAO

Farid Fouchal................................ LU

Tarek Hassan .... LU

Steven Firth .... LU

Shen Wei .... LU

José Manuel Tofiño .... GSM

Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

<table>
<tr><th colspan="9">Deliverable administration</th></tr>
<tr><td>No & name</td><td colspan="8">D3.1 Current State and requirements</td></tr>
<tr><td>Status</td><td colspan="4">Draft / Working / Released</td><td>Due</td><td>M12</td><td>Date</td><td>2014-09-30</td></tr>
<tr><td>Author(s)</td><td colspan="8">Team Symelec, Team Fraunhofer IAO, Farid Fouchal, Tarek Hassan and Steven Firth, Shen Wei, José Manuel Tofiño</td></tr>
<tr><td>Description of the related task and the deliverable in the DoW</td><td colspan="8">Task 3.1. Current State and requirements in Components and energy systems data bases
Task leader: SYM Partners involved: LU, FHR, GSM
Identification of requirements for Components and energy systems data and information. Execution of a stakeholder analysis through a minimum of 30 semi-structured interviews covering all major stakeholders of the envisioned systems. Classification and evaluation of existing data base solutions in the context of energy efficient buildings concerning their current capabilities and the fulfilment of the identified requirements.</td></tr>
<tr><td rowspan="2">Planned resources PM</td><td>SYM</td><td>LU</td><td>FHR</td><td>GSM</td><td></td><td></td><td></td><td>Total</td></tr>
<tr><td>2</td><td>2</td><td>4</td><td>2</td><td></td><td></td><td></td><td>10</td></tr>
<tr><td>Comments</td><td colspan="8"></td></tr>
<tr><td>V</td><td>Date</td><td>Authors</td><td colspan="6">Description</td></tr>
<tr><td>1</td><td>2014-02-01</td><td>SYM</td><td colspan="6">Table of content and distribution of tasks by partners for D3.1 Current State and requirements</td></tr>
<tr><td>2</td><td>2014-04-29</td><td>SYM</td><td colspan="6">Updated Index</td></tr>
<tr><td>3.1</td><td>2014-05-22</td><td>FHR</td><td colspan="6">Contribution from FHR</td></tr>
<tr><td>3.2</td><td>2014-07-09</td><td>FHR</td><td colspan="6">Updated the structure, contribution from FHR</td></tr>
<tr><td>4</td><td>2014-11-25</td><td>GSM</td><td colspan="6">Contribution from GSM</td></tr>
<tr><td>5</td><td>2014-11-27</td><td>LU</td><td colspan="6">Contribution from LU</td></tr>
<tr><td>6</td><td>2014-12-11</td><td>SYM</td><td colspan="6">Version ready for internal review</td></tr>
<tr><td>7</td><td>2014-12-12</td><td>WP leader</td><td colspan="6">Checked and released to the Other Checkers and reviewers.</td></tr>
<tr><td></td><td></td><td>Checker</td><td colspan="6"></td></tr>
<tr><td></td><td></td><td>Reviewer</td><td colspan="6"></td></tr>
<tr><td></td><td></td><td></td><td colspan="6">.</td></tr>
</table>

Disclaimer

Table of contents

Figures

Tables

1. PUBLISHABLE EXECUTIVE SUMMARY

This deliverable firstly identifies the major related stakeholder of the envisioned platform and project outputs. Taking into account the project objectives and the interests of the analysed stakeholders, this report brings the requirement for components and energy systems database (DB), that defines and recommends the parameters for different building components such as wall, roof, floor, windows and doors, lighting system, renewable energy, heat pump, boiler, energy storage and distribution, operation and maintenance issues and simulation outputs which could help the end users or architects to understand the energetic performance of their on-going design. Interviews, questionnaire, literature review, internal discussions with partners and energy experts, investigation of the simulation software and BIM technologies are the main data sources.

With the objective to develop a suitable database for the Design4Energy (D4E) workspace, the requirement identification of the component and energy system database also take references of other existing database solutions. The classification, evaluation and analysis of the state of the art of the BIM and energy efficiency oriented database have inspired the requirement identification and also the concept design in T3.2.

The key information presented within this deliverable can be summarised as follows:

- Objectives and vision of the component and energy system database.
- Identification and analysis of the major stakeholders related to the D4E scope.
- Questionnaire design and the collected results
- Database requirement description of building components, including envelope (wall, covers/roof, floor), window and door. The recommended parameters are given in table format.
- Database requirement description of energy systems, focusing on the subcategories like lighting system, renewable energy, heat pump, boiler, energy storage and distribution, in each subcategory, requirements for specific technologies are described. Introduction of the strengthens and weaknesses of the latest and popular technologies is also included in appendices.
- Database requirement description of the simulation outputs, specifying the interesting data which could help the end users to understand their on-going building design.
- Database requirement description of the operation and maintenance related issues.
- Database requirement in system architecture, interoperability, data structure, user interface and user management.
- Analysis of existing database solutions. By classifying the current practices into three categories: construction material databases, component database and others such as building type databases, different technologies and platforms are analysed.

2. INTRODUCTION

2.1 Purpose and target group

The purpose of this deliverable is to report on the current practices of the database solution in the energy efficient (EE) building design, collection and study of the requirements for the D4E database.

It involved a review of activities, literatures, solutions from other projects and products, interview of experts and questionnaires distributed to different stakeholders to collect different perspectives on building components and energy systems. Within this report, database requirements for building components, energy systems, simulation outputs and operation and maintenance, system (architecture, data structure, user interface and management) are described, stakeholder and current database solution are also analysed.

The target groups are mainly the D4E partners (mainly WP3), and other general and expert readers with interest in the D4E database solution.

2.2 Contributions of partners

Table 1 shows the contributions from different partners in this report. It is also important to state that during the collection of database requirement, the interviewee have contributed a lot, this includes the consortium partners and their collaborators, external experts, ext.

Table 1 Partner's contributions

Partners	Contribution to section & Author (s)
SYM	Section 1, 2, 3, 5, 6, 8, 10, 13
LU	Section 7, 9
FHR	Section 2, 3, 8, 9, 10
GSM	Section 3.3, 4, 5, 8

2.3 Baseline

The main baselines for this deliverable are:

- Current existing database solutions.
- Questionnaire and interviews carried out.
- Literature about energy system and building components.
- Descriptions about simulators and their data requirements.
- Discussion results from the project meetings.

2.4 Relations to other activities [FHR]

The database system is accessed by different modules of the D4E platform. From the defined use case scenario vision it can be seen that some of these modules are the relation to simulation and operation and maintenance module. Further there are groups that are involved directly in the creation and use of database content.

The simulation module already describes some use cases. Renewable energy generation plants are characterized by performance features depending on climate, weather, age of the plant, operation costs, and historical performance as noted from real cases and susceptibility. The task of the database will be to store the energy systems as object while interlinking its performance attributes to the given condition. A series of real case data that is already interlinked with the conditions serves as a reference from which the D4E platform can predict performances. The same data template is used to record output of energy system simulations in accordance to certain simulation condition. The input and output of the data is the same since the functionality describes the storage of data.

The operation and maintenance module already describes some use cases. Input and output of data will be again the same with the addition to make interlinked data requests. Stored data is e.g. deterioration curves, cost of operating and replacements, energy performance and demands of components or the building along the lifecycle, cost in future operation and maintenance, and cost effectiveness of different solutions.

The highest interaction will be with users that directly interact with the database content. Building components have to be initially stored by users. This cannot happen automatically.

- User interaction has to provide a connection to BIM models.
- The visualized data makes conclusions possible for building architecture and positioning.
- BIM models have to be provided to the relevant stakeholders such as engineers for energy systems.
- Solutions with their operational attributes, maturity, deterioration, experienced costs or first referring to best practices of similar projects
- Material characterization (e.g. type, functionality, thickness, thermal conductivity, density specific heat, internal and external solar absorbance, and emissivity)
- Data visualization (see conceptual design for the system architecture)
- Team management (see conceptual design for the system architecture)
- A more specific description can be seen in chapter “Stakeholder Analysis”.

2.5 Structure of the Document

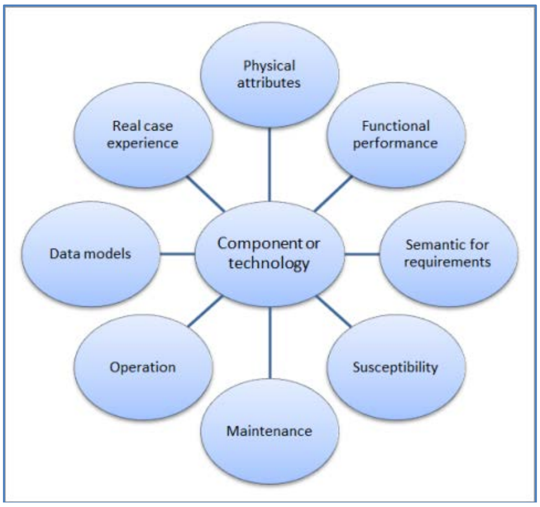
Section 3 first analyses the objective and vision of the database, stakeholders and the design of the questionnaire, which is the baseline of the extraction of the requirements. Section 4, 5, 6, 7 describe the database requirement for building components, energy systems, simulation outputs and operation and maintenance respectively, requirements are given in form of table or list, descriptions like strengthens and weaknesses of the latest technologies are also included, more details can be found in the appendices in section 12. Section 8 shows the general requirement of the database as a system: requirements in architecture, interoperability, data structure, user interface functions and user management are concluded and presented in tables. Section 9 will then investigate the state-of-the-art in database solutions that will serve as important baselines for the future development and implementation of database. Section 10 will summarise the findings.

3. REQUIREMENT ANALYSIS

3.1 Objetives and visions (FHR)

In the concept phase of a building project the choice of building components determines the energy efficiency significantly. On the one side energy related systems such as HVAC systems, lighting, energy use and generation systems are chosen. On the other side the designer has to configure building components such as windows, walls, thermal insulation, roofing systems etc. to optimize the energy efficiency. A gap in current practice lies between the collection of customer requirements and the first energy simulations with the configured building components. Energy system solutions that are new for companies are hardly taken into account at the design stage. Designers most commonly make component choices that could potentially have higher costs of operation, maintenance and consumption because of poor knowledge bases. To predict and to influence the performance of energy efficiency, it is necessary to make better informed decisions at building the life cycle level, including operation and maintenance. Figure 1 shows a schema of the component or technology related information stored in the database.

Figure 1 Database schema



The D4E project plans to develop a system supported by a database structure that will be used to support the choice of building components by making relevant data available to the stakeholders on a multi-disciplinary platform. The technology based information sharing goes alongside with the common concept of technology management to identify, evaluate and observe technologies, in this case building components [26]. Contracting parties, solution or service providers have a strong involvement in design decision. They depend on knowledge/information such as budgetary issues, experience of prior projects and performance. In the planned component database the designs or components will be stored to promote re-usability; they can be searched by customer requirements or simple attributes and can easily be taken for further assessments or simulations. Requirements therefore can be applicable in special use cases. Displayed attributes differ depending on the technology type. As an example materials are characterized by type, functionality, thickness, thermal conductivity, density specific heat, internal and external solar absorbance, and emissivity. Furthermore, its characteristics change by age and use case. Additionally, renewable energy generation plants are characterized by performance features depending on climate, weather, age of the plant, operation costs, and historical performance as noted from real cases and susceptibility.

The value of the component database comes for two actions: the conceptual design of the building and the energy system design. Architects are always confronted with budgetary issues. Promoters and investors of e.g. residential buildings need to request financial support and further reduce the risk of cost increase through modifications during the detail design and construction phase. The component database allows browsing energy system by attributes such as performance and estimated life cycle costs (LCC). In consequence buildings can be evaluated as investment objects with inversion of chosen energy systems and not only be construction costs. Therefore, information needed is cost of operating and replacements. Certificates such as BREEAM assess the sustainability of buildings by operation and maintenance during the building lifespan of e.g. 40 years. Needed information that should be accessible in the database is therefore the energy performance along the lifecycle, cost in future operation and maintenance, and cost effectiveness of different solutions.

With the database the architect is aware of energy systems such as different plants for renewable energy. This influences directly the building architecture and positioning as for example the direction and type of the roof should be considered if solar plants are intended to be used. After getting first drafts or even the BIM model of a building the mechanical engineer investigates in the next steps the design of energy systems. The database lets him browse through the nearly unmanageable amount of solutions (e.g. HVAC systems) and identify the right components from the library. He evaluates the solutions by their operational attributes, maturity, deterioration, experienced costs or first referring to best practices of similar projects. Comparative information and recommendations are available and the engineers can take advantage of better technologies and lower risk in life time predictions.

Firstly, the database is reachable through the browsing interface that also allows search requests by the user. Secondly it is connected to other parts of the D4E platform that work with its information and provide e.g. decision support on maintenance and operation or simulations based on certain data.

3.2 Stakeholder analysis (FHR)

3.2.1 Introduction

The intended database system aims at supporting the collaborative design process in terms of the provision of relevant data. Therefore an analysis of the D4E platform users, which show a relation to the database content, is conducted. In the following a description of the users, their roles in the design process and at the usage of the database, and their situation and needs, are exploited. The basic roles are determined out of the use cases the consortium has defined. A complementation of the roles and their tasks is made upon the research of existing database solutions and a closer image of their needs is made upon a questionnaire conducted among different stakeholders.

The design of the questionnaire can be seen in Chapter 3.3.1 "Methodology and Questionnaire design". It aimed at giving an overview of the important aspects and information during the decision making processes in the design phase of one or more buildings, which relates to design on district level. This basically relates to simulation and analysis of e.g. building costs, ecological damage, or different indicators of energy efficiency. Basically persons with influence or responsibility on the design phase of buildings were targeted. The participants were asked for their specific role and the process of their decisions. The questionnaire received 14 answers of which 6 were given by architects, 3 by technology and solution provider, 1 building owner, 1 planner and 3 undefined roles.

3.2.2 Persons involved in the design process

The design processes defined in D4E contain five roles which are the client, energy experts, architects, MEP engineers, and electrical engineers. The concept design of the building is made in collaboration with the client, the facility manager and the architect. Next to the design and energy requirements a 3D sketch is made. A preliminary design model in an IFC file, local weather profiles, natural lightning and materials provide the bases for energy simulation. For the approved design the energy experts are confronted with thermal simulations. The architect optimizes the heat loss and deals with the choice of e.g. building envelopes and fenestration. The MEP engineer designs the HVAC machinery, media connections, renewable energy sources, and building's in-built equipment related to required environmental certificate's mark. For some simulations of the building, such as simulation of the thermal performance, the configuration of the wall and windows can be changed to see the influence of the different configurations. The client then may come to a conclusion to use one or another material or change the thickness of the wall.

Together with “consultants” these roles can also be found in the search for existing database solutions. To add value to their work models of buildings or building components are provided on web platforms. Further a quality check for their models through sharing their work ensures consistency and error validation. The questionnaire revealed that a correction of predictions of proposed buildings' energy performance is a main effort. Some consultants offer approvals and certifications of products and buildings.

Mostly these stakeholders are confronted a few times a month with decisions on building components. These decisions are said to be either important or essential for their businesses. Important information the decisions are based on can be categorized in:

- Costs such as the budget, future energy costs, life-cycle costs, and construction costs;
- Resident factors such as user comfort, usage frequency, type of user;
- External energetic influences such as local energy sources (radiation and wind), climate;
- Energetic characteristics of the design objects such as efficiency of the equipment, the age and type of the building.

A provision of the information on all these factors could be found in the research of existing database solutions.

The decisions on technologies influenced by the aspect of neighbourhood or districts are usually based on regulatory issues or the energy supply. Important factors are on the one side district heating contracts, design regulatory or on the other side available renewable energy sources.

Next to owners and general contractors the most important roles that influence the decisions are funds, banks, grant managers, or investors, and further technology and building solution providers.

3.2.3 Providers of services and products related to construction activities

Participant of the questionnaire claimed that the most important sources their design decisions are based on are experts such as researchers, databases, technology suppliers, partners, company websites and catalogues, and experience from prior projects. Consulting services provide information of the energy efficiency and cost of the equipment together with the assessment of the life-cycle cost of the equipment. The research for existing database solution showed that this group has an important contributing role. Common services or products are software solutions, the provision of information, e.g. physical characteristics of buildings or materials, building components such as façades or windows, and energy systems such heat pumps. Their interest is to develop and distribute their products, for which they use the web platforms. A database solution therefor should integrate products of technology providers, the consultancy of researchers and the experience of other firms.

Software solutions in this context are desktop or web applications that help to estimate energetic attributes, costs or environmental influence of a building over its lifecycle. These tools usually depend on similar real cases or experience values. The usage of these values needs expertise and tools are often developed by researchers, engineers or specialists.

3.2.4 Conclusions

This chapter analysed stakeholders and their interests that have a connection to the database system. To build a successful database the interests and actions in the design process have to be supported accordingly. Opportunities for this support are:

- Support of the energetic simulation and environmental influence through the provision of energy system performance data and physical characteristics of building materials,
- Support of the cost simulation over the life cycle through e.g. the provision of data from similar real cases,
- Support of the design process through possibilities to share design results,
- Support of the owners' decision through providing information about utilization and sustainability aspects of building components and energy systems.

The stakeholders usually fall back on services from researchers, consultants, building component databases or software solutions, which support their decisions. However, it is not possible to substitute all these sources with one database system. So the next development should focus on most relevant aspects.

3.3 Questionnaire design and interviews

3.3.1 Methodology and Questionnaire design

The methods used include the following:

1. Data gathering: (a) Questionnaires and interviews, distributed to project partners and their collaborators, other project partners like EcoShopping, external architects and energy experts; (b) Literature survey that was mainly desktop search supported by internal consultations, review of research projects (of energy–efficient building, retrofit projects, BIM solution, energy simulators); (c) Discussions during the project meetings carried out;

2. Sources: Cordis, World Wide Web project sites and official sites of government organizations, database providers, EU projects, commercial products and work contacts from the building energy, BIM, ICT domain;

3. Analysing data: The results were reviewed at internal meetings, between partners meetings and iterative workshops;

4. Summaries and recommendations are made.

The semi structured interviews is carried out in forms of face to face interview, internal discussion, teleconference, and questionnaires. Base on the objectives and vision for this task, and the analysis of the stakeholders, the questionnaire is designed including the following sections:

- Stakeholders – Role of the interviewee
- Decision Process – How often and how they make decisions, and who and factors affects the decisions.
- Component: HVAC Equipment – relevant parameters for HVAC equipment
- Components: Lighting – relevant parameters for Lighting
- Components: Envelope – relevant parameters for Envelop in general

- Components: Wall/Cover/Floor – relevant parameters for wall, roof and floor
- Components: Windows/Doors – relevant parameters for window/doors

The questionnaire is not only designed to collect the relevant parameters for the database, but more importantly, to know the decision process, factors that decision is based on in different phase, decisions on technologies influenced by the aspect of neighbourhood, information sources etc. thus the result will help during the design and implementation of the database and other research activities, surely, it also served as kind of dissemination activity since it is distributed to different stakeholders from different organization and co-workers by introducing the project ideas and purpose of the questionnaire.

3.3.2 Summary of the interviewed

In this section, some key information from the questionnaire will be presented. For more details of the response, refer to the Appendix 9.

3.3.2.1 Interviewees

Totally 30 responses are collected from different sectors, about 23% are Architects and designers, and another 20% are technology and solution providers. Building owner and construction companies also count 10% of the total interviewed. Below is the summary of stakeholders that have responded the questionnaire:

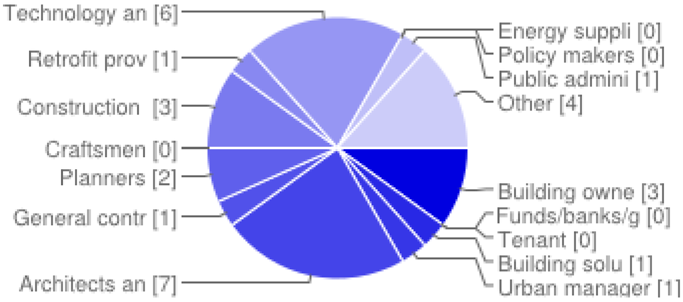


Figure 2 Stake holders participated in the questionnaire

3.3.2.2 Decision making on building component

80% of the participant states that the decision making on building components is important or essential for their business; only one reported that it not. This match the ideas of the project and the selection of the building components are considered as relevant for building, and according to other feedback and internal discussions with energy experts, the building components can affect a lot the building performance and thus the future energy consumption of the building.

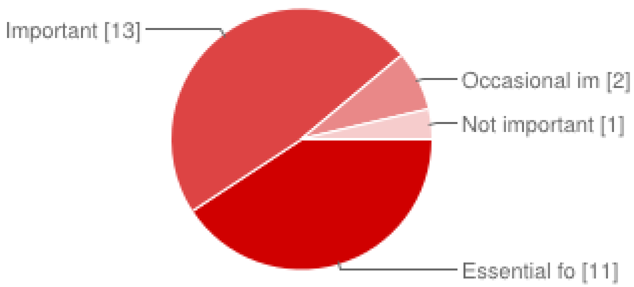


Figure 3 Opinion on building component

3.3.2.3 Component - HVAC Equipment

Among the interviewed, over 60% of the participants considers the investment cost and operation cost are important factors (noted as more than 7/10), and consider energy efficiency and thermal comfort of the HVAC equipment are relevant when they design the system. The levels of importance (the X axis) are set as: 1 (not considered/not important) - 10 (extremely important):

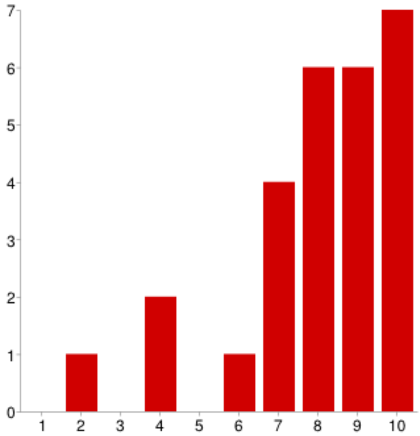


Figure 4 Evaluation on investment cost

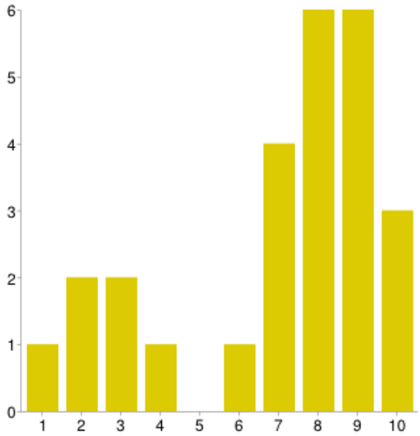


Figure 5 Evaluation on operating cost

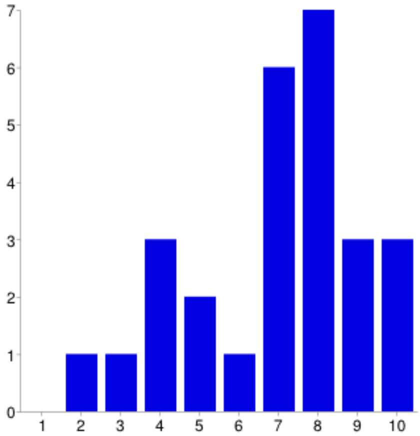


Figure 6 Evaluation on energy efficiency

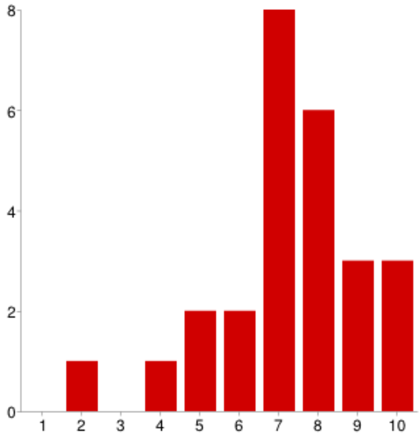


Figure 7 Evaluation on thermal comfort

Among many of the parameters of HVAC system, Coefficient of Performance (COP), Thermal efficiency and electrical efficiency are consider as relevant factors when they decide to use a equipment.

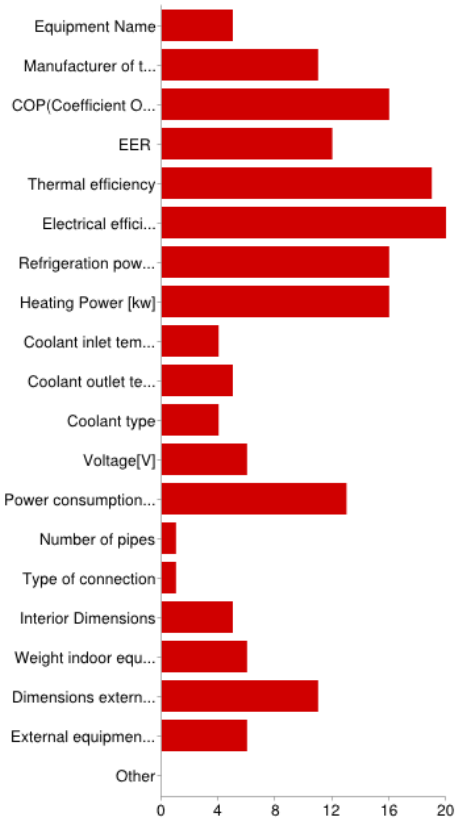


Figure 8 Evaluation on importance of the properties of HVAC systems

3.3.2.4 Component - Lighting

When it comes to the evaluation of the relevant factor for designing a lighting system, typology of the lighting system, lamp power, lumen output and efficiency, average lift are those most marked factors:

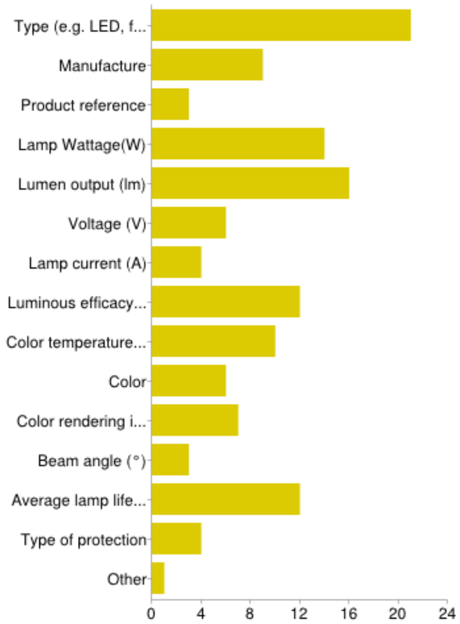


Figure 9 Evaluation on importance of the properties of lighting systems

3.3.2.5 Component – Envelope

During the design of an energy efficient building, several types of envelops may be considered. In the questionnaire, subcategories of envelops (Wall, windows, doors, covers and floor) are reviewed, the evaluation given by the participants are positives, which reveals that they agree that these components have great effects on the energy performance of a building. The same as HVAC components, the evaluated level of importance is ranged from 1 (not important) to 10 (extremely important).

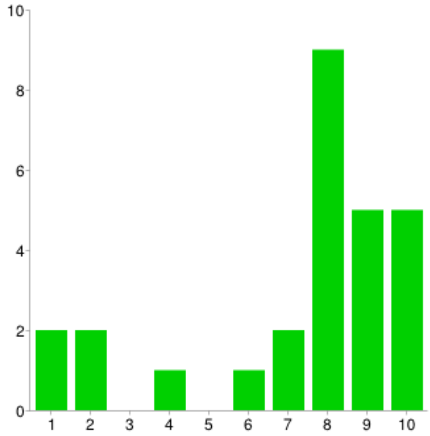


Figure 10 Evaluation on wall

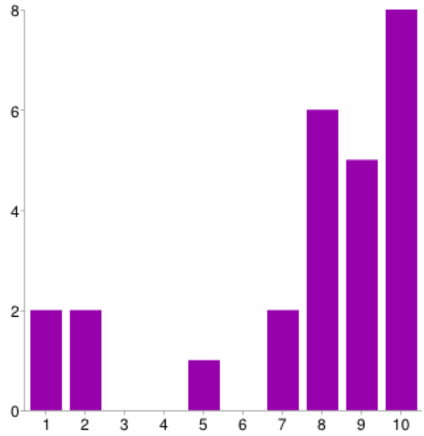


Figure 11 Evaluation on windows

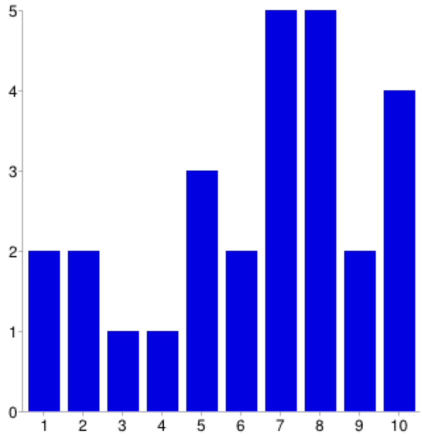


Figure 12 Evaluation on doors

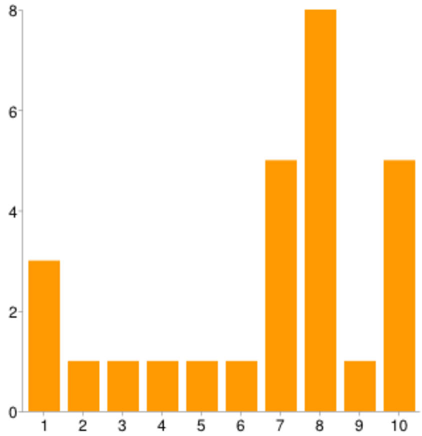


Figure 13 Evaluation on covers

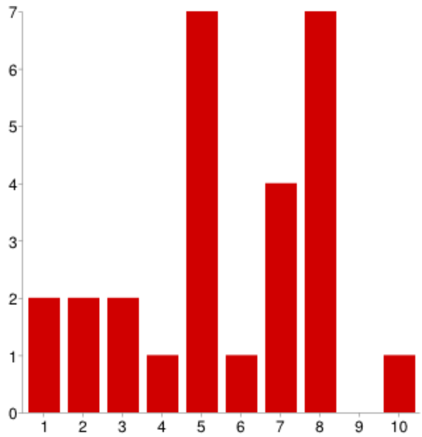


Figure 14 Evaluation on floor

3.3.2.6 Other results

More details of the response are available in Appendix 9.

4. BUILDING COMPONENT D.B. REQUIREMENT (GSM)

Unlike the normal database of building components or libraries, the components envisioned in D4E should contain energy related information and be integrated during the design phase, which can facilitate the energy performance simulation once the draft BIM model is completed, in this way, the end user or architects could get the energy performance data of their design without requesting energy experts to remodel the building for performance simulation or at least, the energy expert could make use of the BIM model and shorten the performance calculation. The end user then is empowered to view the weakness in energy performance and carry out a quick modification of this design, in this way, it is expected to greatly reduce the resource and increase the energy performance of the building designed.

4.1 Overview and clasification of building component

Among many indicators, heating/cooling demands, or saying energy consumption in another perspective, are the main parameters that the designer should pay attention to for an energy efficient building design. Furthermore, this heating/cooling demands information is also needed in the future detailed HVAC system design. Beside the building location such as the latitude and altitude, and internal loads, the building component is critical for evaluating the building performance and HVAC design and is classified into two categories:

- Building envelope typology and properties: roof, walls (for facades orientation is also needed), floors and internal partitions.
- Typology, properties of window/door

In the design of the questionnaire, potential useful energy related parameters of building components have been carefully studied. Essential outputs from the questionnaire have been very useful in the database requirement analysis. Not all the interviewees are experts in energy performance, but are building owners, constructors and other related stakeholders, although some energy related parameters, which could be needed by energy simulators and are recommended by the energy expert in other informal interviews, may not have been considered as important in the questionnaire, they will be considered as necessary for future database design and will be included in this deliverable.

The description of the requirement in building components in this section will focus on building envelops, which includes wall, floor, roof and interior partition, windows and doors.

4.2 Building envelope

For an easy understanding, key parameters considered as important for building envelop database design are included in Table *2* in a clear way. The parameters that appear in the right column are the required values to evaluate the performance through an energy simulation tool.

Table 2 Main parameters for building envelop

Typology of building thermal enclosure	Parameters
Roof • Buried	Dimensions (length, width) U value - Thermal transmittance (W/m2K) Degradation rate on U value

• In contact with air	Specific heat capacity (kJ/kgK) Density (kg/m3) Solar absorptance Dimensions (length, width) U value - Thermal transmittance (W/m2K) Degradation rate on U value Specific heat capacity (kJ/kgK) Density (kg/m3) Solar absorptance
Wall • In contact with the ground • Facade • Party wall	 Dimensions (length, width) U value - Thermal transmittance (W/m2K) Degradation rate on U value Specific heat capacity (kJ/kgK) Density (kg/m3) Dimensions (length, width) U value - Thermal transmittance (W/m2K) Degradation rate on U value Specific heat capacity (kJ/kgK) Density (kg/m3) Solar absorptance Orientation Dimensions (length, width) U value - Thermal transmittance (W/m2K) Degradation rate on U value Specific heat capacity (kJ/kgK) Solar absorptance Density (kg/m3): Heavy >=200kg/m2 Lightweight<200kg/m2
Floor	Dimensions (length, width) U value - Thermal transmittance (W/m2K)

	Degradation rate on U value Specific heat capacity (kJ/kgK) Density (kg/m3) Solar absorptance
Interior partition • Vertical	Dimensions (length, width) U value - Thermal transmittance (W/m2K) Degradation rate on U value Specific heat capacity (kJ/kgK) Density (kg/m3) Solar absorptance
• Horizontal (in contact with no habitable space above)	Dimensions (length, width) U value - Thermal transmittance (W/m2K) Degradation rate on U value Specific heat capacity (kJ/kgK) Density (kg/m3) Solar absorptance
• Horizontal (in contact with no habitable space below)	Dimensions (length, width) U value - Thermal transmittance (W/m2K) Degradation rate on U value Specific heat capacity (kJ/kgK) Density (kg/m3) Solar absorptance

The detailed data for different products could be facilitated by technology providers or constructors. The designer, knowing the wanted envelop (typology, material, etc.) and specific values (dimensions and even thermal transmittance), then can use directly the building components contained in the workspace and integrate it into his current design.

The thickness of each layer is generally variable (with space and economic constraints), architects/end user could change this parameter to optimize the energy performance of the building during the design phase. Also designer could also define each component modifying the properties. Appendix 1 lists information about thermal conductivity (W/mK), density (kg/m3) and specific heat (J/kgK) of different materials, is expected to help the end user to directly modify the properties of the material.

4.3 Windows and doors

Table 3 contains the main characteristics needed for energy performance simulation and are expected to be integrated in the database of windows and doors. The parameters listed in the right column are the required values to evaluate energetically the energy performance:

Table 3 Main parameters for Windows and doors

Glazing	
U- value	W/m2K
g- value	%
U annual degradation rate	%
Solar Heat Gain Coefficient	%
Visual Light Transmittance	%
Frame	
Area frame/window (100% for doors without glazing)	%
U- value	W/m2K
U annual degradation rate	%
Solar absortance	
Window/door	
Dimensions (width, height)	Mm
Infiltration rate	m3/hm2
Sound Insulation	dBA
Solar Heat Gain Coefficient	%
Visual Light Transmittance	%
Associated wall (in which wall is the window located?)	

The following information is considered relevant for the database, users can modify directly the parameters in the case of missing data or they have no idea about the values listed in Table 3:

Table 4 Other relevant parameters for Windows and doors

Glazing	
Typology	• Single glazed • Doubled glazed • Low emissivity doubled glazed
Frame	
Area frame/window	%

Typology		• Aluminium without thermal bridge breakage • Aluminium with thermal bridge breakage • PVC • Wood	
Solar absortance of the frame			
Color	**Light**	**Medium**	**Dark**
White	0.2	0.3	-
Yellow	0.3	0.5	0.7
Beige	0.35	0.55	0.75
Brown	0.5	0.75	0.92
Red	0.65	0.8	0.9
Green	0.4	0.7	0.88
Blue	0.5	0.8	0.95
Grey	0.4	0.65	-
Black	-	0.96	-
Window/door			
Dimensions (width, height)		mm	
Infiltration rate		Little airtight: 100 m3/hm2 Airtight: 50 m3/hm2	
Sound Insulation		dBA	

Economical aspect appears to be interesting for the project; the following table shows the key parameters could be integrated in the database of the building components:

Table 5 Economical parameters for Windows and doors

Economical	
Investment cost	€
Operational cost	€/year Especially if there is any inert gas or vacuum in the doubled glazed chamber
Life expectancy	Years

5. ENERGY SYSTEM D.B. REQUIREMENT

In the detail design phase of a building, energy system come into main topic and target for energy performance optimization. The design of the energy system dominates the future operation and maintenance cost and user comfort. In large projects, energy experts may use specific software for detailed calculation while in many small projects like residential buildings, detached buildings, designers may not dedicate too much effort in considering the energy efficiency and future operation cost. With the aim of facilitating the experts for detail system design and optimization, quick calculation of the performance of energy system, and helping the designer to have a better understanding of the energy components to be used, a database of the energy systems with relevant data, not only is energy performance but also the benefits, becomes into necessary for D4E project. MEP engineers can directly use the D4E library in their design, select proper systems and have quick evaluations. The database is also expected to help the economical evaluation and give sufficient information to the end uses besides MEP engineers.

5.1 Overview and classification of energy system

To identify the database requirement of energy system, relevant literatures and standards are reviewed, more importantly, besides the questionnaire mentioned in section 3.3, informal interviews have been conducted involving energy experts to collect useful information for building performance simulation and HVAC system design, at the meantime, feedbacks from project partners and discussions in the project meetings have been also of great important. Database requirements described in this deliverable are initial ideas and serve as guidelines for database development, however, the database in future implementation may have the possibility to integrate more parameters adapting the needs discovered along with the project progress.

For an easy management and development, the energy systems have been classified into six categories, which are:

- Lighting
- Renewable energies
- Heat pumps
- Boiler
- Energy storage
- Distribution

These six categories will be described in detail in the following showing relevant parameters like energy efficiency and cost related in form of tables, furthermore, brief introductions of the latest technologies will be given as an example and more descriptions can also be found in Appendix 2.

5.2 Lighting

In homes and offices from 20 to 50 percent of total energy consumed is due to lighting [1]. Even for some buildings, over 90 percent of lighting energy consumed can be unnecessary due to over-illumination [1] and to the use of inefficient lighting technologies. It comes into need that the designer of lighting system should have their knowledge up to date and conscious about the energy efficiency. In order to facilitate the design process and to optimize the lighting system design and operation and maintenance cost, a workspace with relevant information appears to be essential. Based on the literature reviews, questionnaire and interviews, the following information of the lighting products is recommended to be included in the product database:

Table 6 Relevant parameters for lighting system

LIGHTING	
PARAMETER	**UNIT**
Type	• Incandescent • Halogen • Compact Fluorescent Lamp • LED • OLED
Lamp Wattage	W
Lumen output	lm
Voltage	V
Lamp current	A
Luminous efficacy	lm/W
Annual degradation rate in Luminous efficacy	%
Colour temperature	K
Colour	
Colour rendering index	Ra
Beam angle	º
Average lamp life	h
Type of protection	
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

Strengths and weakness of LED lighting are described as below:

Strengths

- Low energy consumption – retrofit bulbs range from 0.83 to 7.3 Watts
- Long service life – LED bulbs can last up to 50,000 hours
- Durable – LED bulbs are resistant to thermal and vibrational shocks and turn on instantly from -40C° to 185C°, making them ideal for applications subject to frequent on-off cycling, such garages and basements
- Directional distribution of light – good for interior task lighting
- No infrared or ultraviolet radiation – excellent for outdoor use because UV light attracts bugs
- Safety and environmentally conscious – LEDs contain no mercury and remain cool to the touch, because LEDs generate much less heat compared to other lighting systems.
- Fully dimmable – LEDs do not change their colour tint when dimmed unlike incandescent lamps that turn yellow
- No frequency interference – no ballast to interfere with radio and television signals
- Range of colour – LEDs can be manufactured produce all colours of the spectrum without filters, they can also produce white light in a variety of colour temperatures

- Could replace all applications of light fixtures after some years of development
- Continuing Energy-saving as LED light enrichment protection appeal for industrial and commercial lighting
- Online opportunities worldwide
- Government policy support in many European countries

Weaknesses

- Very expensive
- Does not perform well under high wattage applications yet
- Still in development phase of technology
- High glare effect
- High quantities of aluminium used for heat sinks
- Re-lamping expensive – the whole LED arrays needs to be replaced
- Single LED failures create negative visual effect
- Still under development and may not reach reasonable price levels for years
- Domestic market purchasing power of customer
- The biggest limitation to LED for common residential use is the cost of manufacturing due to still-limited production runs. Manufacturers claim production will increase considerably in the near future, further lowering prices. Currently, there is a limited number of LED fixture manufactures, but this is changing. Retrofit bulbs range from €20 to €60 for night lights and small lamps.
- The development of new technologies like Microplasma lightning

LED lighting can be divided into two categories: LED Lamps and LED Tubes. This division could be interesting for the replacement of existing lighting, for detail description of these two sub categories and other lighting technologies such as compact fluorescent lamp refer to Appendix 2.

5.3 Renewable energies

Renewable energies are more and more welcomed in nowadays design and are key technologies in the zero net energy (ZNE) building design. The application of new energies allows the building to highly reduce the energy cost, greenhouse gas emission and even economic benefits for the owner.

Among the main technologies, solar power, wind power, hydropower, biomass, biofuel, and geothermal energy are well developed. In most of the case, solar power, wind power and geothermal energy are the best options in building integration, while hydropower (mini hydro) and biomass (for district or of small capacity) can also be attractive. In this section, solar power and wind power will be described, while the geothermal energy will be grouped into next section as ground source heat pump.

Strengths and weakness of solar photovoltaic are included in this section, for more details about the solar water heating and micro wind turbine, refer to Appendix 3.

5.3.1 Solar photovoltaic system

Solar photovoltaic (PV) is now the third (after hydro and wind power) most important renewable energy source in terms of globally installed capacity. Driven by advances in technology and increases in manufacturing scale and sophistication, the cost of solar panel has declined greatly [2][3], and the levelised cost of electricity (LCOE) from PV is competitive with conventional electricity sources in many geographic regions [4], furthermore, net metering and financial incentives, such as feed-in tariffs for solar-generated electricity, have supported solar PV installations in many countries [5], all this make the distributed systems, such as roof mounted and building integrated solar system, become a new trend.

To integrate solar panel, the designer need to access the at least some basic information, such as the building orientation, latitude, area available, mounting system etc., for the solar panels, it is envisioned that the database could offer the following data:

Table 7 Relevant parameters for Solar Panel

SOLAR PHOTOVOLTAIC SYSTEMS	
PARAMETER	**UNIT**
Quantity of modules	PCs
Cell efficiency	%
Panel efficiency	%
Annual degradation rate in panel efficiency (estimated lineal degradation)	%
Panel efficiency after 10 years	%
Panel efficiency after 20 years	%
Annual Energy yield	kWh/m2
Total surface (depth, width)	mm
Nominal Power P*max	kW
Open Circuit Voltage V*oc	V
Short Circuit Current I*sc	A
Circuit Voltage at Nominal Power V*max	V
Circuit Current at Nominal Power I*max	A
Normal operating cell temperature NOCT	ºC
Temperature Coefficient Temperature Coefficient of VOC	V/ºC
Maximum Voltage for safety design purpose Maximum Voltage (-15ºC)	V
Maximum Current for safety design purpose Maximum Current	A
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

Inverter may be needed in the system to convert direct current (DC) into alternative current (AC). Table 8 shows the basic parameters needed for a system design:

Table 8 Relevant parameters for solar inverter

SOLAR INVERTER	
PARAMETER	**UNIT**
Type	Grid connected /off grid
Output	Single / Three-phase
Maximum power output in DC	(kW)
Maximum power output in AC	kW
Range of input (entrance) voltage	V
Range of voltage in Maximum Power	V
Maximum input current	A
Maximum efficiency	%

Annual degradation rate in efficiency	%
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

Strengths

- Solar energy is a locally available resource (amount depends on location).
- Potentially suitable for a large number of properties
- 0% small business loan available
- Short project timescale
- Most manufacturers offer a 25 year performance warranty on the panels which guarantees their performance after 25 years will be at least 80% of the initial performance (90% after 10 years).
- Running costs associated with PV systems are minimal. There are no moving parts to service and the installation should be mostly self-cleaning, although likely to benefit from an annual wash.
- PV systems provide green, renewable power by exploiting solar energy. We can use PV panels as an alternative energy source in place of electricity generated from conventional fossil fuels.
- PV panels can last up to 25 years or more, some with a maximum efficiency loss of 18% only, even after 20 years of operation.
- Unlike wind turbines, PV panels operate autonomous without any noise generation as they do not incorporate any moving mechanical parts.
- Panels may be mounted on adjustable rotating basis which is mounted on a fixed pole and allows some movement for better and longer solar tuning – turning the solar panel to follow the sun.
- Potential for individual properties to benefit from electricity bill and carbon savings and FIT
- Highly visible and good promotional tool
- Potential installation work for local businesses
- A typical 4kWp solar PV system would be expected to generate in the region of 3,000 kWh per year of electricity and therefore save 1.57 tonnes of CO2 in replacing grid generated electricity.
- A typical 2kWp PV system will comprise 8-10 panels depending on the panel size, and occupy around 14m2 of roof space
- Reduce our impact to the environment by reducing CO2 emissions into the atmosphere.
- With respect to operating costs and maintenance costs, PV panels, unlike other renewable energy technologies, require minimum operating or maintenance costs; just performing some regular cleaning of the panel surface is adequate to keep them operating at highest efficiency levels as stated by manufacturers' specs.
- By maintaining relatively small power generation stations in a distributed power network, we can minimize energy losses in the network that are caused by the long distance between power generation and power consumption points
- One of the most important advantages of PV systems is actually inherited by all solar energy systems in general; solar energy peak power generation usually coincides with peak energy demand
- Their high popularity has been driven on one hand by the ease of installation and use and, on the other hand, by reduction in PV costs (PV investment and installation) driven by

industrial maturity of PV technologies. In the recent past, prices of PV systems have witnessed a drastic decrease bringing the total cost around $1 to $1.3 per PV watt installed (cost for complete PV deployment)
- Wide location possibilities: Roof tops, PV panels at building facades or through incorporated systems for PV on window glass
- Solutions promoted by financial institutions (banks) through green-power financial incentives and green-projects.

Weaknesses
- Planning applications required for ground mounted systems
- Likely that insufficient scope for community project
- PV systems cost in the region of £2,500 - £5,000 per kw installed
- It is likely that the inverter will need to be replaced at least once over the lifetime of the panels.
- The feasibility depends on the location
- Perhaps the biggest disadvantage of PV panels is their limited efficiency levels; compared to other renewable energy sources – such as solar thermal – PV systems have a relatively low efficiency level ranging between 12-20%.
- PV panels produce DC which must be converted to AC before it can be used for consumption (either to be transferred to the power grid, or directly for own consumption). To convert DC to AC, PV panel systems use inverters, expensive electronic equipment and with certain technological limitations,
- Low voltage output or fluctuation in PV electric current may lead to increased waste of electricity since it cannot be transmitted onto the network (intermittent output).
- Solar PV panels' main disadvantage is that it delivers only in direct sunlight and it cannot store excess amounts of produced energy for later use. This is particularly important when energy is needed for the night when there is no sunlight or when weather conditions are fluctuating
- Structural surveys required for roof mounted systems
- Paybacks around 15-20 years
- Solar PV energy is very subsidized in many European countries. Recently Spain and Germany have drastically cut their subsidies, because they were unaffordable and unworkable. Some experts believe that alternatives to fossil fuels will be developed, but they will only work if they are affordable. Wind and solar aren't, and that isn't changed by shifting the costs from consumers and producers to the taxpayers.
- Obsolescence equipment are expensive to eliminate

5.3.2 Solar water heating

The recommended parameters for solar water heating system are listed in Table 9:

Table 9 Relevant parameters for solar water heating system

SOLAR WATER HEATING	
PARAMETER	**UNIT**
Quantity of modules	
Operating efficiency	%
Annual degradation rate in efficiency	%
Annual produced energy	kWh
Tank capacity	litres
Hot water temperature	ºC
Working pressure of the system	Bar

Total surface (depth, width)	mm
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

Descriptions of strengthens and weakness of solar water heating system can be found in Appendix 3.

5.3.3 Micro wind turbines

The recommended parameters for solar water heating system are listed in Table 10:

Table 10 Relevant parameters for micro wind turbines

MICRO WIND TURBINES	
PARAMETER	**UNIT**
Nominal power	kW
Nominal wind speed	m/s
Start wind speed	m/s
Stop wind speed	m/s
Maximum wind speed allowed	m/s
Rotor weight	kg
Rotor diameter	m
Rotor surface	m2
Mast height	m
Maximum rotation speed	Rotations/min
Transmission	
Safety	
Number of blades	
Material blades	
Voltage (AC)	V
Minimum operating temperature	ºC
Maximum operating temperature	ºC
Noise at 25 m distance with 10 m/s	dBA
Positioning	
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

Descriptions of strengthens and weakness of micro wind turbine can be found in Appendix 3.

5.4 Heat pumps

As aforementioned, the ground source heat pump is a renewable technology, and is widely used in many new buildings. As well as for the air and water source heat pumps that to be described in this section, depending on the COP, they can be considered as renewable.

5.4.1 Ground Source heat pump

The recommended parameters for Ground Source Heat Pump are listed in Table 11:

Table 11 Relevant parameters for ground source heat pump

GROUND SOURCE HEAT PUMP	
PARAMETER	**UNIT**
Dimensions (Width, Depth, Height)	mm
Weight	Kg
COP	
EER	
COP Annual degradation rate	%
Permitted operating temperature	ºC
Heating capacity	kW
Cooling capacity	kW
Heat transfer nominal flow	l/s
Max. Pressure	Pa
Sound power level	dBA
Type of refrigerant	
CO Emissions (maximum)	ppm
NOX Emission (maximum)	ppm
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

Strengths

- The constant temperature of the earth heats or cools the circulating water loop as needed to balance the building's year-round heating-and-cooling requirements.
- The constant ground temperature provides, by correct dimensioning, a favourable seasonal performance factor and long lifetime for the heat pump;
- A 25 to 40 percent of reduction in heating and cooling costs.
- No central system to fail or shut down the entire building.
- Good Energy Efficiency, between 2 and 4.9 times the input energy produced
- Most Efficient of the 3 types of Heat Pump
- Highly durable piping (the life expectancy is between 30 and 50 years).
- No high-maintenance, freezing-prone cooling tower.
- No boiler to clean or maintain
- No air conditioning equipment on roof to cause leaks

- Standard, simple controls
- No need for a highly specialized chillier technician or boiler operator
- Costs vary from project to project.
- Highly durable piping (the life expectancy is between 30 and 50 years)
- No risk with transportation, storage, and operation
- Leaks are rare, but the piping system is designed to make it easy to find and repair a leak.
- Pipes can be grouped in clusters of 20, with each cluster having its own valve. Even if a leak occurs, the system will continue to run while one of the clusters is closed off from the system for repairs.
- The underground piping often carries warranties of 25 to 50 years, and the heat pumps often last 20 years or more.
- The GHP systems are installed in a decentralized manner, to fit individual needs.
- No harmful chemicals
- No danger of fire, asphyxiation, or explosion from coal, gas, or oil
- No risk of groundwater contaminations
- Emission free operation on-site
- There is spare ground on site that could be used
- Standard, simple controls.
- Can be used with Air Conditioning System
- Runs from electrical grid, does not require other resource supply
- Low operating costs (no oil or gas purchases, burner controls etc. as with fossil-fueled heating systems);
- The system is emission-free on-site and helps to reduce greenhouse gas emissions like CO2.
- No central system to fail or shut down the entire building.
- Nothing outside to vandalize or steal.
- Relative to air-source heat pumps, they are quieter, last longer, need little maintenance, and do not depend on the temperature of the outside air.

Weaknesses

- Will not work in section of building with existing radiators, or other type of high temperature heating system
- Choice of location
- Although the installation costs for geothermal systems can be higher than for other less-efficient systems, the cost is rapidly offset by substantially lower utility bills.
- High Installation Costs
- Take up facility ground space
- Needs supplement to bring DHW to 60 degrees C
- Choice of location
- Take up facility ground space
- Gas costs are similar 3.5p / 4p per kW
- More developed technologies available

5.4.2 Air Source heat pump

The recommended parameters for Air Source Heat Pump are listed in Table 12:

Table 12 Relevant parameters for air source heat pump

AIR SOURCE HEAT PUMP	
PARAMETER	**UNIT**
Dimensions (Width, Depth, Height)	mm

Weight	Kg
COP	
COP annual degradation rate	%
Heating capacity	Kw
Power input – heating	Kw
EER	
Cooling capacity	Kw
Power input – cooling	Kw
Heat transfer nominal flow	l/s
Max. Pressure	Pa
Sound power level	Dba
Type of refrigerant	
CO Emissions (maximum)	ppm
NOX Emission (maximum)	ppm
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

Descriptions of strengthens and weakness of air source heat pump can be found in Appendix 4.

5.4.3 Water Source heat pump

The recommended parameters for Air Source Heat Pump are listed in Table 13:

Table 13 Relevant parameters for water source heat pump

WATER SOURCE HEAT PUMP	
PARAMETER	**UNIT**
Dimensions (Width, Depth, Height)	mm
Weight	Kg
COP	
EER	
COP annual degradation rate	%
Permitted operating temperature	ºC
Heating capacity	kW
Cooling capacity	kW
Heat transfer nominal flow	l/s
Max. Pressure	Pa
Sound power level	dBA
Type of refrigerant	

CO Emissions (maximum)	ppm
NOX Emission (maximum)	ppm
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

Descriptions of strengthens and weakness of water source heat pump can be found in Appendix 4.

5.5 Boiler

In most buildings, boiler is the equipment commonly used. The selection of boiler affects the future energy consumption and thus the operation and maintenance cost of the building.

In this section, the description will mainly focus on the three main typologies, which are conventional boiler, (including condensing or biomass), combi boiler and micro CHP boiler. Strengthen and weakness of Condensing boiler will be introduced, more details regarding biomass and other boilers can be accessed in Appendix 5.

Table 14 shows the recommended parameters for boiler:

Table 14 Relevant parameters of conventional boiler

BOILER	
PARAMETER	**UNIT**
Fuel	• Natural gas • Diesel • LPG • Electricity • Biomass (wood pellet/chip)
Operating efficiency	%
Annual degradation rate in efficiency	%
Input capacity	kW
Output capacity	kW
Water capacity	litres
Water flow temperature (Maximum/Minimum)	ºC
Water return temperature (Maximum/Minimum)	ºC
Dimensions (depth, width, height)	mm
Weight	kg
Operating Pressure	Pa
Heating Surface	mm2
Noise Level	dBA
CO Emissions (maximum)	ppm
NOX Emission (maximum)	ppm

Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

5.5.1 Condensing boiler

Strengths

- More heat is being extracted so the Condensing Boiler is more efficient.
- It will give the same heating output for lower cost.
- Correspondingly will cause less pollution: Carbon dioxide emissions reduction.
- A condensing boiler should be 'A' rated (which means a stated efficiency greater than 90%). A modern non-condensing boiler could have an efficiency in the region of 80% indicating a theoretical gain of the order of 10% to 12%. Old boilers may be down at 65%, or even very old, heavy-weight boilers down to 55%.
- A condensing boiler will always have a better operating efficiency than a conventional non-condensing one, due to its larger and more efficient heat exchanger.

Weaknesses

- The exhaust gases are relatively cool and a fan is needed to compensate for the lower convection flow.
- The condensation process produces a liquid which is acidic (due to sulphur and nitrogen impurities), which requires the use of materials not needed in conventional boilers and necessitates the addition of a fluid draining system
- This draining system can be awkward to route to a suitable drain point and must be adequately insulated against severe frost (something easily overlooked as we can vouch)
- The exhaust will appear as a continuous plume of steam which can be off-putting in some positioning and gives less flexibility in placement options
- Fitting a condensing boiler to an existing system may require the system to be power-flushed and that can add several hundred pounds of extra expense.
- Because the technology is relatively new and plumbing expertise is well based in existing technology you may find some difficulty in locating installers capable of doing the work to your satisfaction at a reasonable price and (in the UK) being thorough enough to provide a valid log
- For the same reason you may find problems with locating plumbers who are capable and willing to repair faults when they occur
- Not all boilers have a good reputation so it is important to choose one with a good record and long guarantee, and this can be a difficult exercise (The consumer magazine 'Which?' did an in-depth test on gas-fired condensing boilers in September 2006). We have been told that several boilers, apparently from different manufacturers, have the same innards.
- Condensing boilers can easily go wrong and can be costly to maintain and it is rumoured that their lifetime can be only half that of traditional boilers
- The new systems are more sensitive to the method of operation, tuning and state of repair, for example if not working at full load the efficiency may be impaired
- If excessive servicing is required the cost benefit to the consumer can be reduced or cancelled and the extra fuel burnt by repair vans reduces the environmental benefits
- We can add our own bit here since in October 2006 we had a new gas-fired system installed (with a Glow-Worm, heat-only boiler). Everything appeared to go well but our

plumber (who did a first class job) refused to give a final verdict on how good they are saying there needs to be a 10 year track record before a reliable judgment can be made

5.5.2 Combi boiler

High-efficiency combination boilers， or condensing "combi", are very popular because they can save space and money. Unlike conventional systems, combi boilers do not store domestic hot water. They heat water from the cold mains directly and It can work like hot water cylinders and central heating boilers, it is a compact and efficient unit that provides all the heat and hot water a small home needs while saving on operating and installation costs.

The recommended parameters for combi boiler are listed in Table 15:

Table 15 Relevant parameters for combi boier

COMBI BOILER	
PARAMETER	**UNIT**
Fuel	Wood pellet / chip / …
Operating efficiency	%
Annual degradation rate in efficiency	%
Heat Output Central Heating (CH) (70°C Mean)	kW
Heat Output DHW	kW
Dimensions (depth, width, height)	mm
Weight	kg
Maximum DHW Flow Rate	l/min
Minimum DHW Flow Rate Required	l/min
Minimum Operating DHW Pressure Required	Bar
Mechanical & Hydraulic Connections	
CH Flow/Return Pipe Size	Mm
DHW Flow/Inlet/PRV Size	Mm
Noise level	dBA
CO Emissions (maximum)	ppm
NOX Emission (maximum)	ppm
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

Descriptions of strengthens and weakness of combi boiler can be found in Appendix 5.

5.5.3 Micro CHP boiler

Micro CHP or micro combined heat and power is an extension of the idea of cogeneration to the single/multi family home or small office building in the range 0.3 - 50 kW. Micro CHP boilers in homes, small office building or small commercial buildings are used primarily for generation, driven by heat-demand, and electricity is a by-product, while in many cases, CHP systems are controlled by electricity demand delivering heat as the by-product.

The recommended parameters for micro CHP boiler are listed in Table 16:

Table 16 Relevant parameters for Micro CHP boiler

MICRO-CHP BOILER	
PARAMETER	**UNIT**
Fuel	• Natural gas • Diesel • LPG • Electricity • Biomass (wood pellet/chip)
Electrical output	kW
Thermal output	kW
Electrical efficiency	%
Thermal efficiency	%
Total efficiency	%
Annual degradation rate in total efficiency	%
Dimensions (depth, width, height)	mm
Weight	Kg
Maximum working pressure	Pa
Heating flow temperature	ºC
Noise level	dBA
CO Emissions (maximum)	ppm
NOX Emission (maximum)	ppm
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

5.6 Energy storage

The energy storage can be divided into two types of technologies: thermal and electrical storage. Phase Change Materials (PCMs - thermal storage) and Lithium ion battery (electrical storage) are described in detail in this section. Detail description of strengthens and weakness of each technology can be found in Appendix 6.

5.6.1 Thermal storage (PCMs)

The recommended parameters for PCMs are listed in Table 17:

Table 17 Relevant parameters for thermal storage (PCMs)

THERMAL STORAGE (PCMs)

PARAMETER	UNIT
Material of PCM	Material name
Material size	mm
Material weight	Kg
Quantity per cubic meters	
Phase Change Temperature	ºC
Heat of fusion	kJ/kg
Latent Heat	(kW.h/m3)
Recharging cycle (life cycle)	
Degradation per 500 cycles (or more)	%
Maximum operating temperature	ºC
Tank volume	m3
Tank external diameter	mm
Tank total length	mm
Heat transfer fluid volume	m3
Total weight (tank + PCM)	Kg
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

5.6.2 Electrical storage (Lithium Ion Battery)

The recommended parameters for electrical storage (lithium ion battery) are listed in Table 18:

Table 18 Relevant parameters for electrical storage (lithium ion battery)

ELECTRICAL STORAGE (LITHIUM ION BATTERY)	
PARAMETER	UNIT
Voltage	V
Dimensions (length, width, height)	Mm
Weight	Kg
Nominal capacity 1 hour rate	Ah
Nominal capacity 4 hour rate	Ah
Nominal capacity 8 hour rate	Ah
Nominal capacity 24 hour rate	Ah
Energy density (20 hour rate)	Wh/m
Specific energy (20 hour rate)	Wh/kg
Internal resistance	Ohms
Max. Discharge current (7 min)	Amp.

Max. Short-duration discharge current (10sec)	Amp
Shelf life 1 month	%
Shelf life 3 month	%
Shelf life 6 month	%
Charge Operating temperature range	ºC
Discharge Operating temperature range	ºC
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Battery Cycle Life	
Battery Calendar Life	Years

5.7 Distribution

As the terminal of a heating/cooling system, the "distributor" is always a key role in the HVAC systems, the efficiency can be different from technology to technology, and some of them can be perfectly integrated into the building with low energy consumptions, while in many cases, the conventional systems are still essential for a traditional HVAC system. In this section, database requirements will mainly focus on the Radiant Heating/Cooling system (Hydronic radiant systems), conventional radiators, fan coils and air handling unit (AHU). Detail descriptions of strengthens and weakness of each technology will be introduced in Appendix 7.

5.7.1 Radiant Heating/Cooling system (Hydronic radiant systems)

Hydronic radiant heating and cooling system is water based radiant heating/cooling system. In this system, panels or embedded building components (floors, ceilings or walls) are used to exchange heat with their surrounding environment through convection and radiation. It usually can be perfectly integrated into the building, but important portions of building surfaces are usually required for the radiant exchange.

Table 19 shows the recommended parameters for radiant heating/cooling system database.

Table 19 Relevant parameters for radiant heating/cooling system

RADIANT HEATING/COOLING SYSTEM	
PARAMETER	**UNIT**
Material	
Moisture barrier	Y/N
Thickness of mortar	mm
Diameter	mm
Water volume	l/m
Thermal gradient heating	ºC
Thermal gradient cooling	ºC

Thermal conductivity	W/mK
Separation between pipes	mm
Covered surface	m2
Peripheral Zone	Y/N
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

5.7.2 Conventional radiators

Conventional radiators refer to hot-water radiator which consists of a sealed hollow metal container filled with hot water by gravity feed heat, a pressure pump, or convection. They are exchangers designed to transfer thermal energy from one medium to another for the purpose of space heating.

The recommended parameters for conventional radiators database are listed in Table 20:

Table 20 Relevant parameters for conventional radiators

CONVENTIONAL RADIATORS	
PARAMETER	**UNIT**
Material	Steel / Aluminium
Heat power (Delta 50)	W
Heat power (Delta 42.5)	W
Heat power (Delta 37.5)	W
Height of single element	Mm
Width of single element	Mm
Depth of single element	Mm
Water capacity	L
Weight	Kg
Operating pressure	Bar
Investement cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

5.7.3 Fan coils

Fan coils, as part of conventional HVAC system, can be found in residential, commercial, and industrial buildings. Due to their simplicity, fan coil units are more economical to install than ducted or central heating systems with air handling unit (AHU).

The recommended parameters for fan coils database are listed in Table 21:

Table 21 Relevant parameters for fan coils

FAN COIL	
PARAMETER	**UNIT**
Power input	kW
Cooling total capacity	kW
Cooling sensible capacity	kW
Heating capacity	kW
Dimensions (Height, width, depth)	Mm
Weight	kg
Sound level	dBA
Water flow (Heating)	l/s
Water flow (Cooling)	l/s
Water pressure drop (Heating)	Pa
Water pressure drop (Cooling)	Pa
Air-flow rate	m3/s
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

5.7.4 Air handling unit

AHU is a device used to regulate and circulate air. AHU is a very complex equipment containing a blower, heating or cooling elements, filter racks or chambers, sound attenuators, and dampers. AHU is key component in conventional HVAC system, and is usually connected to a ductwork ventilation system that distributes the conditioned air through the building and returns it to the AHU.

The recommended parameters for AHU database are listed in Table 22:

Table 22 Relevant parameters for AHU

AIR HANDLING UNIT	
PARAMETER	**UNIT**
Cooling capacity	kW
Heating capacity	kW
EER	
COP	
COP annual degradation rate	%

Dimensions (height, width, depth)	mm
Weight	Kg
Air flow rate (Heating)	m3/min
Air flow rate (Cooling)	m3/min
Sound level	dBA
Cooling min ºCDB	ºC
Cooling max ºCDB	ºC
Heating min ºCWB	ºC
Heating max ºCWB	ºC
Investment cost	€
Operational cost	€/year
Replacement cost	€/year
Life expectancy	Years

6. D.B REQUIREMENT IN SIMULATION INFORMATION

6.1 Energy simulation software

Reliable estimation and quantification of energy benefits are essential in a sustainable building design and retrofit decision-support for prioritization of building design and retrofit measures. The performance of different design is commonly evaluated through energy simulation and modelling. There are a variety of whole-of-building energy simulation packages, such as Energy Plus, eQUEST, TRNSYS, IES, IDA, HAP etc., that can be used to simulate the thermodynamic characteristics and energy performance of different building designs and retrofit measures.

Appendix 8 contains the potential simulation software for the project, considering the software requirement, simulation output, complexity, openness and capability, EnergyPlus is selected as the simulation tool of D4E.

6.2 EnergyPlus

EnergyPlus is a whole building energy simulation program that engineers, architects, and researchers use to model energy. Modelling the performance of a building with EnergyPlus enables building professionals to optimize the building design to use less energy.
The flow chart and modules are shown in Figure 15 and Figure 16

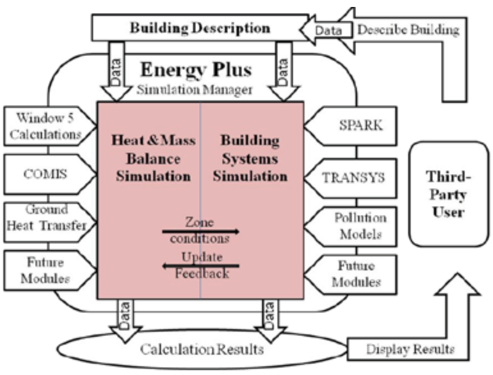


Figure 15 Energy plus flow chart

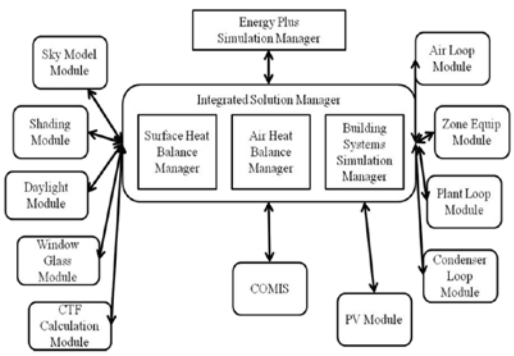


Figure 16 Energy plus modules

It provides innovative simulation capabilities including time steps of less than an hour, modular systems simulation modules that are integrated with a heat balance-based zone simulation and input and output data structures tailored to facilitate third party interface development. Other planned simulation capabilities include solar thermal, multi-zone airflow, fuel cells.

- Position, orientation of buildings and influence of neighbouring structures

EnergyPlus can model remote shading such as the effect of other buildings and landscape to model the effect of solar protection.

- Zoning capabilities to distinguish the different thermal zones existing in the building

The building can be zoned according to activity, HVAC, lighting system facade orientation in as required. This capability allows the user to distinguish the different thermal zones existing in the building. Below there is a 3D example of the ability to establish zones of a building.

- Hourly analysis for energy flows

The EnergyPlus engine allows hourly (or more usually sub-hourly) time steps and can analyse 8760 hours per year and report results in hourly format.

- Hourly variation of input data

The EnergyPlus engine allows to enter hourly (or sub-hourly) scheduled lighting, appliances etc.

- Heat gains from internal activities and occupants

The EnergyPlus engine allows to enter hourly (or sub-hourly) scheduled occupancy. The heat gains from internal activities and occupants can be modelled.

- Thermal performance of building components (floors, walls, roof, windows and doors)

Definition of opaque and glazed constructions can be fully detailed (material characteristics, thickness, and thermal bridges). Glazing can also be defined using simple descriptions.

- Solar exposure (heat gains and solar protection)

Various types of solar shading can be applied including local shading (overhangs, side fins, louvers) and larger custom shading devices to model the effect of solar protection.

Heat gains through windows is calculated based on orientation and inclination of the glazing, glazing type, height of the sun and radiation intensity related to the location, season, time etc as well as shading.

- Infiltration

The infiltration rate includes the effect of both gains and heat losses.

- Ventilation

EnergyPlus allows analysing in detail ventilation fresh air delivery. It includes natural and mechanical systems, heat gains/ losses, heat recovery efficiency, room temperature feedback on varying ventilation rates. These parameters are taken into consideration to simulate the ventilation effects on the Internal Air Quality (IAQ) and energy consumption.

- Artificial lighting and natural daylighting

Type of artificial lighting, lamp wattage and luminous efficacy are some of the main required parameters to define the lighting products.
Photo-electric dimming of electric lights by daylight allows reduced heat gains and light energy consumption to be modelled.

- Space and water heating and cooling systems

Space and water heating and cooling systems can be modeled.

6.3 DB requirements for simulation outputs

Taking into account the simulator to be used and the role of calculation of building performance in design4energy, the main expected outputs form simulation is listed below for future database design, this includes the Indoor Air Quality (IAQ), energy consumption and building component performance.

6.3.1 IAQ and Energy consumption

The main requested outputs for a correct valorisation of the IAQ and the Energy consumption of the building facilities are expected to include the following parameters in the following table:

Fuel (kW)	• Heating /Coooling • Electricity • DHW (Domestic Hot Water) • Lighting
Temperature (ºC)	• Air temperature • Radiant temperature • Operative temperature • Outside dry-bulb temperature.
Heat Balance (kW)	• External infiltration • External Ventilation • General Lighting • Computer+ Equipment • Occupancy • Solar Gains Exterior Windows • Zone sensitive heating/cooling • Zone heating/cooling
Total fresh air	• Mechanical ventilation • Natural ventilation • Infiltration

These parameter results could be displayed in sub-hourly or hourly formats for the whole year or for parts of the year.

6.3.2 Thermal performance of building components

As previously described in section 4, each material is defined containing these parameters: Thermal conductivity, Density and Specific heat. Solar absorptance and emissivity will be only required for both external and internal faces of the envelope wall. This information will be essential for simulation of the thermal performance of the building components.

The expected simulation output will be values of time depended heat balance (kW) or heat flows and temperatures in the different building components, which includes glazing, walls, ceiling, floors, roofs, lighting, window, by showing by zone, block or building level.

7. D.B REQUIREMENT IN OPERATION AND MAINTENANCE (FHR, LU, 5 pages)

7.1 Methodology for acquistion of maintenance and operation DB requirement

The methodology adopted to identify the database requirement in terms of design for operation and maintenance included review of relevant literature, standards and guidelines to first highlight the generic domains of requirement.

The next step in undertaking this exercise involves development of a questionnaire with the aim of gauging more specific requirement to different usage groups on databases which will support design for building operation and maintenance.

Among the samples interviewed were academics at Loughborough University who have particular expertise in building services, facility management and BIM. A second group of interviewees involved real-world practitioners of building operation and maintenance, who were mainly from facility management and energy system design and manufacturing. All interviewees were interviewed on a one to one basis over a 30 minute section each.

The findings were analysed and clustered as follows.

7.2 DB requirement identification

There are different routes to identify /find stakeholders' requirements for maintenance and retrofit which include:

- Return to the point of reference which is the original brief from clients;
- Assess against building regulations;
- Building design standards from ASHRAE, ISO and CIBSE, or commercial building performance rating methods such as BREEAM and LEED;
- Engage existing users in workshops or through organised surveys;
- Need for more double glazing to meet the new standards;
- Measurement of air tightness;
- Measurement of natural daylight;
- Need for the software/smartness to help to do day to day activities;
- Need to enable informed decision through usage of decision support tools;
- Review of design life of different components;
- Review of current energy consumption;
- Sensors data to be fed into the platform such as D4E, to create warnings;

7.3 DB usage requirement for maintenance and retrofit

For implementation of a D4E platform in the maintenance and retrofit stage, a number of key stakeholders should have access to the corresponding databases. Those who need information through access and retrieval of data on systems and processes of maintenance and retrofit systems are mainly designers including architects, mechanical engineers, service engineers, some sub-contractors and also suppliers involved in linking manufacturers to designers as they focus more on the end-users' needs and are more aware of capabilities and problems of different components and systems.

However from the owner's side point of view, FM requires accessing the databases with some capabilities to alter them when necessary, or for acquiring policy on energy target, or information on seasonal weather conditions. All of the involved stakeholders (should have either read access or read and write access). These could be an FM person, a decision maker, an original designer, an occupant, a mechanical engineer or an architect as a main overseer, regulators such as building control officer for automatic part control such as compliance. For ease of use and usefulness these different users should have customized accesses to provide them only the relevant information to their activities.

To better design buildings for energy efficiency these databases need to be accessible and usable by all the tools that are available to all these user groups. These should include: all energy modelling tools; computer aided FM tools (CAFM), COBie (that transfers IFC objects & spaces into a spreadsheet); BMS (lighting, HVAC systems, heating etc. monitor and control); Revit (conceptual energy modeller, rough "Good, Medium or Bad"), standard BIM tool; Specific energy modellers (such as DesignBuilder, EnergyPlus, Bentley (Microstation) and Graphisoft (ArchiCAD)).

7.4 DB for maintenance and retrofit format and sources

In the UK the search for new building components is generally undertaken through a number of common databases such as the National BIM library for the UK that is run by the NBS (National Building Specification), or search manufacturer/supplier websites. The NBS is an object library and it supports different BIM platforms such as IFC and Revit.

The search syntax is mainly performed using specific common terminologies, and this is then refined by what the experts think. This will give you the best response. The usage of exact performance metrics for specifications (such as the U-value) does provide precise findings. However, different components do require identification by different attributes and therefore the syntax can be different for each. Additionally, stakeholders do have different requirements and worries and may search for the same product with different intentions/approaches.

Among these attributes, cost is the most important, followed by energy ratings and energy performance. Commercial building performance rating methods, such as BREEAM and LEED, provide adequate criteria for the search, which can guide the choice making process. For example, for civil applications one can use SQual. Some of these criteria would be in the IFC already with some useful check boxes or sliders.

Once the information on new components is retrieved from some libraries many designers would like to have these component libraries linked to BIM. Components used in BIM models need to be linked to parent source/library for automated updates of availability, cost etc. It is desired to download as many as possible, whatever attributes used and stored for future use. The new trend is also reliance on having access to databases without need of downloading for example the cloud-based databases. On these databases one can refer to Google 3D component warehouse, where suppliers are continuously putting catalogues on Revit manufacturers to maintain and update the database.

The level of detailed information on building components that is suggested to be provided in a database includes:

- Specification;
- Physical geometry;
- Energy performance and sustainability;
- Different components that are available;
- Government policy requirement (Zero carbon by 2050);
- Physical properties;

- Performance;
- Cost;
- Availability;
- Embodied carbon and energy;
- Working life;
- Warranty information;
- Maintenance plans/schedule.

The kind of information that is usually difficult to find but should be on the database for end-users could include:

- Preventive maintenance schedules;
- Spare parts sources (especial old versions of components);
- Design life of components;
- Live information on energy consumption at granular level for each Energy using Products (EuP);
- Need to have an attractive graphical interface with meaningful information;
- For FM repair they need predictive maintenance with monitoring capabilities.

There are different types of data generated by simulation and should be stored in the database, these include:

- Predicted performance (air flow, temperature, consumption, carbon emission, lighting, acoustic "sound transmission or noise reduction");
- Performance against targets;
- Energy consumption against target;
- Performance rating (BREAM excellent);
- Sustainability data.

8. D.B. REQUIREMENT IN DATABASE SYSTEM

Beside the requirements in building component and energy system, as the main focus of this report, database requirement in the database architecture, data structure, user interface and user management is also investigated. The sources of this requirement collection have been very extensive, similar to the component and energy system, the ideas are concluded from project partners (by filling a template and brain storming), the usage scenarios that the partner have been working with during the last year, existing database solution and technologies, internal discussions etc.

In this section, the description will be presented in a table, which contains the name of the requirement, brief description and the potential impact weighting from zero (not needed) to three (extremely needed) .

8.1 Architecture and interoperability

Considering the architecture and the interoperability with other components of the future D4E platform and other tools, the design of the database should be as much compatible as possible.

Table 23 shows the consideration of interoperability and general requirements. This requirements could be extended and be more specific during the development of the database.

Table 23 DB requirement in architecture and interoperability

Name	Description	impact (0 to 3)
Parameterization of component models	Component models (IFC files of doors, windows, walls, floors, roofs etc.) can be clearly read and parameterized by the CAD tools ArchiCAD and Revit and stored again in the database	2
Search of parameterized data	Parameterized data can also be browsed	2
Web interface for users	The component library provides a user interface to content over http (web interface)	2
Web interface for applications	Attached files can be downloaded and load into simulation tools based on a web interface.	2

8.2 Data structures

Similar to any kind of database, the requirement in data structure is essential. Taking reference in the existing database solution, feedbacks from the architects and the expected functions, Table 24 shows the overall consideration in data structure of the database. These requirements could be extended and modified during the development of the database.

Table 24 DB requirement in data structures

Name	Description	impact (0 to 3)
Database objects	The database system contains different kinds of objects like building components, energy systems, material etc., which are heterogeneous in their attribute types.	2

Database object datasets	Different object types have different datasets, which show a table of the object specific characteristics.	2
Object status	Different statuses or versions of the shared object can be commented.	1
IFC attachment to database objects	Building component objects of the database can be connected to IFC files	3
File attachment to database objects	File sharing of further file formats for the collaboration of the design team	1
Product list attachment to database objects	To each object in the database system such as building components, energy systems or materials a list of products can be attached, which has specific performance attributes.	3
Product characteristics	A product in the product list shows characteristics that are relevant for the usage and for the customer.	3
Quality assurance	Content, which represents the user such as a product or a developed software tool, can be created unrestricted. Content, which is freely used by the platform community, has to be reviewed and released by an authorized user.	3
Cost information of components	It should be possible to attach cost estimations to database objects that are taken from similar real cases.	3
Energy and cost related data	Provide energy and cost related data linked to components.	3
Utilization aspects of technologies	The description of energy technologies contains a general description of functionality, sustainability, use case and barriers, advantages and disadvantages, and links with further information on the topic.	3
Level of classification of building components	classification of building components in more than three levels: e.g. "construction technologies -> facade technologies -> solar thermal systems"	3

8.3 User interface and user management

Additionally, a user interface will be designed to connect to and manage the database. The description of the following requirements (Table 25, Table 26) will not focus on the graphical design, but the functions, which defines how the interface could interact with the end user, and the security aspects that the database should consider when the database is publicly available.

Table 25 DB requirement in user interface

Name	Description	impact (0 to 3)
Ability to brows	Ability to brows and search appropriately components	2
Browsing of content	The content of materials, energy systems or building components is reachable through firstly a search mask and secondly through a hierarchical structure of categories, which is defined by the D4E consortium.	2
Search of content	The content can be searched with filters (e.g. only building components) and based on the characteristic of objects.	2

Upload of products	Manufacturer and technology provider have the opportunity to further upload products referring to an object of the database such as a material, building component or energy system. The condition is to be registered accordingly.	2
Frontend implementation	The frontend consists of the open source application SemanticMediaWiki, which provides a basic user interface and role management. Each of these user roles has a specific set of capabilities. For example, users can start discussion, create pages, edit their own private data or watchlists, read pages or use the write API. The specific roles for this project will be defined.	3
Presentation of a database object	The MediaWiki provides the possibility to create and organize articles, which will be equivalent to a database object. These articles will be structured into the sections "general description", "technical description", "product list", and "file sharing".	3
Connection of database and frontend	The MediaWiki contains basically static content. An interface with the database system will ensure the currency of the wiki's content.	3
Database object versions	Pages are stored versioned. Every save action creates a new version of the current page. Previous page versions can be viewed, restored and compared to the current version.	3

Table 26 DB requirement in user management

Name	Description	impact (0 to 3)
General features	A user is identified by an email address. Hence for every user the email address must be different.	3
Registration process	After the registration, the email has to be confirmed. A not approved user has no access to the database system.	3
Omnipotence of platform administrator	The platform administrator retains the right to confirm or delete a user.	3
User role differentiation	The accessibility of the data is restricted for: general users; general users, who are group administrators; general users who participate in groups; contributing users.	3
Role of contributing users	Contributing users can add technology descriptions, products. They ought to be manufacturer and experts. These users have to be registered.	3
Role of general users	General users can access generally released data, which has no group restriction. A condition is to be registered.	3
Role of group administrators	General users, who create a group, become administrators of these groups and are responsible for memberships, the group contents and for the revision of the content.	3
Role of group members	General users, who requested a membership in a group and are permitted by a group administrator to join a group, can share and read content within this group.	3

Role of platform administration	The platform administration hast to nominate users that are responsible for reviewing the content and releasing it.	2

9. ANALYSIS OF EXISTING DATABASE SOLUTION (FHR, VTT, LU, 15-20 pages)

This part deals with classification and evaluation of existing data base solutions in the context of energy efficient buildings concerning their current capabilities and the fulfilment of the identified requirements.

9.1 Overview of current databases

The development of CAD in the construction industry brought an integration of further data in to the building models. The three dimensional models can be extended through time information (4D) for the projection of construction activities, cost information (5D) for the integration of quantities, prices etc., and as-built operational data (6D) for the usage of BIM models during the construction process[6].

However, the information is not always attached to the data file itself but is provided by different web platforms, service provider or databases.

The search for existing database solutions refers to known requirements of the consortium such as the storage of building components or the demand for information regarding energy systems such as HVAC. The searched areas are software producers for building CAD, research institutes and research projects. The findings of the search can be categorized into the categories:

- “Construction material databases”
- “Component databases”,
- “Others” such as building type databases.

Since the databases are a wide spread concept among CAD software, different solutions have been developed to provide “frameworks” for building such databases. Some of these frameworks are also included in the results to complement the findings. All in all, this is also the order, in which the search results are presented.

9.1.1 IT Frameworks

9.1.1.1 OpenStudio by NREL

The national renewable energy laboratory (NREL) conducted an open source project to build up a collection of software tools for energy modelling, daylight analysis and various other simulations. It can be installed on Windows, Mac or Linux and has a software development kit with which the developers community is able to program plugins, applications, viewer, analysis tools or run managers. The objective is to support the designing process of a building such as by building owners, architects, designers, engineers to design more energy efficient. Thereby it takes a focus on the areas design, simulation, analysis, and feedback on the design such as requirements, costs and building codes. General questions being asked by the application users are “how much energy will be saved?” and “how much is the project going to cost?”. The value for developers is to provide a relational object model, which is the general knowledge needed to create a building model.[7] Stated values of the platform for the design process are workflow speed and quality, facilitated team integration, rapid feedback on energy performance.[8]

Roles involved in the platform are: design teams such as building owners, architects, engineers and consultants; developers of software, which are said to be the primary users and produce and sell their own software or contribute to projects of the community; researcher, who create easily user interfaces or use scripting to create applications supporting their research;

9.1.1.2 xBIM

xBIM is an open source development platform, which allows to create application for BIM based on the IFC standard. It was started by some researchers from the Northumbria University. The xBIM Explorer allows opening and viewing IFC files, navigating through models in different settings and their detailed information. The development library contains far more functions to manipulate the IFC files.

The libraries can be integrated in a .net environment and are mostly written in C#. The currently supported IFC version is IFC2x3.[9]

9.1.1.3 TNO BIM Server

The Building Information Modelserver (short: BIMserver) is an open source development platform, which allows to create application for BIM based on the IFC standard. The project was started by the Netherlands organisation for applied scientific research TNO and the Eindhoven University of Technology. The BIMserver allows mainly querying, merging and filtering the BIM-model and generating IFC files on the fly. Further important functions include versioning, notifications, goelocating models, authentication and plug-in infrastructure. The development library of contains far more functions to manipulate the IFC files. The libraries can be used in a Java environment. The currently supported IFC version is IFC2x3.[10]

9.1.1.4 BuildingSMART

The buildingSMART Data Dictionary (bSDD) is a reference library or a framework that aims at supporting improved interoperability in the building and construction industry. It can connect software applications to product databases or attach specific attributes to construction designs created by an architect. These references can include information from a product manufacturer, typical room requirements, cost data or environmental data. The library is based on the standard ISO 12006-3: 2007 (Building construction: Organization of information about construction works, Part 3: Framework for object-oriented information) and is accessible through a web interface (e.g. http://www.ifdbrowser.no/) or a desktop application.[11][12]

9.1.2 Component and energy system catalogues

Component catalogues relational databases accessible through internet protocols. They contain components of buildings in a format that can be read by CAD software.

9.1.2.1 Technology Performance Exchange by NREL

The Technology Performance Exchange is a central accessible web platform for technology suppliers, third-party testing laboratories, and other stakeholder, which allows uploading product performance data. It is administrated by the National Renewable Energy Laboratory.

The main purpose is to provide data for technology evaluators such as performance data to make better informed buying decisions. The database content can be searched by "company" and by technology category. The most cultivated categories are “lamps” in “electric lightning”, “Packaged Unitary Equipment” and “Boilers” in “HVAC”, and “Photovoltaic Systems” in “On-site Power Generation”. Registered users of the platform can query the site via the “search” module and download the performance data with the “download” module.[13]

Roles included are: companies, whose products are included in the platform such as technology suppliers, third-party testing laboratories; developers, who are authenticated users and use the API for querying the site and downloading data; commercial building engineers, private and public sector technology evaluators, and designers confronted with novel or little used energy efficiency technologies, who make fact-based procurement decisions.

9.1.2.2 Building Component Library by NREL

The Building Component Library (BCL) was established by the U.S. Department of Energy. It provides searchable information about energy efficiency related technologies and a list of measures to meet energetic issues. It is especially used by planners to create more reliable and more credible energy models. The reasons for this aim are firstly a lack of credibility in the area of building modelling. And secondly modelers have a limited amount of models and parts, which they have created without a verification of quality.[14] The included information can represent physical characteristics of buildings such as windows, walls, and doors, or can refer to related operational information such as occupancy, equipment schedules and weather information. Each measure and energy system can be downloaded as a XML-, RB- and OSM-file describing these components.[15]

Roles included are: practitioners, which are individual users for downloading and creating content to use in energy models or groups and their administrators for sharing specific restricted content; developers, who create applications through the API to query the library.

9.1.2.3 Data Repository of the ISES project

The European project ISES delivers ICT that includes a cloud-based data repository. It contains information that is used in the ISES framework, e.g. climate data or stochastic templates but most interestingly energy product and material catalogues containing energy properties of products and materials. The elements that are saved in this database are “ifcBuildingElement”, “ifcMaterial”, “IfcMaterialProperties sub-types”, and “ifcDistributionElement”. They are used for creating physical constructs incorporated into the building out of product and material properties.[16]

The vision of this repository is to bring component manufacturers effectively together with their customers in order to keep the market open for their products. Further it aims at choosing appropriate components by energy-related characteristics due to the high requirements of both designers and MEP specialists.

The library uses the PLIB ontology model (based on ISO 13584). All information is saved in the ifc file format.[17]

The ontology provides a user management based on their roles. Some of them are part suppliers, MEP specialists and architects. However, the main focus is to provide the framework and functionality rather than to conduct a user analysis.

9.1.2.4 MagiCAD Product Database

The MagiCAD Product Database is a product catalogue or database that contains over one million products from over hundred manufacturers. The value is to provide existing products with accurate dimensions and technical data. A designer can choose components through a plugin directly via the CAD-tool interface. This interface is connected to a plugin on the manufacturers' side, to their products and their calculations of them. Therefore MagiCAD also connects to simulation results.[18]

The database focuses on MEP designers as the main user group. Manufacturers of the products simply cultivate their own product database, to which MagiCAD is connected.

9.1.2.5 Proprietary component databases

Some CAD tools for buildings provide component libraries with parametric objects that are either provided by the software producer itself such as https://bimcomponents.com/, http://archicad-talk.graphisoft.com/object_depository.php or http://seek.autodesk.com/ or it is provided by its developer community such as http://www.archibase.net/gdl or http://www.opengdl.org/. The objects are stored in the CAD specific format, e.g. the "Geometric Description Language", which is the programming language of ArchiCAD library parts, and describe building elements as 2D CAD symbols, 3D models and text specifications for use in drawings, presentations and calculations.[19]

Roles included are: platform providers, who are responsible for the content and promote the fill-up of the databases with content and who are not necessarily the software producer; participating users, who upload content; practitioners, who use the models in their constructions.

9.1.2.6 OpenEI

The Open Energy Information Platform (OpenEI) is a Media Wiki administrated by NREL that summarizes various information platforms dealing with energy issues. Its aim is to provide the most current information needed to make informed decisions on energy, market investment, and technology development. This information includes metadata as well as a cost database. The platform is divided into the parts "OpenEI Wiki", "Datasets", and "Community" and handles topics such as buildings, geothermal, hydrogen, smart grid, solar, utilities, water and wind energy.[20]

9.1.2.7 NBS National BIM Library for BIM users (LU)

The NBS National BIM Library for BIM users is a collection of both generic and manufacturer objects which enables the use of BIM objects throughout a project. These contain an extensive number of generic objects that can be used for outlining design stages. It also contains a vast range of specific manufacturer objects for later use in the project. These BIM objects are authored by experts from a large pool of manufacturers and designers to ensure consistency. Somehow it demonstrates the ease and simplicity in which one can be engaged in BIM and apply it into their building projects. One key part of this ecosystem is the plug-ins, which allow drag and drop of BIM objects directly into NBS specifications. Within the NBS Plug-in each BIM object also has the relevant NBS product guidance so as to reduce searching time. It is enabled with an intuitive design to quickly and easily locate and download BIM objects. This system can also send an email to let the users know when an object has been downloaded or updated.

9.1.3 Construction material catalogues

9.1.3.1 Eurobau

The portal eurobau.com provides a data pool of construction materials. It was created by inndata Datentechnik GmbH to support construction firms with the implementation of the EU directive 89/106/EWG and its higher requirements on documentation of construction products.

The data content is generally structured by the application case of the materials, e.g. underground engineering, insulation or interior construction. Further the material is linked to a firm that provides it. Main values of the platform are material and scientific information, directory of planners and norms, fair information, and CAD details.[21]

9.1.3.2 Masea

Masea is a database accessible through a web platform which contains a set of different materials. The materials are described with their typical physical characteristics. The aim is to support calculations and decision making to create more hygric and energy efficient renovation. At the time of revision the database included 474 entries about various materials such as painting, plaster, stones, insulations, wall cladding and others. The description of the materials contains detailed information about physical and structural parameters, pictures, hints on usage, diagrams with information among others about moisture retention, water absorption, drying process, and further information about manufacturer. The data of each material is downloadable as XML file. Further the database is used in the tools WUFI®, DELPHIN®, and EPASS HELENA®, where the data is used for simulations regarding energy, moisture und temperatures.[22][23]

9.1.4 Others

9.1.4.1 National Residential Efficiency Measures Database by NREL

This measures database is a project conducted by the NREL and aims at providing a national unified database of residential building retrofit measures and associated costs. It is based on a publicly accessible, centralized database to provide standardized formats, consistency and accuracy, viewing retrofit information and support of building science. The data is accessible for developers of applications that evaluate residential efficiency measures. The website further defines measures, components, properties and cost data as well as additional information.

9.1.4.2 Wiki of the Climate-Smart Planning Platform

The Climate-Smart Planning Platform Wiki is a collaborative workspace of www.climatesmartplanning.org. It aims at establishing a development community for openly accessible climate planning and modelling tools. It has the vision to provide a platform for experts, developer and practitioner to discuss, share and gain information on customer needs covered by a locally oriented tool, databases filled with local information, derived and beta tool versions, case studies on methodologies, and quality checks on the tool applicability. The wiki uses a semantic Wiki technology.

Roles included are: experts; developers; software users.[24]

9.1.4.3 Building catalogue EMPORIS

Emporis is a provider of building information, which collects information on buildings with public and economic interest. Thereby the organisation Emporis Standards sets information standards for facilitating and connecting the collected data. The product portfolio consists of database access, licencing of pictures, presentation of firm profiles and other commercials. The provided data refers to the whole building life cycle and covers various building usage types such as offices, hotels, rail stations, masts, tunnels, bridges and others. The data is collected from data scientists, firms of the constructions industry, municipalities, technology provider and an editorial community. A possible description of a building contains Name, EBN, type, usage type, address, geometrical data, and involved firms such as owner, project management etc.[25]

9.2 Conclusions

The search for databases in the construction industry shows a big variety of solutions, which cover different steps in the process of simulation and analysis of buildings. Generally the aim of the solutions is to support the designing process of a building in terms of simulation and analysis e.g. of building costs, ecological damage, or different indicators of energy efficiency. On the one side roles that are usually involved in this process are building owners, architects, design teams, engineers, and consultants. Their interests are a platform for free resources but also a quality check for their building models. Sharing their work ensures consistency and error validation. On the other side the web platforms have contributing users that support to fill the databases. These users are usually developers, researchers, manufacturers, and technology providers. Their interests are usually to develop their existing or new resources such as software solutions, physical characteristics of building or materials, or simply the distribution of their services.

The role of manufacturers and technology providers appear to be highly important. Firstly the technologies are abstract objects, which become usable through products. Products determine the characteristics of technologies which differ widely. To give manufacturers the opportunity to present their products provides insights into on the maturity of the according technology. Characteristics such as performance or geometry become concrete values. And the database has a further source of information and extends constantly.

The basic function of the platforms is to share data in terms of a collaborative environment. The construction industry is said to be much segmented in terms of its services and heterogeneity is a basic characteristic of BIM. The found concepts of sharing allow users to share software versions or datasets they have developed, improved or populated with further data. The findings have in common to set different accessibility for the above mentioned user roles on the platform. The component databases go even further to restrict the access to certain components by development groups. Each group member can only access and share building components within this group. Reasons for the group restrictions could be sensitivity of the shared data or systematic exploitation of different user groups.

The platforms usually provide access to their content through web interfaces in terms of desktop applications, development APIs or simple http requests. Usually a defined search pattern allows the user of these interfaces to create database queries based on categories or characteristics of the database contents. Thereby different types of objects such as a material, building component or energy system have different characteristics and different data tables at the description of the object such as the description of concrete on the website http://www.masea-ensan.com/cgi-bin/viewmaterial?xml=Beton.xml. Among these object categories no unified pattern for the object description could be found. Several websites such as http://seek.autodesk.com/search/HVAC?source=QuickLinks&resetft=true&locale=en-us attach files to the building component or product description. Here no consistent file type could be found, too. The attachments are of the type RFA-, RVT-, PDF-, DOC-, RB-, OSM-, or XML-based data files.

To ensure a high quality of the database content the possibility of creating new content is restricted to a specific group of users. Content, which represents the user such as a product or a developed software tool, can be created unrestricted. Content, which is freely used by the platform community, has to be reviewed and released by an authorized user.

10. Conclusions

10.1 Summary of achievements

This deliverable aimed at identifying the requirements of the Design4energy database. The database is a web-based solution that contains a library of components and energy systems used in the novel design method of the Design4Energy project. This deliverable is also the bases for Task 3.2, which contains the conception and development of the content, the IT-structure and the user friendly interface of the database.

At first a preliminary analysis was conducted to specify the topic of technology databases and to understand the major stakeholder, which included the roles involved in the design phase, their application case and thereby their needs during the possible usage of the database.

The stakeholders were analysed through different sources. A questionnaire was designed and conducted among the relevant stakeholders. These include among others architects, energy system experts and other external consultants that are engaged in technological decision during the design process.

For basic requirements on the IT-structure and the usage of the system software applications and existing database solutions in the area of energy efficiency and BIM were investigated.

Next the requirements on the stored content were defined. Besides building components and energy systems the database should provide static information about simulation outcomes and information to support the maintenance and retrofit of a building. For these issues relevant literature, standards and guidelines to first highlight the generic domains of requirements were reviewed. Also another questionnaire among facility managers, BIM experts and practitioners of building operation and maintenance was designed and conducted to complement and refine the results.

The specific information that is stored in the database regarding characteristics of building components and energy systems were further examined through expert surveys, analysis of existing software solutions and literature reviews. It contains among other the description of walls, covers, floors, windows and doors. Further the energy systems contain HVAC equipment, lightning and envelopes.

The described requirements are expected to support the decision making and design process described within the Design4Energy framework. They serve as the baseline for the further conceptualization and development of a database prototype.

10.2 Relation to continued developments

This deliverable provides input to T3.2 and T3.3 on the database design. Furthermore, the data collected with the questionnaire and interviews will contribute the D5.4 on Decision Support Tool Development due in M45 and neighbourhood integration.

11. ACRONYMS AND TERMS

D4E............................. Desgn4Energy.

DB .... Database.

HVAC......................... Desgn4Energy.

MEP............................ Database.

LCC .... life cycle costs

BREEAM .... Database.

COP .... Coeficiente of Performance.

ZNE .... Zero net energy

LCOE .... Levelised cost of electricity

PV............................... Photovoltaic

DC .... Direct current

AC .... Alternative current

IAQ............................. Indoor Air Quality

DHW .... Domestic Hot Water

DCL............................ Building Component Library

OpenEI .... Open Energy Information Platform

12. REFERENCES (All, m12, 1 page)

[1] Hawken, Paul; Lovins, Amory; Lovins, L. Hunter (2000). Natural Capitalism. Back Bay Press, Time Warner Book Group. ISBN 0-316-35300-0.

[2] M Bazilian, I Onyeji, M Liebreich, I MacGill, J Chase, J Shah, D Gielen... (2013). "Re-considering the economics of photovoltaic power". Renewable Energy (53).

[3] Swanson, R. M. (2009). "Photovoltaics Power Up". Science 324 (5929): 891–2. doi:10.1126/science.1169616. PMID 19443773.

[4] Branker, K.; Pathak, M.J.M.; Pearce, J.M. (2011). "A Review of Solar Photovoltaic Levelized Cost of Electricity". Renewable and Sustainable Energy Reviews 15 (9): 4470. doi:10.1016/j.rser.2011.07.104. hdl:1974/6879.

[5] Renewable Energy Policy Network for the 21st century (REN21), Renewables 2010 Global Status Report, Paris, 2010, pp. 1–80.

[6] Smith, Peter: BIM & the 5D Project Cost Manager, 27th IPMA World Congress, 2014, darin Kameedan

[7] OpenStudio: http://openstudio.nrel.gov/

[8] About NREL's OpenStudio Application Suite and Development Platform https://www.youtube.com/watch?v=ovLt4-q_UEg

[9] The eXtensible Building Information Modelling (xBIM) Toolkit: http://xbim.codeplex.com/

[10] Open source BIM Server: http://bimserver.org/

[11] ifd standards from buildingSMART: http://www.buildingsmart.org/standards/ifd

[12] IFD Library and IFD Library Group for buildingSMART: http://www.ifd-library.org/

[13] Technology Performance Exchange: https://performance.nrel.gov/about

[14] Katherine Fleming, Nicholas Long, and Alex Swindler “The Building Component Library: An Online Repository to Facilitate Building Energy Model Creation”, ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, California August 12-17, 2012 http://www.nrel.gov/docs/fy12osti/54710.pdf

[15] Building Component Library: https://bcl.nrel.gov/about

[16] European project ISES, Deliverable D4.1, download at http://ises.eu-project.info/documents/ISES-D4.1.pdf, viewed: 20.10.2014

[17] European project ISES, Deliverable D4.3, download at http://ises.eu-project.info/documents/ISES-D4.3.pdf, viewed: 20.10.2014

[18] MagiCAD product database and plugins, source: http://www.magicad.com/en/content/product-database, viewed: 20.10.2014

[19] ArchiCAD Object Download Sites: http://www.graphisoft.com/downloads/parametric_objects.html

[20] Open EI: Energy Information, Data and other resource: http://en.openei.org/wiki/

[21] Europäisches Bauinformationssystem: http://www.eurobau.com/

[22] Materialdatensammlung für die energetische Altbausanierung: http://www.masea-ensan.com/

[23] Materialdaten für die energetische Altbausanierun: ghttp://www.bine.info/publikationen/publikation/materialdaten-fuer-die-energetische-altbausanierung/materialdatenbank/

[24] Climate-Smart Planning Platform: https://www.climatesmartplanning.org/wiki

[25] Die größte Plattform für Gebäudeinformationen und Bauprojekte weltweit: http://www.emporis.de/

13. APPENDICES

Further information is described in related background documents:

Appendix 1. Building components properties
Appendix 2. Lighting
Appendix 3. Renewable energies
Appendix 4. Heat pump
Appendix 5. Boiler
Appendix 6. Energy storage
Appendix 7. Energy Distribution
Appendix 8. Simulators
Appendix 9. Questionnaire and response

Appendix 1. Building components properties

List of the material typologies:

- Metals
- Concretes
- Plastics
- Bituminous products
- Insulation
- Unidirectional slabs
- Solid concrete slabs
- Woods
- Mortar and gypsum
- Ceramics
- Glasses
- Bricks
- Reticular slabs
- Air chamber

λ: thermal conductivity (W/mK), ρ: density (kg/m3) and Sp. Heat: specific heat (J/kgK)

Metals		
Steel λ: 50 W/mK ρ: 7800 kg/m3 Sp. Heat: 450 J/kgK	Stainless steel λ: 17 W/mK ρ: 7900 kg/m3 Sp. Heat: 460 J/kgK	Aluminium λ: 230 W/mK ρ: 2700 kg/m3 Sp. Heat: 880 J/kgK
Aluminium alloys λ: 160 W/mK ρ: 2800 kg/m3 Sp. Heat: 880 J/kgK	Bronze λ: 65 W/mK ρ: 8700 kg/m3 Sp. Heat: 380 J/kgK	Copper λ: 380 W/mK ρ: 8900 kg/m3 Sp. Heat: 380 J/kgK
Chromium λ: 93.7 W/mK ρ: 7160 kg/m3 Sp. Heat: 449 J/kgK	Tin λ: 66.6 W/mK ρ: 7310 kg/m3 Sp. Heat: 227 J/kgK	Iron λ: 72 W/mK ρ: 7870 kg/m3 Sp. Heat: 450 J/kgK
Brass λ: 120 W/mK ρ: 8400 kg/m3 Sp. Heat: 380 J/kgK	Nickel λ: 90.7 W/mK ρ: 8900 kg/m3 Sp. Heat: 444 J/kgK	Lead λ: 35 W/mK ρ: 11300 kg/m3 Sp. Heat: 130 J/kgK
Titanium λ: 21.9 W/mK ρ: 4500 kg/m3 Sp. Heat: 522 J/kgK	Zinc λ: 110 W/mK ρ: 7200 kg/m3 Sp. Heat: 380 J/kgK	

Woods		
Leafy λ: 0.18 W/mK ρ: 660 kg/m3	Conifer λ: 0.15 W/mK ρ: 480 kg/m3	Balsa λ: 0.057 W/mK ρ: 180 kg/m3

Sp. Heat: 1600 J/kgK	Sp. Heat: 1600 J/kgK	Sp. Heat: 1600 J/kgK
Plywood board λ: 0.17 W/mK ρ: 550 kg/m3 Sp. Heat: 1600 J/kgK	Particle board λ: 0.15 W/mK ρ: 545 kg/m3 Sp. Heat: 1700 J/kgK	Fiber board λ: 0.18 W/mK ρ: 650 kg/m3 Sp. Heat: 1700 J/kgK
Oriented strand board λ: 0.13 W/mK ρ: 600 kg/m3 Sp. Heat: 1700 J/kgK	Compressed cork λ: 0.1 W/mK ρ: 450 kg/m3 Sp. Heat: 1560 J/kgK	

Concretes	
Reinforced concrete λ: 2.5 W/mK ρ: 2600 kg/m3 Sp. Heat: 1000 J/kgK	Conventional concrete λ: 1.57 W/mK ρ: 2200 kg/m3 Sp. Heat: 1000 J/kgK
Expanded clay concrete λ: 0.19 W/mK ρ: 600 kg/m3 Sp. Heat: 1000 J/kgK	Light weight concrete λ: 1.22 W/mK ρ: 1800 kg/m3 Sp. Heat: 1000 J/kgK

Mortar and gypsum	
Mortar d>2000 λ: 1.8 W/mK ρ: 2100 kg/m3 Sp. Heat: 1000 J/kgK	Mortar 1450>d>1600 λ: 0.8 W/mK ρ: 1520 kg/m3 Sp. Heat: 1000 J/kgK
High strength gypsum λ: 0.56 W/mK ρ: 1350 kg/m3 Sp. Heat: 1000 J/kgK	Medium strength gypsum λ: 0.3 W/mK ρ: 750 kg/m3 Sp. Heat: 1000 J/kgK

Plastics		
Acrylics λ: 0.2 W/mK ρ: 1050 kg/m3	Polyvinyl chloride (PVC) λ: 0.17 W/mK ρ: 1390 kg/m3	Linoleum λ: 0.17 W/mK ρ: 1200 kg/m3

Sp. Heat: 1500 J/kgK	Sp. Heat: 900 J/kgK	Sp. Heat: 1400 J/kgK
Polyacetate λ: 0.3 W/mK ρ: 1410 kg/m3 Sp. Heat: 1400 J/kgK	Polyamide (PA) λ: 0.25 W/mK ρ: 1150 kg/m3 Sp. Heat: 1600 J/kgK	Polycarbonates (PC) λ: 0.2 W/mK ρ: 1200 kg/m3 Sp. Heat: 1200 J/kgK
Polystyrene (PS) λ: 0.16 W/mK ρ: 1050 kg/m3 Sp. Heat: 1300 J/kgK	High Density Polyethylene (HDPE) λ: 0.5 W/mK ρ: 980 kg/m3 Sp. Heat: 1800 J/kgK	Low Density Polyethylene (LDPE) λ: 0.33 W/mK ρ: 920 kg/m3 Sp. Heat: 2200 J/kgK
Polymethacrylate (PMMA) λ: 0.18 W/mK ρ: 1180 kg/m3 Sp. Heat: 1500 J/kgK	Polypropylene (PP) λ: 0.22 W/mK ρ: 910 kg/m3 Sp. Heat: 1800 J/kgK	Polytetrafluoroethylene (PTFE) λ: 0.25 W/mK ρ: 2200 kg/m3 Sp. Heat: 1000 J/kgK
Polyurethane (PU) λ: 0.25 W/mK ρ: 1200 kg/m3 Sp. Heat: 1800 J/kgK	Epoxy resin λ: 0.2 W/mK ρ: 1200 kg/m3 Sp. Heat: 1400 J/kgK	Phenolic resin λ: 0.3 W/mK ρ: 1300 kg/m3 Sp. Heat: 1700 J/kgK

Ceramics		
Ceramic tiling λ: 1.3 W/mK ρ: 2300 kg/m3 Sp. Heat: 840 J/kgK	Lightweight clay ceramic block λ: 0.28 W/mK ρ: 910 kg/m3 Sp. Heat: 1000 J/kgK	Clay hollow bricks λ: 0.67 W/mK ρ: 500 kg/m3 Sp. Heat: 1000 J/kgK
Ceramic panel λ: 0.29 W/mK ρ: 650 kg/m3 Sp. Heat: 1000 J/kgK	Clay roofing tiles λ: 1 W/mK ρ: 2000 kg/m3 Sp. Heat: 800 J/kgK	

Bituminous products		
Asphalt λ: 0.7 W/mK ρ: 2100 kg/m3	Sandy asphalt λ: 0.15 W/mK ρ: 2100 kg/m3	Pure bitumen λ: 0.17 W/mK ρ: 1050 kg/m3

Sp. Heat: 1000 J/kgK	Sp. Heat: 1000 J/kgK	Sp. Heat: 1000 J/kgK

Glasses		
Soda-lime λ: 1 W/mK ρ: 2500 kg/m3 Sp. Heat: 750 J/kgK	Quartz λ: 1.4 W/mK ρ: 2200 kg/m3 Sp. Heat: 750 J/kgK	Pressed glass λ: 1.2 W/mK ρ: 2000 kg/m3 Sp. Heat: 750 J/kgK

Insulation	
Expanded polystyrene (EPS) λ: 0.0375 W/mK ρ: 30 kg/m3 Sp. Heat: 1000 J/kgK	Extruded polystyrene (XPS) λ: 0.034 W/mK ρ: 37.5 kg/m3 Sp. Heat: 1000 J/kgK
Mineral wool (MW) λ: 0.0405 W/mK ρ: 40 kg/m3 Sp. Heat: 1000 J/kgK	Projected polyurethane (PUR) λ: 0.028 W/mK ρ: 45 kg/m3 Sp. Heat: 1000 J/kgK
Expanded perlite panel (EPB) λ: 0.062 W/mK ρ: 190 kg/m3 Sp. Heat: 1000 J/kgK	Sandwich type panel with polyurethane λ: 0.03 W/mK ρ: 42 kg/m3 Sp. Heat: 1000 J/kgK
Sandwich type panel with mineral wool λ: 0.043 W/mK ρ: 137 kg/m3 Sp. Heat: 1000 J/kgK	Sandwich type panel with expanded polystyrene λ: 0.034 W/mK ρ: 30 kg/m3 Sp. Heat: 1000 J/kgK
Sandwich type panel with extruded polystyrene λ: 0.036 W/mK ρ: 30 kg/m3 Sp. Heat: 1000 J/kgK	

Bricks	
Simple brick Thickness: 0.04 m λ: 0.445 W/mK	Double brick Thickness: 0.07 m λ: 0.432 W/mK

ρ: 1000 kg/m3 Sp. Heat: 1000 J/kgK	ρ: 930 kg/m3 Sp. Heat: 1000 J/kgK
Triple brick Thickness: 0.1 m λ: 0.427 W/mK ρ: 920 kg/m3 Sp. Heat: 1000 J/kgK	½ foot Thickness: 0.115 m λ: 0.567 W/mK ρ: 1020 kg/m3 Sp. Heat: 1000 J/kgK
1 foot Thickness: 0.24 m λ: 0.567 W/mK ρ: 1150 kg/m3 Sp. Heat: 1000 J/kgK	Conventional concrete brick (0.29) Thickness: 0.29 m λ: 1.115 W/mK ρ: 1000 kg/m3 Sp. Heat: 1000 J/kgK
Conventional concrete brick (0.14) Thickness: 0.14 m λ: 0.737 W/mK ρ: 1200 kg/m3 Sp. Heat: 1000 J/kgK	Perforated lightweight aggregate concrete brick (0,29) Thickness: 0.29 m λ: 0.305 W/mK ρ: 860 kg/m3 Sp. Heat: 1000 J/kgK
Perforated lightweight aggregate concrete brick(0.14) Thickness: 0.14 m λ: 0.206 W/mK ρ: 1000 kg/m3 Sp. Heat: 1000 J/kgK	Solid lightweight aggregate concrete brick (0.29) Thickness: 0.29 m λ: 0.305 W/mK ρ: 1050 kg/m3 Sp. Heat: 1000 J/kgK
Solid lightweight aggregate concrete brick (0.14) Thickness: 0.14 m λ: 0.175 W/mK ρ: 1134 kg/m3 Sp. Heat: 1000 J/kgK	

Unidirectional slabs		
Ceramic beam filling Thickness: 0.3 m λ: 0.846 W/mK	Concrete beam filling Thickness: 0.3 m λ: 1.422 W/mK	Lightweight concrete beam filling Thickness: 0.3 m

ρ: 1110 kg/m3 Sp. Heat: 1000 J/kgK	ρ: 1240 kg/m3 Sp. Heat: 1000 J/kgK	λ: 1.128 W/mK ρ: 1140 kg/m3 Sp. Heat: 1000 J/kgK
Mechanised EPS beam filling Thickness: 0.3 m λ: 0.256 W/mK ρ: 750 kg/m3 Sp. Heat: 1000 J/kgK	Molded EPS beam filling Thickness: 0.3 m λ: 0.341 W/mK ρ: 740 kg/m3 Sp. Heat: 1000 J/kgK	

Reticular slabs		
Ceramic beam filling Thickness: 0.3 m λ: 1.678 W/mK ρ: 1215 kg/m3 Sp. Heat: 1000 J/kgK	Concrete beam filling Thickness: 0.3 m λ: 1.947 W/mK ρ: 1285 kg/m3 Sp. Heat: 1000 J/kgK	Lightweight concrete beam filling Thickness: 0.3 m λ: 1.838 W/mK ρ: 1231 kg/m3 Sp. Heat: 1000 J/kgK
Mechanised EPS beam filling Thickness: 0.35 m λ: 1.296 W/mK ρ: 1092 kg/m3 Sp. Heat: 1000 J/kgK	Molded EPS beam filling Thickness: 0.35 m λ: 1.4 W/mK ρ: 1092 kg/m3 Sp. Heat: 1000 J/kgK	

Solid concrete slabs	
Concrete Thickness: 0.35 m λ: 2.5 W/mK ρ: 2500 kg/m3 Sp. Heat: 1000 J/kgK	Lightweight aggregate concrete Thickness: 0.35 m λ: 1.666 W/mK ρ: 2000 kg/m3 Sp. Heat: 1000 J/kgK

Air chamber	
Unventilated horizontal air chamber (1cm) R: 0.15 m2K/W	Unventilated horizontal air chamber (2cm) R: 0.16 m2K/W
Unventilated horizontal air chamber (5cm) R: 0.16 m2K/W	Unventilated horizontal air chamber (10cm) R: 0.18 m2K/W

Unventilated vertical air chamber (1cm) R: 0.15 m2K/W	Unventilated vertical air chamber (2cm) R: 0.17 m2K/W
Unventilated vertical air chamber (5cm) R: 0.18 m2K/W	Unventilated vertical air chamber (10cm) R: 0.19 m2K/W
Slightly ventilated horizontal air chamber (1cm) R: 0.03 m2K/W	Slightly ventilated horizontal air chamber (2cm) R: 0.08 m2K/W
Slightly ventilated horizontal air chamber (5cm) R: 0.08 m2K/W	Slightly ventilated horizontal air chamber (10cm) R: 0.09 m2K/W
Slightly ventilated vertical air chamber (1cm) R: 0.08 m2K/W	Slightly ventilated vertical air chamber (2cm) R: 0.09 m2K/W
Slightly ventilated vertical air chamber (5cm) R: 0.09 m2K/W	Slightly ventilated vertical air chamber (10cm) R: 0.09 m2K/W

Appendix 2. Lighting

1. LED lighting

1) LED Lamps

Product Features

- Customisable lamp cover
- Lifetime of 25,000 to 40,000 hours
- Low energy consumption: 7-40W
- CRI > 80
- UV and IR free light
- Broad compatibility with transformers

Product Benefits

- Freedom to design your lamp with a choice of lamp covers
- 80% energy saving (short payback time)
- Range of colour – LEDs can be manufactured produce all colours of the spectrum without filters, they can also produce white light in a variety of colour temperatures
- Directional distribution of light – good for interior task lighting

2) LED Tubes

Product Features

- Only 50% energy consumption compared to fluorescent tubes
- Extra-long life of 40,000 hours
- Retrofit to existing fluorescent lamps on ballast installations
- Safety and environmentally conscious – LEDs contain no mercury and remain cool to the touch

Product Benefits

- Reduced operational cost thanks to lower energy consumption
- Lower maintenance cost thanks to 2-3 times longer lifetime than normal fluorescent tubes
- Fastest and easiest way to upgrade existing luminaire to LED technology; 100%- safe installation process
- No frequency interference – no ballast to interfere with radio and television signals

2. Compact Fluorescent Lamp

Strengths

- Elimination of prolonged lamp outages and reduced maintenance costs.
- Improved lamp light output (four to five times more per watt than comparable incandescent lamps).
- Longer rated life (10 to 20 times longer than for incandescent lamps).
- Replacing incandescent lamps with CFLs would reduce energy use 75 to 80%.
- Reduction in energy costs. The effect on GHG would vary greatly by country due to difference in electricity generation. CFLs used three hours per day can have a payback period of less than one year.
- Increased efficiency of CFLs reduces the lighting heat addition, offsetting the energy and greenhouse gas benefits of conversion to more efficient lighting sources (assuming the electricity generation mix remains the same).
- Warm white CFLs are available as well.
- Lightweight, superior long-life alternative to incandescent lamps
- Very good lumen maintenance throughout the lifetime of the lamp
- Long-life alternative to incandescent lamps

- Light output after 1 minute 85%
- Recommended ambient temperature range to ensure almost constant light output (>90%): between +10°C and +45°C
- Long lifetime
- Low mercury content
- Smallest dimensions ensuring optimal physical fit
- Highest reliability throughout life which is especially beneficial where lighting is required for longer periods of time and/or where lamp replacement is difficult

Weaknesses

- Initial Cost is greater than comparable products. CFL bulbs can range from €3 to €12 depending on their type. This is much more than typical incandescent bulbs, but their lifetime and energy savings are significant.
- CFLs are ill-suited for recessed and enclosed fixtures
- A typical CFL contains a very small amount (5 mg) of mercury, a toxic substance. Without an effective recycling program it is assumed CFLs will end up in landfills, which is a potential environmental issue if CFL use increases substantially. Conversely, electricity generation, particularly coal-fired, also releases mercury into the environment. Therefore reduced demand for coal-fired electric generation could reduce the amount of atmospheric mercury emissions. These effects represent both a cost and benefit; a fair comparison of these relative effects is required to evaluate the overall environmental effect of this regulation.
- Consumer surveys and laboratory tests report premature CFL failure due to rapid-cycling and other operating conditions such as elevated temperatures. It is likely that increased use may result in a higher number of CFLs operating under less than ideal conditions.
- Such use could lead to a higher number of CFL failures, thereby increasing costs to the consumer due to premature replacement as well as increasing the amount of mercury disposal relative to ideal lamp operation.

3. OLED lighting

Strengths

- OLED material is very light weight, thin and transparent.
- OLEDs can be printed on a thin layer of film or even a sheet of paper, so its flexibility and small size is a determining advantage.
- Displays applying OLEDs are generally brighter compared to other display solutions
- OLED displays are more energy-efficient in general, and have a wider viewing angle compared to other display solutions.
- OLEDs are easier to produce and can be made to larger sizes. Because OLEDs are essentially plastics, they can be made into large, thin sheets.
- OLEDs are the fastest growing flat panel display technology today, with Europe playing a key role as a technology developer.
- Success for OLEDs depends on two key technical advances: first, the operating lifetime, which is based on the stability of each colour; and second, the production process. If the latter can be developed, with consistent high quality at low cost by using low cost printing and room temperature processes, that combination could take unit costs well below other products.
- Nano Markets predicts that from zero in 2008, the general purpose market for printed lighting will grow to about $119 million in 2010 and to over $1.5 billion in 2014, consisting mainly of OLEDs.

Weaknesses

- OLEDs are not used for lighting purposes at the moment. The brilliance of the diodes are not high enough for this application.

- OLEDS slowly lose their light-emitting properties. The current materials use dare expected to last between 10,000 and 14,000 hours although this is expected to improve. Some would say this is long enough as it implies a screen usage of 5.5 years for a 7 hour per day usage (Conti, 2008)
- Manufacturing processes are expensive right now.
- Water can easily damage OLEDs.
- The market for lighting is potentially enormous but more uncertain. OLED lighting seems likely to remain a niche product for the foreseeable future, owing to investment in existing incompatible infrastructure.
- Attempts have been made to use it as a main source of light: the first one was by Osram in 2009 November, but the Orbeos light panel, besides the above mentioned problems, had the disadvantage of high price as well.
- OLEDs may not be suitable for main source of lighting at the moment; it allows a new range of unconventional lighting solutions, hopefully to appear on the market within a few years. Novaled OLED panels are a good example for this - these panels are transparent layers applied on a window for instance, letting in sun light during the day as a regular window, but serving as a source of light during the night. This background light solution can be obtained other ways as well. Since OLEDs can be printed on any thin layer or sheet, they are an alternative solution for wallpapers as a background light. OLED wallpapers - which are the combination of art and technology - are due to appear on the market in 2012.
- These peculiar solutions of lighting are going to revolutionize our idea about home or commercial lighting, hopefully in the near future

4. Incandescent

Strengths

- Instant start
- Very good CRI +95
- Lower Wattages
- Easy to dim
- Old reliable technology

Weaknesses

- Not good for high bay applications
- Very low efficacy 10-35 lumen per watt
- Low lamp life expectancy 1,000-6,000 hours
- 95% of energy is converted to radiant energy (heat) while only 5% is visible light

5. Microplasma lighting

Characteristics

- The lighting can be any shape or colour.
- Flexible sheets
- It is mercury-free, contains no toxins, and environmentally friendly
- Ultra-thin (less than 3mm) and flat form factors that can be flexible and formed, unlike fluorescent and HID sources
- Eliminates the need for external reflectors to control the light distribution
- Longer lasting light source: Offers long life of up to 50,000 hours
- Surpasses functional LED system efficacy
- Operates cool and generates less heat
- Its plastic, glass and aluminium contents are easily repurposed and recyclable.

- Because of the rate of production, the MCA is not cost-competitive with current lighting options

Strengths

- The lighting can be any shape or colour.
- Flexible sheets
- It is mercury-free, contains no toxins, and environmentally friendly
- Ultra-thin (less than 3mm) and flat form factors that can be flexible and formed, unlike fluorescent and HID sources
- Eliminates the need for external reflectors to control the light distribution
- Longer lasting light source: Offers long life of up to 50,000 hours
- Surpasses functional LED system efficacy
- Operates cool and generates less heat
- Its plastic, glass and aluminium contents are easily repurposed and recyclable.
- Hold considerable promise as the next generation of lighting technology
- US Congress mandated that incandescent lights be phased out in 2014. EU will possibly act similarly.

Weaknesses

- Currently, the largest arrays produced are 6 sq. in.
- Because of the rate of production, the MCA is not cost-competitive with current lighting options
- It is not a fully developed technology

6. Sulphur plasma lighting

Characteristics

- Sulphur Plasma lamps are between 25% & 100% more efficient than any other artificial source of high quality white light.
- The light is true full spectrum daylight and thus features all of the qualitative benefits of sunlight.
- The light is almost 100% PUR and thus perfect for photosynthesis.
- Light can be efficiently distributed over large spaces, superior to all arc-based lamp technology in every sense, and costing no more than lamps which are used extensively in the Film and Theatre industry.
- Unlike all other artificial light sources, the light output and colour (light output quality) does not degrade over time and it is fully dimmable down to 30%.
- It contains no lead, unlike most other lamps, no mercury, unlike all fluorescent lighting and no arsenic unlike most LEDs (Gallium Arsenide).
- The lamp's output is low in infrared energy, and less than 1% is ultraviolet light. As much as 75% of the emitted radiation is in the visible spectrum, far more than other types of lamps.
- Limited life – Magnetrons had limited lives.
- Large size
- Its market is restricted to very specific needs

Strengths

- Sulphur Plasma lamps are between 25% - 100% more efficient than any other artificial source of high quality white light.
- The light is true full spectrum daylight and thus features all of the qualitative benefits of sunlight.
- The light is almost 100% PUR and thus perfect for photosynthesis.

- Light can be efficiently distributed over large spaces, superior to all arc-based lamp technology in every sense, and costing no more than lamps which are used extensively in the Film and Theatre industry.
- Unlike all other artificial light sources, the light output and colour (light output quality) does not degrade over time and it is fully dimmable down to 30%.
- It contains no lead, unlike most other lamps, no mercury, unlike all fluorescent lighting and no arsenic unlike most LEDs (Gallium Arsenide).
- The lamp's output is low in infrared energy, and less than 1% is ultraviolet light. As much as 75% of the emitted radiation is in the visible spectrum, far more than other types of lamps.

Weaknesses

- Limited life – Magnetrons had limited lives.
- Large size
- Heat – The sulphur burnt through the bulb wall unless they were rotated rapidly.
- High power demand – They could not sustain a plasma in powers under 1000 W.
- Its market is restricted to very specific needs

Appendix 3. Renewable energies

1. Solar water heating

Strengths

- A 5m2 solar thermal system cost around €5-6,000, including a new hot water cylinder with solar coil.
- 5m2 of solar collector could be expected to provide 2,250 kWh of hot water per year (mainly during summer months).
- Hot water throughout the year: the system works all year round, though is needed to heat the water further with a boiler or immersion heater during the winter months.
- Cut carbon footprint: solar hot water is a green, renewable heating system and can reduce your carbon dioxide emissions.
- Maintenance costs for solar water heating systems are generally very low.
- Most solar water heating systems come with a five-year or ten-year warranty
- Different types of collectors are available, which makes integration flexible for different building types
- Solar thermal panels require minimal maintenance, although may require periodic cleaning to ensure optimal performance. An annual service is recommended alongside the main heating system.
- CO2 savings Tones pa: 1 ton per m2
- Typical carbon savings are around 230kgCO2/year when replacing gas and 510kgCO2/year when replacing electric immersion heating.
- Tax credits help lower upfront cost, and there are often local incentives that also help offset part of the initial investment
- Use the free energy of the sun to heat your water
- They are friendly to our environment since use the solar energy as the source power and don't produce CO or CO2. So it is reasonable if we call them as 100 percent of the clean heating technology.
- Use them optimally during winter season with the right system. There are some popular systems that are based on the climate.
- Financial incentives, especially if you live in Canada, USA, and some European countries.

Weaknesses

- Savings are moderate - the system could provide most of the hot water in the summer, but much less during colder weather.
- May not have as great of performance in climates that do not receive a lot of sunshine
- Tank takes up more space than tank-less units, but comparable to (or slightly larger than) "normal" tank type units
- Higher upfront cost for equipment & installation
- High initial cost
- Payback: depends on the climate zone
- Tank can produce a significant amount of heat, so its location will need to be planned accordingly
- They cannot be combined with radiators
- Outdoor units that get the direct sunlight or other extreme weather require more maintenance and should be checked periodically.

2. Micro wind turbines

Strengths

- The manufacture's life expectancy is usually given as 25 years
- Simple solutions – easy to plug in
- Possibilities to reduce the electricity bill
- Wind is an eternal natural resource. Wind is free of charge and does not get affected by other price trends in the world
- Good solution where there is no commercial grid to connect to (islands, mountain areas) or properties located in good windy areas
- Own generated energy can create a feeling of independency and secure the future electricity cost.
- CO_2 savings: 1 tone per kW
- Potential for individual properties to benefit from electricity bill and carbon savings and FIT
- Highly visible and good promotional tool
- Potential installation work for local businesses
- Increasing energy prices in the world force people to look towards other energy alternatives-renewable
- Increased interest for green energy and environmental issues
- Possibilities to create a specific support system that can be applied on small scale wind power
- Government grants and business loans available
- Political support

Weaknesses

- Wind is intermittent, varying from zero to gale force speeds.
- Planning application required
- Limited scope for community project
- It depends on the location. It is prudent to carry out wind speed monitoring during 6-12 months to confirm that estimated wind speeds are likely to be reasonably representative. The cost of this exercise is usually in the region of €3,500.
- Wind turbine cost around €6,000 per kW.
- Expensive in comparison to grid electricity
- Lack of professionals with the right knowledge to design, install and make service on small-scale wind turbines

- Lack of education in the wind power sector
- No standards yet in the business regarding technology etc
- Product quality questionable
- Wind conditions are hard to predict
- Not much research done within small scale wind turbines
- Lack of statistics
- Payback around 7-10 years
- Operational and maintenance costs are typically in the range of 2-3% of capital cost
- Land ownership issues
- Wind monitoring advisable on some sites to confirm wind resource
- A wind turbine would require annual maintenance.
- A wind turbine may need some major parts replacing, such as gearboxes and blades after 5-10 years.
- Planning permission would be required for the installation of a wind turbine
- The commercial electricity to cheap, slows down the development of wind energy
- Competition from other renewable sources such as solar (PV) panels, hydro power
- New rules, permits and laws from the government might complicate for the planned expansion and hinder development
- Noises, shadows and affected landscape view might slow the development and expansion down
- Resistance among people in the society or from neighbours because of noises, shadows, disturbed landscape view

Appendix 4. Heat pump

1. Air source heat pump

Strengths

- Air as a renewable heat source is accessible and practically unlimited
- Good Energy Efficiency, between 2 and 4.9 times the input energy produced
- Always available and inexhaustible source of heat
- 10 year warranty
- Low Installation Costs than geothermal heat-pump
- Runs from electrical grid, does not require other resource supply
- Can be used for heating, cooling, domestic hot water and swimming pools
- Emission free operation on-site
- Can be utilised all year round between +35°C and -25°C.
- No requirement for the cost and land area of ground collectors
- Boiler room placement should give high efficiency
- Can be used with Air Conditioning System
- Ideal for retro fit applications, especially where space is limited

Weaknesses

- Will not work in section of building with existing radiators
- Least Efficient of the 3 types of Heat Pump,
- Low efficiency (COP) below 7°C outside temperature
- You can expect them to operate for 20 years or more, however they do require regular scheduled maintenance.

- A yearly check by you and a more detailed check by a professional installer every 3-5 years should be sufficient.
- Needs supplement to bring DHW to 60 degrees C.
- Noise caused by external unit fan
- Gas costs are similar 3.5p / 4p per Kw
- More developed technologies available

2. Water source heat pump

Strengths

- Relatively low installation costs
- Good Energy Efficiency, between 2 and 4.9 times the input energy produced
- Runs from electrical grid, does not require other resource supply
- The heat transfer rate from water is far higher than that in the ground or air.
- The flow/circulation of the water source provides constant energy replacement.
- The use of a water source removes the need of digging large trenches, often reducing the cost of installation compared to a ground source.
- The return temperature to the heat pump is usually higher than either the ground or winter average air, increasing the COP (coefficient of performance) of the heat pump.
- Obtained excellent comfort
- High efficiency
- Low operating costs
- Emission free operation on-site
- There is a river on site that could be used
- Can be used with Air Conditioning System
- Water source heat pump systems are among the most efficient, economical and environmentally friendly methods to heat and cool buildings

Weaknesses

- It could have high maintenance costs
- Requires damage protection
- Will not work in section of building with existing radiators
- Needs supplement to bring DHW to 60 degrees C.
- Appropriate water-source is needed (ground water, river, etc.)
- May have trouble with river use due to environmental issues
- Gas costs are similar 3.5p / 4p per kW
- More developed technologies available

Appendix 5. Boiler

1. Biomass boiler

Strengths

- Biomass boiler is highly compatible with current technologies
- Biomass boilers are very efficient. Using the best of modern technology, biomass boilers can achieve over 90% efficiency – dramatically more than conventional boilers.
- The boilers have automatic ignition and can modulate between 30% and 100% of full load.
- Easy to maintain and operate. Woodfuel boiler will last much longer than a conventional boiler (25 – 30 years rather than 5 – 10)
- A biomass system is very competitive, ranging from approximately three and a half to six years.

- It should be noted that oil prices are highly volatile and can fluctuate significantly. Utilising biomass therefore is far cheaper in terms of fuel costs.
- Heating, district heating, Domestic hot water (DHW)
- This type of energy production has a limited long term effect on the environment because the carbon in biomass is part of the natural carbon cycle.
- Locally sourced wood chip heating delivers a 95% CO2 emissions reduction compared to a gas boiler.
- Eliminates acid rain (biomass contains no sulphur)
- Improved fuel security through added diversity and local sourcing. Reduces reliance on fossil fuels
- Government grants the usage of this technology depending on the country and on the energy efficiency
- EU Biomass Action Plan
- Biomass heating is often the lowest cost way to reduce CO2 emissions after energy Conservation. Reduces greenhouse gas emissions
- The impact on the creation of employment will be of 11 new jobs (10 in rural and forest medium and 1 in the industrial field) per 1MW generation of energy with biomass
- Will help to minimize the impact of haulage costs
- Reduces amounts of landfill (waste wood used as biomass fuel). Promotes biodiversity through the sustainable management of woodlands
- Modern biomass boilers are computer controlled for optimum efficiency

Weaknesses

- High cost for Harvesting, Transporting, and Chipping System for Forest Biomass.
- The biomass maintenance costs are slightly higher than that for the oil system due to the need for activities such as disposing with ash and cleaning the grate.
- From viewing the capital costs it can be seen that the biomass systems represent a larger initial outlay than the alternative fossil fuel system.
- Place of fuel storing and puffer tank.
- Relatively high heating water temperature.
- Acoustic effect of fuel storing.
- Emission of pollutant material.
- Space requirements to install the boiler and fuel storage
- Fuel not easily available everywhere

2. Combi boiler

Strengths

- Simple compact unit. Space is saved due to the lack of a hot water storage unit, a cold water storage unit and other components that usually make up a normal heating system.
- Monetary savings seen on the cost of hot water
- There are no tanks being placed in the roofing and less pipe work to install.
- Installation is faster and not as difficult thus reducing initial costs as well.
- As combis are so common boiler service costs should be relatively low whilst parts and engineers easy to find.
- Instant, unlimited hot water supply
- Smaller systems – combi boilers eliminate the need for a cold water tank and hot water cylinder
- Drinkable water at all taps because none of the cold water is stored in a tank
- Some smaller capacity combi boilers can be fit into cupboards
- Modern combi boilers can produce up to 18 litres of water a minute at 35°C
- More space since there is no airing cupboard for the cylinder

- An economical choice for smaller households with lower hot water demands.
- More efficient and cheaper to run for hot water supplies

Weaknesses

- In order to get hot water on demand it is needed an adequate supply of cold water.
- Standard combi boilers provide maximum pressure through only one tap at a time.
- The flow rate for all the appliances in the house is limited by the capacity of the rising water main.
- There is a delay in getting hot water out of the tap
- They are also slower to run a bath than hot water systems using stored hot water
- Lower water pressure than some other types of boiler
- Not suitable for big homes where multiple sources of water might be used simultaneously
- Delayed hot water in summer months with some models (not storage combis)
- if the mains water supply is not adequate or you have sudden pressure decreases then this type of boiler is not suitable
- A combi boiler can't be used with a power shower

3. Micro CHP Boiler

Strengths

- Increased efficiency. CHP systems act as energy multiplier which:
- Saves energy
- Saves money
- Reduces carbon emissions by up to 30%
- Increased reliability. System is independent of the grid and therefore immune to grid-level blackouts.
- The technology is available and in use today.
- CHP system is technologically and economically proven
- Technology can be applied to all scales
- Greenhouse Gases are reduced
- Technology can be retrofit
- As an existing technology, it can start reducing carbon emissions today
- CHP can help deal with the waste, heat and energy needs of any country

Weaknesses

- Not an actual energy source, only a means of extending energy
- Could end up pre-empting more sustainable options
- Only suitable where there is a need for both electricity and hot water on site
- Heating and electricity demand must remain fairly consistent
- Capital intensive
- Not long term sustainable when based on fossil fuel technology
- Heating demand must be continuous
- Efficiency claims are sometimes overstated since heat energy and electricity are not equivalent
- CHP markets are in an early stage of development in some countries
- The most efficient application is for district heating networks
- Noise
- CHP has strong dependency on Gas prices are not particularly stable

Appendix 6. Energy storage

1. Thermal storage (PCMs)

Strengths

- To reduce utility bills - largely through peak-shaving
- To reduce equipment size, space and weight
- To reduce compressor kW due to operating at more hours at full load and at night-time lower condensing temperatures
- Availability of cold air distribution when ice is used
- Possible backup cooling or heating redundancy in event of power failure
- When chilled water storage is used, availability of an added fire-protection water source.
- The utilities can gain from reduced peak use, improved load factors, added off-peak sales, deferred peak-capacity expansion costs, and improved competitive position over gas-fired alternatives.

Weaknesses

- May increase first cost of HVAC system
- More complicated system design
- Requires well-trained maintenance crew
- Possible ambient heat gain to storage tanks
- Specifying engineer has little incentive to use as it costs more to design and the firm may have little or no experience with the technology.
- Some of the threats include night-time loads greater than planned, insufficient storage provided so on hot days demand is not saved, improper controls supplied, operator inattention or unskilled, condensation on ducts with low temperature supply air when a fan is out of service

2. Electrical storage (lithium ion battery)

Strengths

- High energy density: The much greater energy density is one of the chief advantages of a lithium ion battery or cell. With electronic equipment such as mobile phones needing to operate longer between charges while still consuming more power, there is always a need to batteries with a much higher energy density. In addition to this, there are many power applications from power tools to electric vehicles. The much higher power density offered by lithium ion batteries is a distinct advantage.
- Self-discharge: One issue with batteries and ells is that they lose their charge over time. This self-discharge can be a major issue. One advantage of lithium ion cells is that their rate of self-discharge is much lower than that of other rechargeable cells such as Ni-Cad and NiMH forms.
- No requirement for priming: Some rechargeable cells need to be primed when they receive their first charge. There is no requirement for this with lithium ion cells and batteries.
- Low maintenance: One major lithium ion battery advantage is that they do not require and maintenance to ensure their performance. Ni-Cad cells required a periodic discharge to ensure that they did not exhibit the memory effect. As this does not affect lithium ion cells, this process or other similar maintenance procedures are not required.
- Variety of types available: There are several types of lithium ion cell available. This advantage of lithium ion batteries can mean that the right technology can be used for the particular application needed. Some forms of lithium ion battery provide a high current density and are ideal for consumer mobile electronic equipment. Others are able to provide much higher current levels and are ideal for power tools and electric vehicles.

Weaknesses

- Protection required: Lithium ion cells and batteries are not as robust as some other rechargeable technologies. They require protection from being over charged and discharged too far. In addition to this, they need to have the current maintained within safe limits. Accordingly one lithium ion battery disadvantage is that they require protection circuitry incorporated to ensure they are kept within their safe operating limits. Fortunately with modern integrated circuit technology, this can be relatively easily incorporated into the battery, or within the equipment if the battery is not interchangeable.
- Ageing: One of the major lithium ion battery disadvantages for consumer electronics is that lithium ion batteries suffer from ageing. Not only is this time or calendar dependent, but it is also dependent upon the number of charge discharge cycles that the battery has undergone. When a typical consumer lithium cobalt oxide, LCO battery or cell needs to be stored it should be partially charged - around 40% to 50% and kept in a cool storage area. Storage under these conditions will help increase the life.
- Transportation: Another disadvantage of lithium ion batteries is that there can be certain restrictions placed on their transportation, especially by air. Although the batteries that could be taken in aircraft carry-on luggage are unlikely to be affected, care should be taken not to carry any more lithium ion batteries than are needed. Any carried separately must be protected against short circuits by protective covers, etc.
- Cost: A major lithium ion battery disadvantage is their cost. Typically they are around 40% more costly to manufacture than Nickel cadmium cells. This is a major factor when considering their use in mass produced consumer items where any additional costs are a major issue.
- Immature technology: Lithium ion battery technology is a developing area. This can be a disadvantage in terms of the fact that the technology does not remain constant. However as new lithium ion technologies are being developed all the time, it can also be an advantage as better solutions are coming available.

Appendix 7. Energy Distribution

1. Radiant Heating/Cooling system (Hydronic radiant systems)

Strengths

- Radiant heating/cooling system is a very efficient method of heat transfer, which in turn keeps fuel costs at a minimum.
- The portion of heat radiation is responsible because the convective portion of heat release is very low, so the necessity of tempering the ambient air directly is not required anymore.
- The flow temperature of surface heating systems is correspondingly lower compared to convective systems.
- Another advantage of the radiant heating/cooling system compared to the convective system is the reduction of the transmission losses of heat.
- Radiant system is an efficient delivery solution when compared to small vents or radiators that try to blast enough heat into a room to warm it up.
- No space is required in order to heat up rooms.
- Can be installed under any type of flooring, walls and ceiling.
- In many cases, the first cost of installation can actually be lower when all design impacts are taken into account.
- It allows room by room temperature control, allowing more heat where you want it most.
- Better indoor air quality (because ventilation air is not recirculated and there are no wet surface cooling coils, thereby reducing the likelihood of bacterial growth).

- Better user comfort, even at room temperatures closer to outside air temperatures, than is possible with convective space conditioning (because radiant heat transfer is direct and draft-free; also, virtually no noise is associated with space conditioning).
- Lower maintenance costs (because of inherent system simplicity—no space conditioning equipment is needed in outside walls, and a common central air system can serve both interior and perimeter zones)
- Possibly smaller sizes of chillers and boilers (because delivery temperatures are closer to room temperatures).

Weaknesses

- Radiant system requires controls in order that the panels operate effectively and efficiently.
- These controls require maintenance on the actuators.
- Radiant heating/cooling system has a very slow heat up period of 5 to 6 hours. This means that careful monitoring must take place in order to ensure that the controls are set up correctly to overcome this disadvantage.
- There are very few installations of this technology
- Condensation: When cooling building surfaces below the ambient temperature, one always runs the risk of condensation forming, with all the associated building damage, mold growth, and so on.
- Lower system capacity: Radiant cooling may not be practical with particularly high cooling loads.
- Higher first cost: In some cases, first cost may be higher than an air system, because of the cost of the panels and plumbing. If this is more than the savings in pump, ducting, and fans, the first cost could be higher.

2. Conventional radiators

Below there is a comparison of strengths and weaknesses of conventional radiators made by steel and aluminium:

Steel radiators

Strengths

- Lower cost of materials (up to 30% less compared to aluminium).
- Very good aesthetics in new models.
- Less area for the same heat transfer (up to 30% compared with cast iron or aluminium).
- Low price
- Very good resistance to corrosion, ensuring a very long life.
- They are very easy to mount correctly because: 1) Low weight; 2) Smaller size; 3) The system of brackets used is very safe and accurate; and 4) No need to use reductions because valves are attached directly to the steel couplings, avoiding problems of loss and damage of the paint.
- Being a completely homogeneous material, there are no problems of stray currents or galvanic corrosion, ensuring a longer life.
- It is very difficult to break if freezing and if it happens are easy to repair with welding and repainting.

Weaknesses

- They are not suitable for steam installations.
- Difficulties to store steel radiators.
- There are fewer designs available.

Aluminum radiators

Strengths

- Good resistance to corrosion in well executed facilities
- Lots of models available
- Very good aesthetics and termination
- Easy to store as it can be easily resized.
- Less size than radiators made by cast iron.

Weaknesses

- They are not safe for use with steam
- The system of brackets has a difficult adjustment and regulation, needing qualified personnel for installation.
- Cuts and seals are the major cause of water loss, causing corrosion problems and deterioration of paint.
- Caps and reductions are very difficult to assemble without damaging the paint.
- The mix of used materials (aluminium/steel) results in problems of stray currents, and it is very difficult to avoid galvanic corrosion.
- Corrosion problems in the replacement of water.
- You cannot paint them if these radiators are damaged.
- In case of freezing, they break and cannot be repaired.

3. Fan coils

Strengths

- Central equipment may be sized smaller by taking advantage of building heating and cooling diversity.
- The system requires only piping installation which takes up less space than all-air duct systems.
- It is usually easier to install wire and water pipes than ducts making this a good choice for retrofit applications.
- Unoccupied areas of the building may be isolated and shut down, saving money.
- Zones can be individually controlled. Flexible control with individual control of superiority and the flexibility to adjust the room temperature to determine the start and stop of the fan coil unit, based on the use of the room.
- Easy to implement system partition control, cooling and heating load toward the press room, the purpose of use, use of time, the system is divided into a number of regional systems, the implementation of the sub-control.
- Small body type of fan coil unit system , small footprint, layout and easy to install, even suitable for the transformation of the old building.
- The system can accommodate up to 100% outside air capability.
- Extra capacity for quick pull down response may be provided.
- Because this system can heat with low-temperature water, it is particularly suitable for solar or heat recovery refrigeration equipment.

Weaknesses

- The Fan Coil System requires more maintenance than "all air" systems, and the maintenance work (such as servicing filters) is performed in occupied areas. The crew dispersed, the more the number of units, maintenance and management of a heavy workload;
- Condensate must be disposed of at each unit.
- Filters are small, low in efficiency, and require frequent changing to maintain air volume.
- Interior zones may require separate ducts to deliver outside (ventilation) air.
- Summer room humidity levels tend to be relatively high, particularly if modulating chilled water control valves are used for room temperature control. Alternatives are two-position

control with variable-speed fans and the bypass unit variable chilled water temperature control.

4. Air handling unit

Strengths

- Improved Indoor Air Quality and Ventilation. When properly designed, installed, used and maintained, make-up air units help dilute and expel airborne contaminants, allowing for exhaust systems to operate more efficiently. Systems can be designed to automatically modulate outdoor air to meet ventilation requirements in cold weather and decrease heat build-up in warm weather.
- Less Heat Stratification, Consistent Temperatures. Building pressurization with make-up air units helps minimize hot and cold spots and increase occupant comfort.
- Many Design Options. Systems can be designed for vertical or horizontal configurations, indoor or outdoor installations. Systems can also be customized to meet specific application requirements.
- Flexible solutions. Flexible solutions with heat recovery and intelligent control functions that are easily adapted to suit current needs, different recovery systems and configurations.
- Large Volumes of Air. When choosing central plants, you will usually need units capable of handling large volumes of air and sometimes the option of communicating with and integrated control system.
- Compact solutions. Changed needs when upgrading or renovating a building usually mean new requirements for air handling. Extreme space-saving solutions and connections for units that can also be split for easier transport and handling at the construction site are able to satisfy all new demands.
- Communication. Integrated control systems. The nature and complexity of requirements for controlling units and functions vary depending on the size of a project. Our factory-integrated solutions with various levels of equipment can handle everything from the simplest requirements to the toughest demands.
- Fast turnaround / installation.
- Low operating costs.
- This system can be used anywhere in the plant.
- Prevents cross contamination.
- Easy to move AHU from one area to another.
- Easy safe change procedure to remove blocked filters.
- Simple damper to regulate the air flow.
- Flashing beacon provides visual sign that unit is operating.

Weaknesses

- Space for ducts
- Pressure loss in ducts entails higher energy consumption on air transport
- Due to the multi-functionality of AHUs the investment cost is high.

Appendix 8. Simulators

Simulators	Complexity (High/Medium/ Low)	User profile	Input/file format	output/file format	Commercial/Free Remark	Introduction
Trnsys	H	Energy engineer	Need to prepare manually. Or also can run from .dck file (parametric run) which is editable.	Figures, tables .out, and txt,	Commercial The input file can be prepare using the software, but difficult to prepare from zero. The input file also has its own Input file syntax	TRNSYS is a software package consisting of a graphical front-end (TRNSYS Simulation Studio) to graphically create a simulation, an interface for the TRNSYS multi-zone building (TRNBuild/Type56), a Google SketchUp plugin for creating the multi-zone building envelope (TRNSYS3D), and a tool for manually editing the TRNSYS input files and creating stand-alone TRNSYS-based applications (TRNEdit/TRNSED). TRNSYS takes a modular, black box component approach to developing and solving simulations: the outputs of one component are sent to the inputs of another component.
eQuest (Doe2)	L(Wizard)/M	Energy engineer	Inputs can be provided at three levels: schematic design wizard, design development wizard, and detailed (DOE-2) interface. Need the UI to prepare the input file.	Graphical summary reports: single-run results summary, a comparative results summary and parametric tabular reports. Hourly simulation results (text and comma-separated variable hourly listings for thousands of simulation variables) are available too.	Free Geometry has to be introduced manually, although a dxf file containing the floor geometry can be used as a template. Up to know, 3D geometry cannot be imported.	eQUEST is a widely used, time-proven whole building energy performance design tool. Its wizards, dynamic defaults, interactive graphics, parametric analysis, and rapid execution make eQUEST uniquely able to conduct whole-building performance simulation analysis throughout the entire design process, from the earliest conceptual stages to the final stages of design. eQUEST's simulation engine, DOE 2.2, is also time-proven, well known, and widely used
Energy Plus	H	Energy engineer	Text input (ASCII file)	Text output, readily adapted into spreadsheet form for further analysis.	Free Text input may make it more difficult to use than graphical interfaces, although there are add-ons like OpenStudio. OpenStudio is a cross-platform (Windows, Mac, and Linux) collection of software tools to support whole building energy modeling using EnergyPlus and advanced daylight analysis using Radiance. OpenStudio is an open source project that includes five tools that work with EnergyPlus, Radiance, and other formats such as gbXML. The SketchUp Plug-in	Energyplus is a whole building energy simulation program that engineers, architects, and researchers use to model energy and water use in buildings. Modeling the performance of a building with EnergyPlus enables building professionals to optimize the building design to use less energy and water. EnergyPlus models heating, cooling, lighting, ventilation, other energy flows, and water use. EnergyPlus includes many innovative simulation capabilities: time-steps less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, water use, natural ventilation, and photovoltaic systems.

					allows users to quickly create geometry for EnergyPlus with SketchUp functionality including drawing tools, integration with Google Earth, Building Maker, and Photo Match. SystemOutliner lets you create and edit HVAC systems. ModelEditor is a generic interface to OpenStudio objects. RunManager manages multiple simulations and workflows. ResultsViewer enables browsing, plotting, and comparing EnergyPlus output data in a graphical format.	
Vasari 3,0	L	Architect	The input template is very limited and is in textual format. Import .rvt (Revit), .dgn (Bentley) and .skp (Sketch up)	Figures, tables, and files as: .gbXML	Beta version The tool is very suitable for early design phases and specially site, solar analysis, and geometry and massing analysis. However, the main disadvantage of the tool lies its restricted energy analysis which does not allow it to be used in later phases or by advanced simulation experts. Even, there is no indication in Vasari to code compliance.	Autodesk Project Vasari v3.0 is a conceptual design tool built on the same technology as the Autodesk Revit platform. Vasari is under development and is primarily intended to reduce the building energy loads, not replace the more detailed analysis tools. It is able to produce conceptual models using both geometric and parametric modelling functionality. The designs can be analysed using the built-in energy modelling and analysis features. The tools depends on Green Building Studio in many input energy related parameters. Concerning the NZEB objective, the tool does consider the NZEB passive and active requirements explicitly. Vasari uses Green Building Studio, which is based on DOE2 energy simulations. DOE-2 has been widely reviewed and validated using the ASHRAE/BESTEST evaluation protocol.
Ecotec	M	Architect	User can import 3D computer models in 3DS or dXF formats from several widely used computer aided design software such as AutoCAD, 3D Studio, Rhinoceros or SketchUp. Ecotec has added the support for IFC and gbXML schemas.	Ecotec exports a strength of visualizing output in the 3D-building model, the results of the thermal anayses (mainly charts), are often difficult to interpret. A huge amount of information is generated.	Commercial The tool´s major strengths are its visual appearance and suitability for early design stages. However, there is a lack of accuracy and reliability for thermal analysis. Also, too many options and too much information are incorporated. There is no indication in Ecotec to code compliance.	ECOTECT can display and animate complex shadows and reflections, generate interactive sun-path diagrams for instant overshadowing analysis, calculate the incident solar radiation on any surface. It can also calculate monthly heat loads and hourly temperature graphs for any zone. Default materials and properties are automatically assigned to building elements, strongly reducing inputs. Component properties can easily be modified and new materials can be created in the material library, but not all required properties are in the architect‘s language.
Calener VYP	L	Architect	User can import 2D files (.dxf)	Calener exports CTE format files mainly charts.	Free Spanish software developed to obtain the Energy Certification. Easy of utilization.	Calener software promoted by the Ministry of Industry, Tourism and Commerce through the IDEA and the General Direction of Architecture and the Ministry of Housing. It´s hard and labourious to draw the architectural model. With complex forms Calener gives errors.
Design	H	Energy	Design Builder supports	the output constitutes	Commercial	Design Builder is a powerful tool for enegy simulations. As

Builder (Energy plus is the engine)		engineer and architect	different levels of data-input, ranging from general to detail. As such, this tool is largely adapted to the different phases and users of the design stages.	one of the major limitations concerning architect-friendliness	Design Builder´s interface is well organized around several tabbed views. However, behind this structure, the designer is often confronted with too much information and too many options, impeding ease of use and navigation	calculation engine, the program that make simulation calculations, Energy Plus is one of the most recognized and internationally used. It has the advantage of allowing more than one system per zone.
HAP (by Carrier)	M	Energy engineer and architect	Building geometry (2D template), envelope construction, internal heat gains and their schedules; equipment components, configurations, controls and efficiencies; utility rates	Design reports provide system sizing information, check figures, component loads and building temperatures. Simulation reports provide hourly, daily, monthly and annual performance data. All reports can be exported for use in word processors and spreadsheets. Energy costs can be calculated using complex utility rates which consider all of the common billing mechanisms for energy use, fuel use and demand	Commercial HAP balances ease of use with technical sophistication. HAP has limitations for use by research scientists. Because it is designed for the practicing engineer, program features are tailored for this audience. Features such as access to the source code, often necessary in research situations, are not offered.	HAP energy analysis module performs an hour-by-hour simulation of building loads and equipment operation for all 8,760 hours in a year. This approach provides superior accuracy versus the reduced hour-by-hour method used by other software programs on the market. This is because a full hour-by-hour calculation considers the unique weather and operating schedules for each day of the year, rather than looking only at average or typical days each month. Such accuracy is crucial when analyzing design alternatives, energy conservation methods and details of off-design and part-load performance for equipment. HAP uses TMY weather and the ASHRAE Transfer Function to calculate dynamic heat flow. Many types of air handling systems, packaged equipment and central plant equipment can be simulated.
IES Virtual Environment	M	Energy engineer and architect	Geometrical building data may be imported from a range of CAD/BIM systems (e.g. Revit/SketchUp/Trelligence/Vectorworks/Graphisoft) or gbXML, IFC, DXF files. Geometrical models may alternatively be entered using facilities within the Virtual Environment	Tabular, graphical, video, photorealistic images, colour contoured 3D geometric visualisation of analysis results, full 3D immersive results viewers, fully populated reportage to match LEED / BREEAM / Building regulations and statistical output for energy / daylighting / solar shading all included within the package	Commercial Good interoperability with other CAD/BIM platforms. The package if composed by different software. Some of them are more focused on engineers while others are focused on architects.	The IES Virtual Environment (IESVE) is a powerful, in-depth suite of building performance analysis tools. It allows the design and operation of comfortable buildings that consume significantly less energy. Whether working on a new build or renovation project, the VE allows designers to test different options, identify best passive solutions, compare low-carbon & renewable technologies, and draw conclusions on energy use, CO2 emissions, occupant comfort, and much more. There are various tools in the suite; each designed to provide sustainable analysis at levels suitable for different design team members and design stages. All utilise our Apache dynamic thermal simulation engine, and an integrated central data model, which has direct links to SketchUp™, Revit® or Trelligence™, and gbXML, IFC & dxf imports.
IDA Early Stage	M	Energy engineer	Locked geometry for the several building	Graphical summary reports: single-run	Free	IDA ESBO is a simulation program for building design optimization. It allows you to experiment with

Building Optimization (ESBO)			types. The free version allows you to experiment with everything except the building geometry. A number of template geometries are available to choose from	results summary. Simulation results by sub-hourly time-steps.	The IDA ESBO tool is a good tool when you want to quickly see and understand the impact of various energy efficiency measures and the impct of renewable energy sources in general. The tool is not suitable for the project based simulations of your own building in the planning phase, because of the pre-selected locked building geometry. (This tool was demonstrated by VTT on 12th June 2014 during consortium meeting in Finland)	variations in a building design and to predict the consequences on energy consumption and comfort. IDA ESBO comes in two variants: Template and General. The free Template version allows you to experiment with everything except the building geometry. A number of template geometries are available to choose from. In the General version, you can adapt the model to suit the geometry of a particular project. The ESBO application does not include the effect of heat transmission or air flow between rooms. For projects where these effects are essential to the overall performance of the building, the full IDA ICE application should be used instead.
IDA-ICE	M	Energy engineer	IDA ICE can import all common 2D and 3D CAD files. It supports IFC BIM models, generated by, e.g. ArchiCAD, Revit, AutoCAD ADT, MagiCAD and many other tools.	Graphical summary reports: single-run results summary, a comparative results summary and parametric tabular reports. Hourly simulation results (text and comma-separated variable hourly listings for thousands of simulation variables) are available too.	Commercial The user interface is designed to make it easy to build and simulate simple cases, but also to offer the advanced user full flexibility. You can refine your model in steps, while always providing both 3D graphical and tabular feedback. You work in a single program and may jump back and forth between tasks.	IDA Indoor Climate and Energy (IDA ICE) is an innovative and trusted whole-year detailed and dynamic multi-zone simulation application for study of thermal indoor climate as well as the energy consumption of the entire building. The physical models of IDA ICE reflect the latest research and best models available, and the computed results compare well with measured data. While serving a global market, IDA ICE is adapted to local languages and requirements (climate data, standards, special systems, special reports, product and material data).
APROS District	H	Energy enegineer	Flow sheet, Manual input, various libraries for smart energy system mopdelling	Hourly simulation data	Beta commercial in 2016 The current version of APROS District is used at VTT only, the expected commercial availability will be on 2016	Apros® District is a unique, integrated environment for the modelling of production, distribution, storage and consumption of energy in different forms, and their conversions at district level. The behaviour of district heating, district cooling, gas and electrical network systems can now be studied taking into account the dynamics of consumer models and e.g. complex renewable energy sources.

Appendix 9. Questionnaire and response

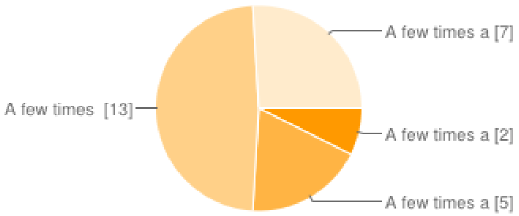
- Relevant data and factors in Design phase

The table below shows the number and typology of stakeholder that have responded the questionnaire:

Role	No.	Percentage
Building owner	3	10%
Funds/banks/grant managers/investors	0	0%
Tenant	0	0%
Building solution providers	1	3%
Urban managers	1	3%
Architects and designers	7	23%
General contractors	1	3%
Planners	2	7%
Craftsmen	0	0%
Construction companies	3	10%
Retrofit providers	1	3%
Technology and solution providers	6	20%
Energy suppliers	0	0%
Policy makers	0	0%
Public administration	1	3%
Other	4	13%

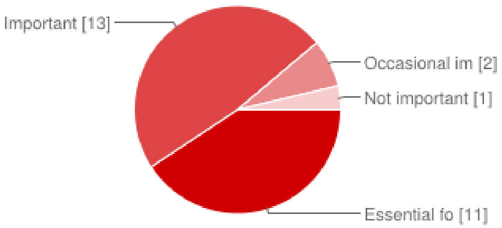
1. Decision Process – 1

1.1 How often are you confronted with decision making on building component choices?



Frequency	No.	%
A few times a day	2	7%
A few times a week	5	17%
A few times a month	13	43%
A few times a year	7	23%

1.2 Please estimate the relevance of decision making on building component choices



Decisions relevance	No.	%
Essential for the business	11	37%
Important	13	43%
Occasional important	2	7%
Not important at all	1	3%

1.3 Please give examples for component decisions at your firm.

- It is important to know the components of structure (envelopes, windows, roof typology,...)
- Material selection like doors and windows, but more are investment related.
- Correct prediction of proposed buildings' energy performance

- Compliance with the current urban rules
- We trying to buy the cheapest best-fit components for the building we are constructing. Assure the health of our workers.
- Construction materials, facilities design, potential retrofit solutions, etc.
- "Green components" that help the building to reduce the energy demand
- Exterior metal panel, plaster etc. types at design phase 2. Construction material and type choice - for cost and schedule optimization - media connections - HVAC machinery standards (capacity, quality, etc) - renewable energy sources (yes or not) - building's in-built equipment related to required environmental certificate's mark - any additional building's components related to functional requirements
- HVAC, electric lighting, envelope materials are common choices in our business
- Any from structure to flooring
- We offer the consulting service to our clients, especially for HVAC and energy system, we provide information of the energy efficiency and cost of the equpiment to our clients, together with the assessment of the life-cycle cost of the equipment. For some simulations of the building, such as simulation of the thermal performance, we can change the configuration of the wall and windows if requested by clients, thus they can see the influence of the different configuration of the walls and windows on the energy performance of the building. The client may come to a conclusion: use one or another material or change the thickness of the wall etc.
- New expansions in cities
- Outside lighting ,building heating from recycled process heat
- I often take in consideration specific volumetry of buildings at the neighbourhood level.
- How is going to be the performance of the components in my building: Envelope of building: facades and roofs. - Components in the openings: fenestration.

1.4 Please indicate/list the factors your decision is based on from the planning phase / the construction phase / the retrofitting phase / the operation phase

- Budget (planning, retrofitting) future energy cost (planning,retrofitting) user comfort (planning,retrofitting) local energy source such as radiation and wind (planning,retrofitting) climate, temperature (planning,retrofitting) occupancy, usage frecuency (planning,retrofitting) Type of user/end user(planning,retrofitting) Locally available commercial products(planning,retrofitting) efficiency of the equipments(all phases) user friendly of the equipment(all)
- Budget constraints/ planning phase
- Orientation (planning) - Traditional construction (construction) - Historically buildings (retrofitting) - Performance of the installations (operation)
- Facilities operation, budget constraints, business expectations constrains, etc
- Payback and capital availabity
- Cost Time Time (delivery day)
- Planning phase: available media sources, required building's standard and function, economical constraints, life-cycle analysis construction phase: budget, specific requirements of contractor companies, execution timeline

- Budget of construction/retrofitting site, Performance of the applied materials and solutions, Time dedicated to each of the construction phase.
- Budget limitation; Awareness of Stakeholders; Knowledge of Construction workers
- Budget issue/ planning
- This client based (the client could be anybody in the construction process and would lead them down the best practice route, for example: - BREEAM BRE Environmental Assessment Method (BREEAM) - http://www.breeam.org/ - Good practice roadmap for the Low Carbon refurbishment process. CTV 038 (2008), Low Carbon Refurbishment of Buildings - A guide to achieving carbon savings from refurbishment of non-domestic buildings, Carbon Trust, free download from http://www.carbontrust.com. - Controls BS EN 15232 (2012): Energy performance of buildings — Impact of Building Automation, Controls and Building Management, British Standards Institute. - Technologies EU Green Public Procurement (GPP) criteria - http://ec.europa.eu/environment/gpp/gpp_criteria_en.htm. UK’s Enhanced Capital Allowance (ECA) scheme and its Energy Technology List (ETL) - https://etl.decc.gov.uk/etl/site.html. UK’s Government Buying Standards (formerly known as Buy Sustainable Quick Wins) - http://sd.defra.gov.uk/advice/public/buying.
- Reduction of building energy demands and reduction of the building primary energy consumption
- From the planning phase a heating/cooling demand analysis is performed with main building components (location, end user needs, setpoints and envelopes). Then, before the construction phase there is planning phase for construction assembly of different components: envelopes, Heating/cooling/DHW and electric system.
- Performance of the installations (operation)
- In common suitable in terms of budget and expected function and design
- Economical aspect. Location of the building. Legislative constraints
- "Building energy performance" for all four phases
- Budget constraints (construction)
- Budget constraints Performance results Spatial constraints
- Energy supply systems : economic return in the planning phase; efficiency in the construction phase ; subsidies in the retrofitting phase
- We are always working on a fixed price/value basis from the beginning of the project i.e. all decision factors are present before any decision
- Rise of population (planning)
- Planning - quality and budget Construction - cost and time efficiency (assuming quality materials and solutions have already been chosen)
- Urban rules / planning

1.5 If have you been confronted with decisions on technologies influenced by the aspect of neighbourhood or districts, please give examples for such decision

- Shadowing of proposed buildings by existing adjacent buildings, district cooling, district heating ...
- Yes see Sustainable and BREEAM communities - http://www.bre.co.uk/page.jsp?id=1768
- What type of energy supply is on the district

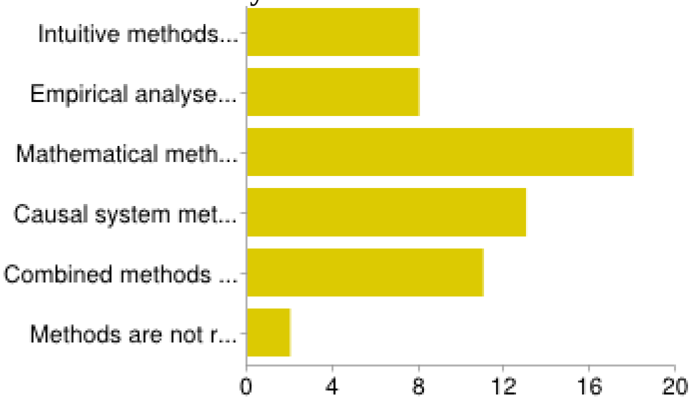
- We have been contracting district heating because we were forced to do so gy regional building law
- In some retrofitting project (consulting service), we have to decide what kind of renewable source/technology, such as wind turbine or PV, we have to evaluate the energy source. For instance, we check our database of solar radiation of the place and perform a calculation, then we get the approximate Return of Investment of PV, then compare with the wind turbine, during the process, we evaluate the wind source, the weather (windy, or too many rainy days etc.), the environment (location, such as near seaside, high humidity etc), we evaluate the place is adequate for one or another technology. Another aspect is the legislation and tariff.
- which energy power is in the district it´s going to be my building
- The aesthetical issues for the envelope typology
- I haven´t got this opportunity.
- Electricity grid connection
- Aesthetical aspects of the roofs when installing RE systems
- Sometimes solar PV/thermal is not allowed (historic neighbourhood) - Boreholes depend on local regulations. - Existing district heating affect decisions.
- Dimension of pavements according the pipes under them.
- The quality of finishing materials on pavements.
- Difficulties for performing an energy grid
- The decision of technologies is always related to local district conditions
- What energy supply is cheaper and better than other

1.6 Please list out the factors your decision on district level is based on

- Yes see Sustainable and BREEAM communities - http://www.bre.co.uk/page.jsp?id=1768
- Comfort of the people is going to live there.
- High predicted energy efficiency of proposed buildings
- Aesthetical issues Legal problems
- Density of people place on the district - dimension of streets and urban spaces
- Usually the district approach is not very relevant
- How many floors are going to have my building 2. Which density of people is required by the urban rules.
- How much cost a sqm in the district it´s going to be my building
- See above, but...in fact the offer was not too bad -costs-
- Local Master Plan constraints, - availability of media, - local environmental requirements,
- We have not worked on district level.
- Agreement between Tenants
- Local available energy source (radiation, wind velocity) heating /cooling degree day. Average ambient temperature ground /water temperature availability of energy source and products (in the case of biomass, we consider if it is easy to buy the raw material) stability of grid (in some project for south America, we have to considerate the stability of the electrical grid), voltage and frequency of the grid. Availability of the heating grid which will affect our decision on buying large boiler or not.
- What appear in the construction project. We have to comply with the design project.

- Return of investment Availability of resources

1.7 Which methods do you use to evaluate the factors?

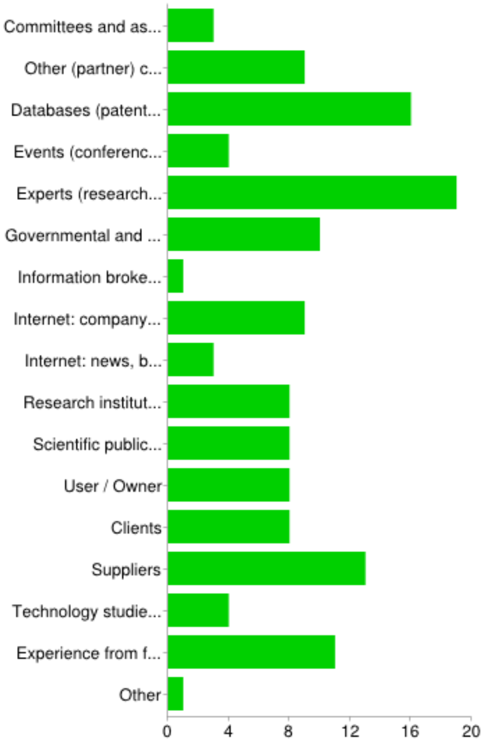


Methods	No.	%
Intuitive methods (Creativity, workshops, interviews, etc.)	8	27%
Empirical analyses (conjoint, patents, publications, etc.)	8	27%
Mathematical methods (statistics, simulations, etc.)	18	60%
Causal system methods (check lists, costs, impacts, portfolios, life cycles, etc.)	13	43%
Combined methods (scenario analysis, technology roadmapping, assessments, etc.)	11	37%
Methods are not relatable with the categories above, please specify	2	7%

Others:

- Current urban rules
- Depending on complexity
- Urban rules
- Scientific approach

1.8 Which sources do you use to evaluate the factors?

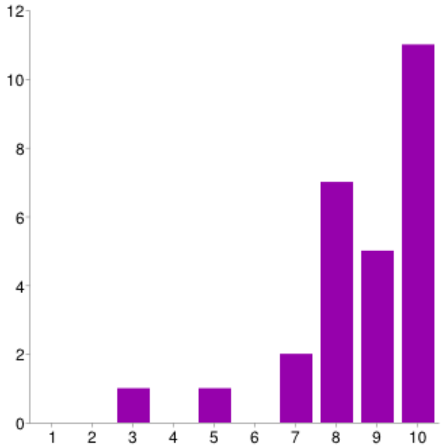


Sources	**No.**	**%**
Committees and associations	3	10%
Other (partner) companies	9	30%
Databases (patents, statistics, etc.)	16	53%
Events (conferences, fairs, seminars, etc.)	4	13%
Experts (researchers, engineers, specialists, etc.)	19	63%
Governmental and public institutions (ministries, regulatory bodies, etc.)	10	33%
Information broker (external specialists, consultants, etc.)	1	3%
Internet: company websites, catalogues etc.	9	30%
Internet: news, blogs, magazines, etc.	3	10%
Research institutes or universities (through research projects, PhD students, etc.)	8	27%
Scientific publications (journals, books, press, etc.)	8	27%
User / Owner	8	27%
Clients	8	27%
Suppliers	13	43%
Technology studies (Delphi studies, competitive analyses, technology analyses, etc.)	4	13%
Experience from former projects	11	37%
Other	1	3%

2. Decision Process - 2

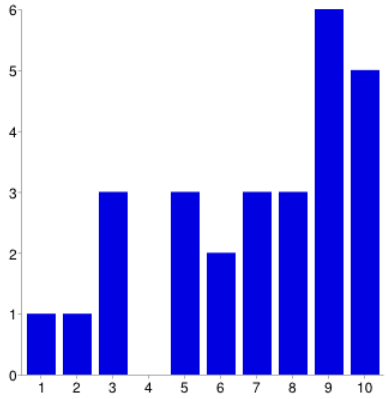
2.1 Please evaluate the following list of stakeholders by importance regarding decision making on component or technology choices with the numbers 1 to 10

- Owner



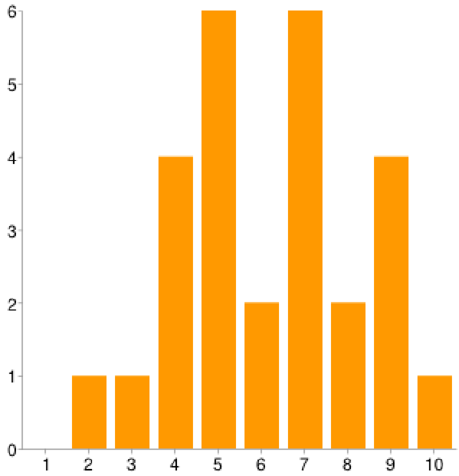
Relevance	**No.**	**%**
1	0	0%
2	0	0%
3	1	3%
4	0	0%
5	1	3%
6	0	0%
7	2	7%
8	7	23%
9	5	17%
10	11	37%

- Funds/banks/grant managers/investors



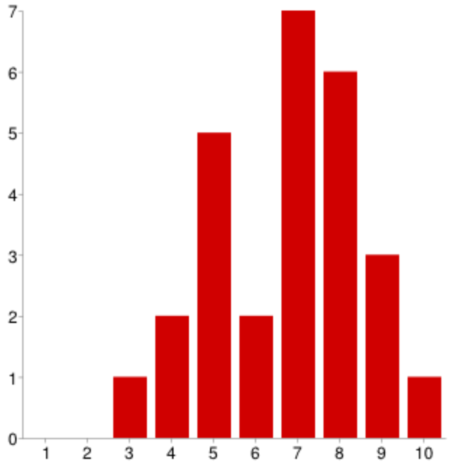
Relevance	No.	%
1	1	3%
2	1	3%
3	3	10%
4	0	0%
5	3	10%
6	2	7%
7	3	10%
8	3	10%
9	6	20%
10	5	17%

- Tenant



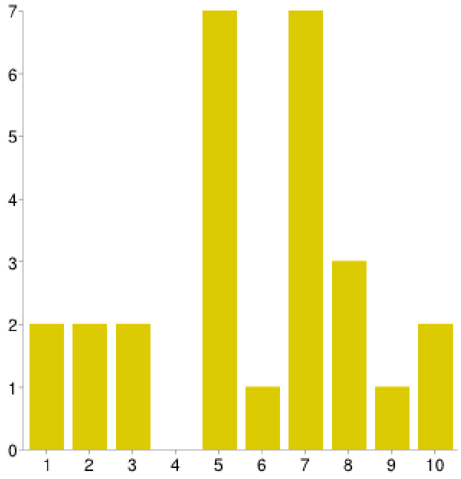
Relevance	No.	%
1	0	0%
2	1	3%
3	1	3%
4	4	13%
5	6	20%
6	2	7%
7	6	20%
8	2	7%
9	4	13%
10	1	3%

- Building solution providers



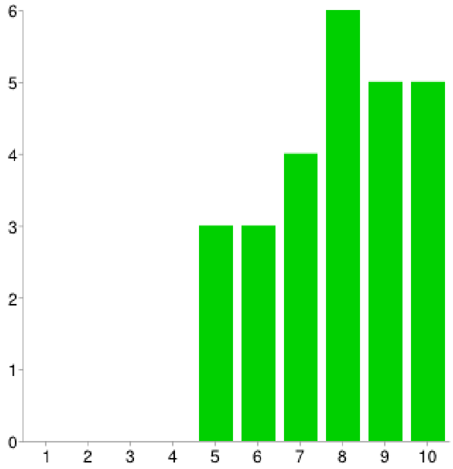
Relevance	No.	%
1	0	0%
2	0	0%
3	1	3%
4	2	7%
5	5	17%
6	2	7%
7	7	23%
8	6	20%
9	3	10%
10	1	3%

- Urban managers



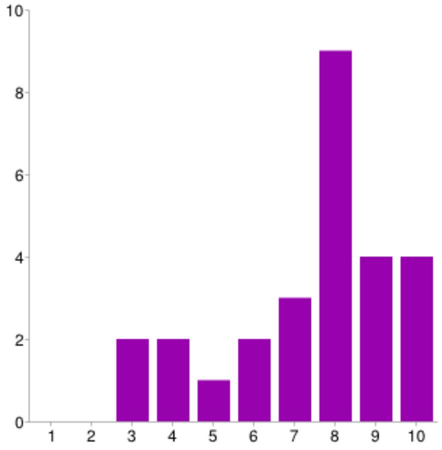
Relevance	No.	%
1	2	7%
2	2	7%
3	2	7%
4	0	0%
5	7	23%
6	1	3%
7	7	23%
8	3	10%
9	1	3%
10	2	7%

- Architects and designers



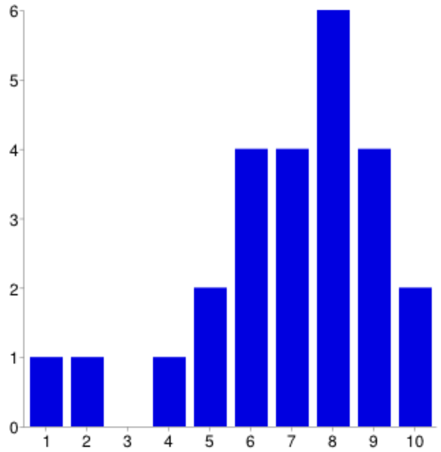
Relevance	No.	%
1	0	0%
2	0	0%
3	0	0%
4	0	0%
5	3	10%
6	3	10%
7	4	13%
8	6	20%
9	5	17%
10	5	17%

- General contractors



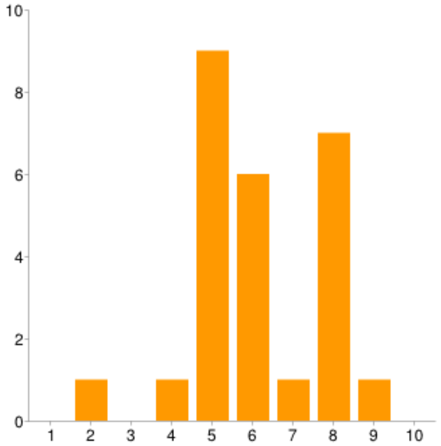
Relevance	No.	%
1	0	0%
2	0	0%
3	2	7%
4	2	7%
5	1	3%
6	2	7%
7	3	10%
8	9	30%
9	4	13%
10	4	13%

- Planners



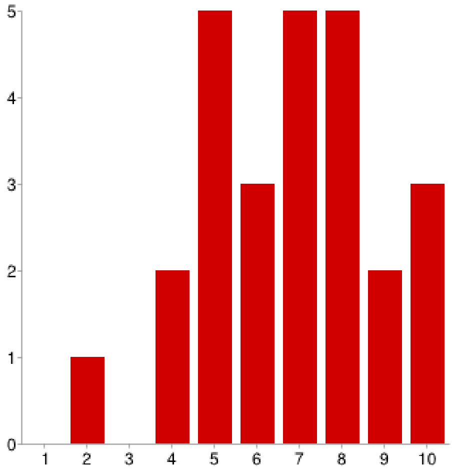
Relevance	No.	%
1	1	3%
2	1	3%
3	0	0%
4	1	3%
5	2	7%
6	4	13%
7	4	13%
8	6	20%
9	4	13%
10	2	7%

- Craftsmen



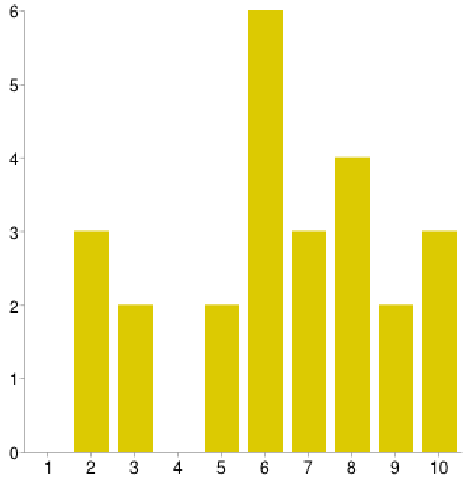
Relevance	No.	%
1	0	0%
2	1	3%
3	0	0%
4	1	3%
5	9	30%
6	6	20%
7	1	3%
8	7	23%
9	1	3%
10	0	0%

- Construction companies



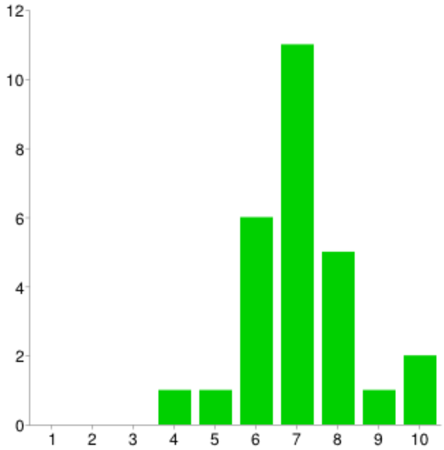
Relevance	No.	%
1	0	0%
2	1	3%
3	0	0%
4	2	7%
5	5	17%
6	3	10%
7	5	17%
8	5	17%
9	2	7%
10	3	10%

- Retrofit providers



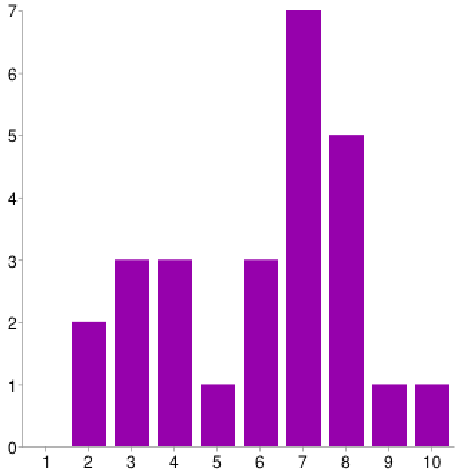
Relevance	No.	%
1	0	0%
2	3	10%
3	2	7%
4	0	0%
5	2	7%
6	6	20%
7	3	10%
8	4	13%
9	2	7%
10	3	10%

- Technology and solution providers



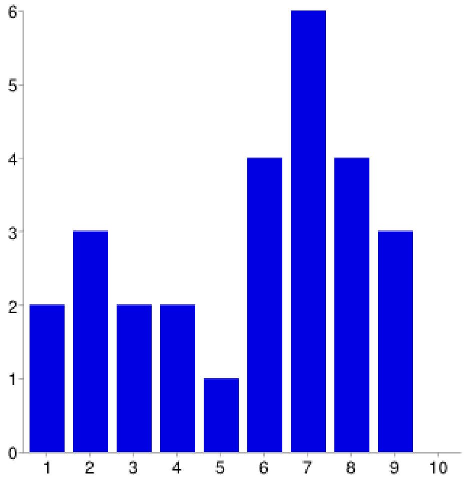
Relevance	No.	%
1	0	0%
2	0	0%
3	0	0%
4	1	3%
5	1	3%
6	6	20%
7	11	37%
8	5	17%
9	1	3%
10	2	7%

- Energy suppliers



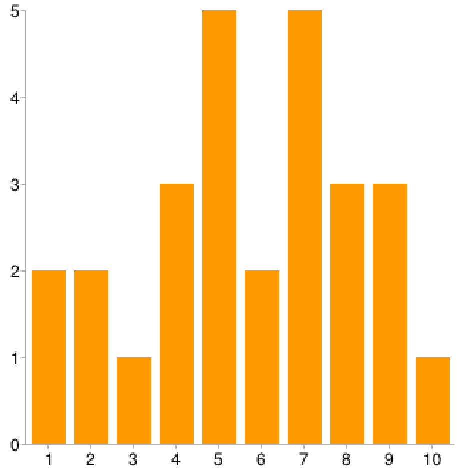
Relevance	No.	%
1	0	0%
2	2	7%
3	3	10%
4	3	10%
5	1	3%
6	3	10%
7	7	23%
8	5	17%
9	1	3%
10	1	3%

- Policy makers



Relevance	No.	%
1	2	7%
2	3	10%
3	2	7%
4	2	7%
5	1	3%
6	4	13%
7	6	20%
8	4	13%
9	3	10%
10	0	0%

- Public ministry



Relevance	No.	%
1	2	7%
2	2	7%
3	1	3%
4	3	10%
5	5	17%
6	2	7%
7	5	17%
8	3	10%
9	3	10%
10	1	3%

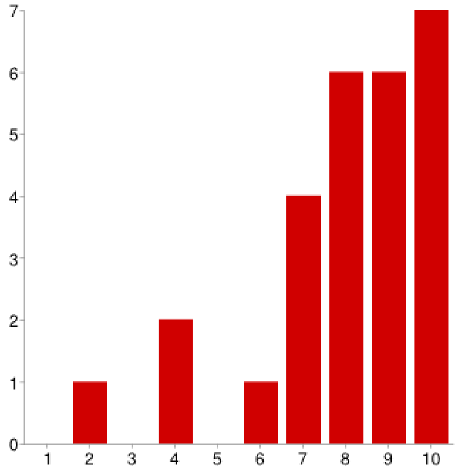
2.2 Which methods do you use to for the identification of customer or user requirements? (if applicable)

- Face meetings and interchange of emails
- Meetings
- Yes see Sustainable and BREEAM communities - http://www.bre.co.uk/page.jsp?id=1768
- interviews, budget, examples
- Surveys
- Interviews, visits to pilots
- The urban districts are near it.
- Establishing the list of building' standards
- None, we are working on high level demands given by law
- First, I use to talk and know the requirements of the client, the programm and space uses are needed.
- Kano methodology of customer satisafction and innovation development

3. Component - HVAC Equipment

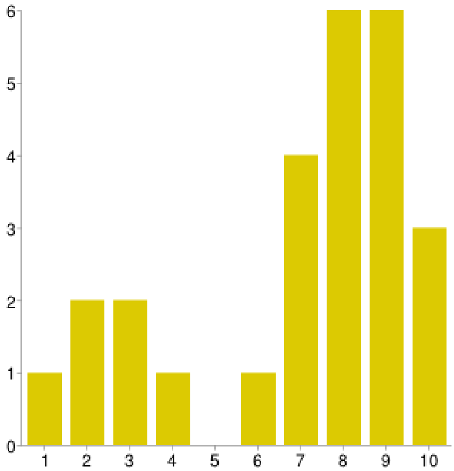
3.1 When thinking about the kind of HVAC equipment that you would prefer for a certain building, please estimate the relevance of the following factors.

- Investment cost



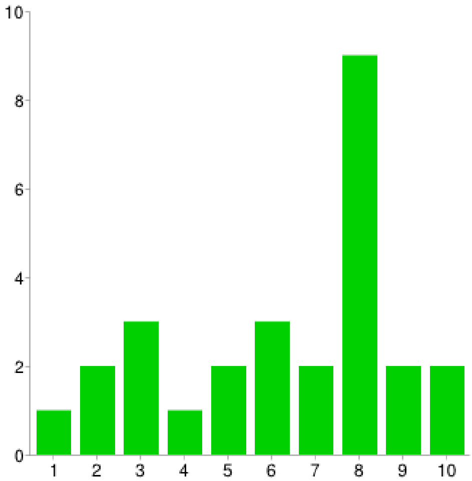
Relevance	No.	%
1	0	0%
2	1	3%
3	0	0%
4	2	7%
5	0	0%
6	1	3%
7	4	13%
8	6	20%
9	6	20%
10	7	23%

- Operating cost



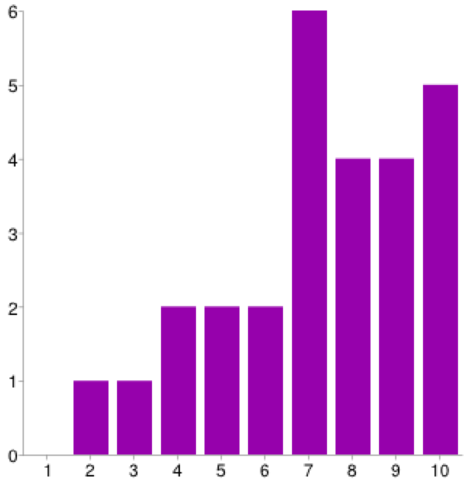
Relevance	No.	%
1	1	3%
2	2	7%
3	2	7%
4	1	3%
5	0	0%
6	1	3%
7	4	13%
8	6	20%
9	6	20%
10	3	10%

- Maintenance issues



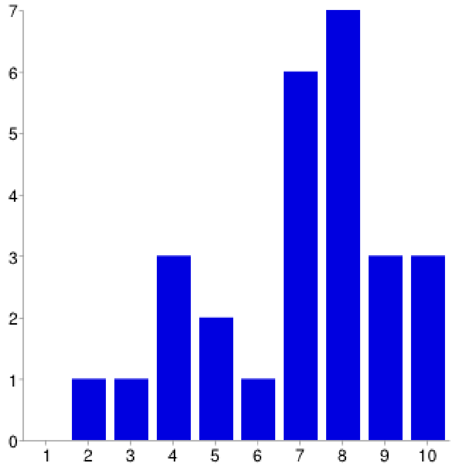
Relevance	No.	%
1	1	3%
2	2	7%
3	3	10%
4	1	3%
5	2	7%
6	3	10%
7	2	7%
8	9	30%
9	2	7%
10	2	7%

- System reliability



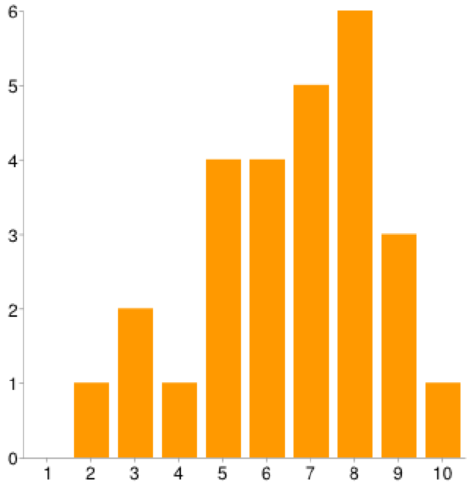
Relevance	No.	%
1	0	0%
2	1	3%
3	1	3%
4	2	7%
5	2	7%
6	2	7%
7	6	20%
8	4	13%
9	4	13%
10	5	17%

- Energy efficiency



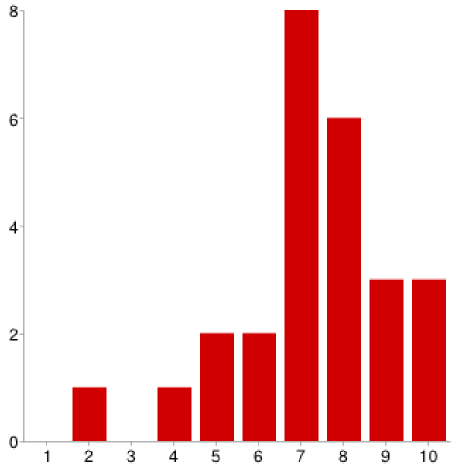
Relevance	No.	%
1	0	0%
2	1	3%
3	1	3%
4	3	10%
5	2	7%
6	1	3%
7	6	20%
8	7	23%
9	3	10%
10	3	10%

- Noise



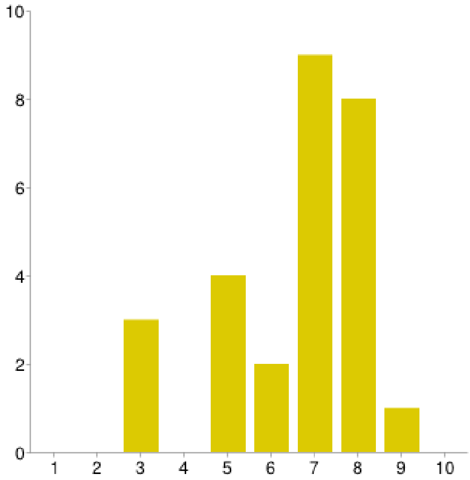
Relevance	No.	%
1	0	0%
2	1	3%
3	2	7%
4	1	3%
5	4	13%
6	4	13%
7	5	17%
8	6	20%
9	3	10%
10	1	3%

- Thermal comfort



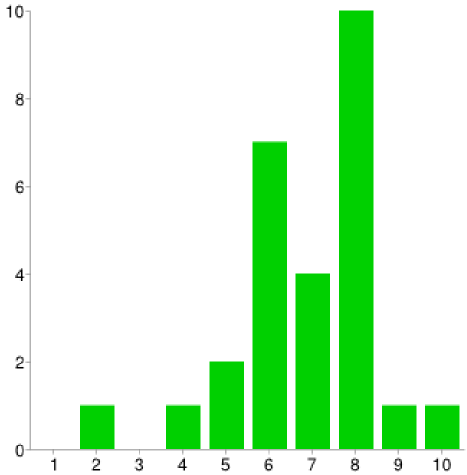
Relevance	No.	%
1	0	0%
2	1	3%
3	0	0%
4	1	3%
5	2	7%
6	2	7%
7	8	27%
8	6	20%
9	3	10%
10	3	10%

- Architectonical aspects (e.g. big air ducts/false ceilings can be necessary)



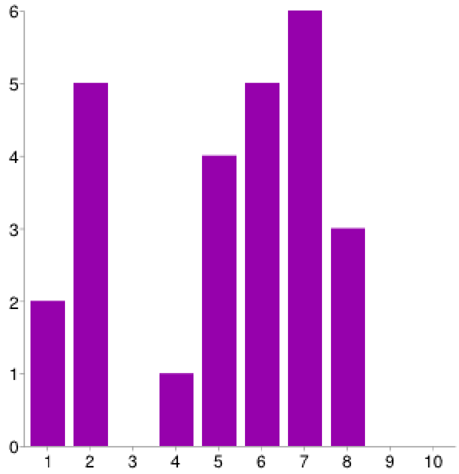
Relevance	No.	%
1	0	0%
2	0	0%
3	3	10%
4	0	0%
5	4	13%
6	2	7%
7	9	30%
8	8	27%
9	1	3%
10	0	0%

- Space occupied in the building



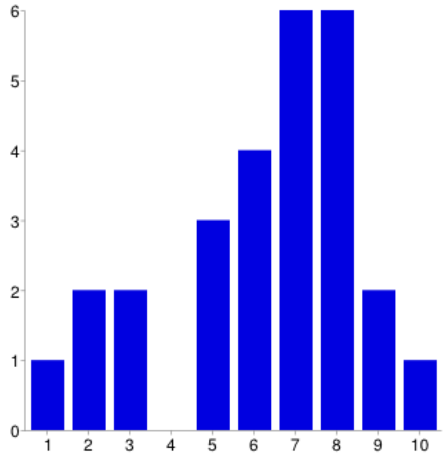
Relevance	No.	%
1	0	0%
2	1	3%
3	0	0%
4	1	3%
5	2	7%
6	7	23%
7	4	13%
8	10	33%
9	1	3%
10	1	3%

- Simplicity of the HVAC project (few calculations)



Relevance	No.	%
1	2	7%
2	5	17%
3	0	0%
4	1	3%
5	4	13%
6	5	17%
7	6	20%
8	3	10%
9	0	0%
10	0	0%

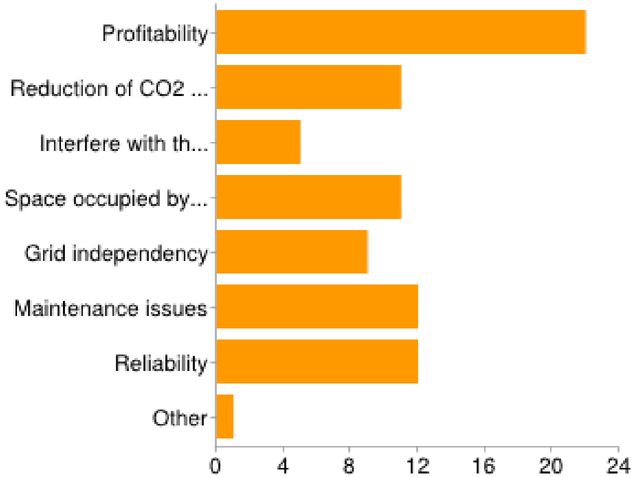
- Simplicity of construction of the HVAC system.



Relevance	No.	%
1	1	3%
2	2	7%
3	2	7%
4	0	0%
5	3	10%
6	4	13%
7	6	20%
8	6	20%
9	2	7%
10	1	3%

- Others
  light pollution

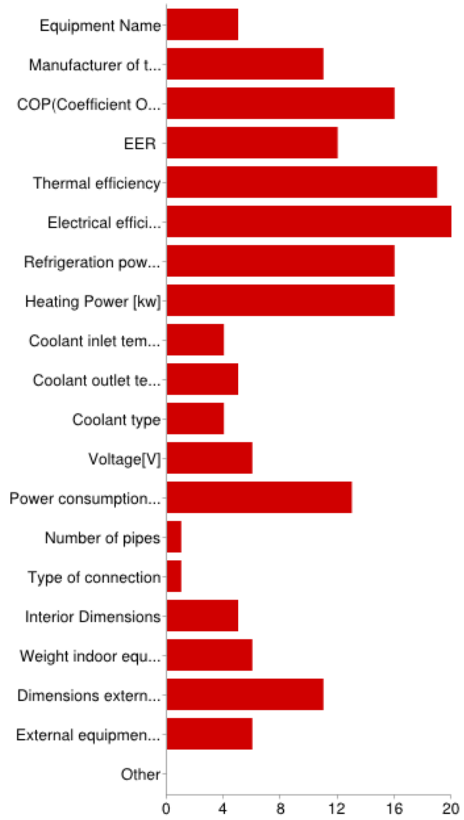
3.2 When deciding about adding renewable energy sources to support your HVAC system. What are the most important factors that you would take into consideration?



Factors	No.	%
Profitability	22	73%

Reduction of CO2 emissions	11	37%
Interfere with the building aesthetics	5	17%
Space occupied by the renewable source.	11	37%
Grid independency	9	30%
Maintenance issues	12	40%
Reliability	12	40%
Other	1	3%

3.3 Please check the information that you consider relevant

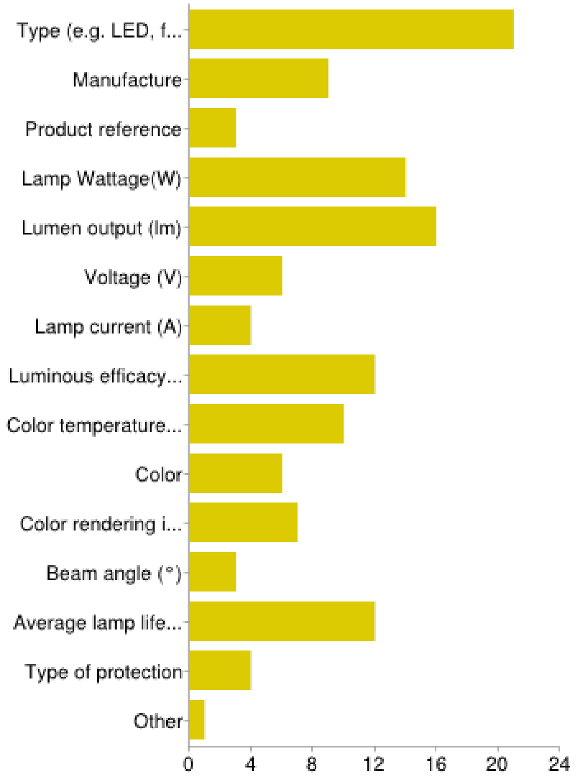


Parameters	No.	%
Equipment Name	5	17%
Manufacturer of the equipment	11	37%
COP(Coefficient Of Performance)	16	53%
EER	12	40%
Thermal efficiency	19	63%
Electrical efficiency	20	67%
Refrigeration power [kw]	16	53%
Heating Power [kw]	16	53%
Coolant inlet temperature [ºC]	4	13%
Coolant outlet temperature [ºC]	5	17%
Coolant type	4	13%
Voltage[V]	6	20%
Power consumption[kw/h]	13	43%
Number of pipes	1	3%

Type of connection	1	3%
Interior Dimensions	5	17%
Weight indoor equipment	6	20%
Dimensions external equipment	11	37%
External equipment Weight	6	20%
Other	0	0%

4. Components - Lighting

4.1 Please check the information that you consider relevant for designing an energy efficient lighting systems

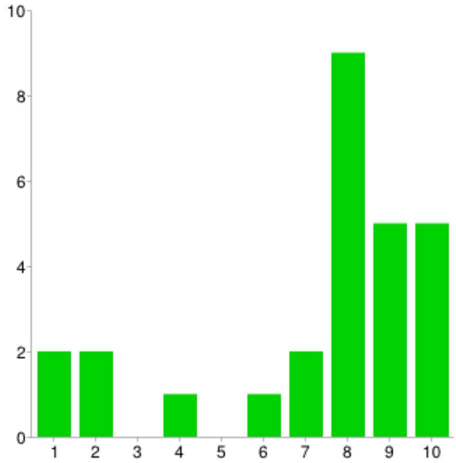


Parameters	No.	%
Type (e.g. LED, florescent)	21	70%
Manufacture	9	30%
Product reference	3	10%
Lamp Wattage(W)	14	47%
Lumen output (lm)	16	53%
Voltage (V)	6	20%
Lamp current (A)	4	13%
Luminous efficacy (lm/W)	12	40%
Color temperature (K)	10	33%
Color	6	20%
Color rendering index (Ra)	7	23%
Beam angle (°)	3	10%
Average lamp life (h)	12	40%
Type of protection	4	13%
Other	1	3%

5. Components – Envelope

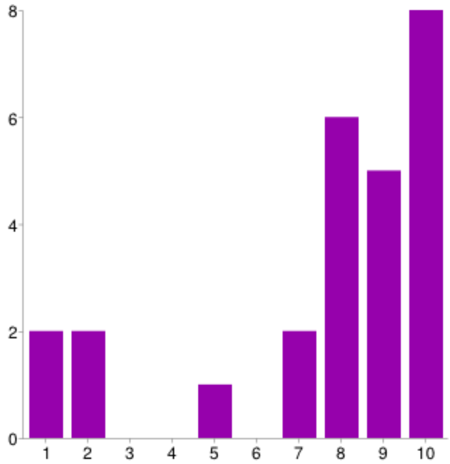
5.1 During the design of an energy efficient building, several types of envelops may be considered, please specify the subcategories of envelops that are important in energy performance. Please include any subcategory of envelope and their contribution in energy performance if it is not in the list.

- Wall



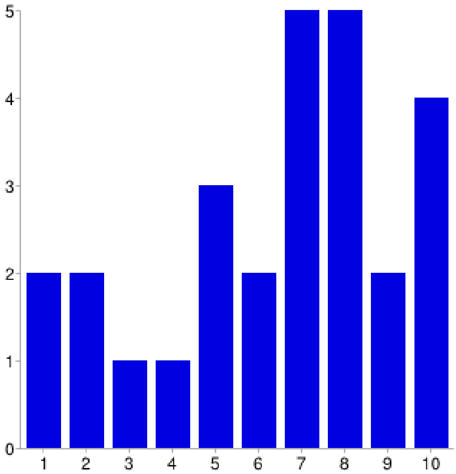
Relevance	No.	%
1	2	7%
2	2	7%
3	0	0%
4	1	3%
5	0	0%
6	1	3%
7	2	7%
8	9	30%
9	5	17%
10	5	17%

- Windows



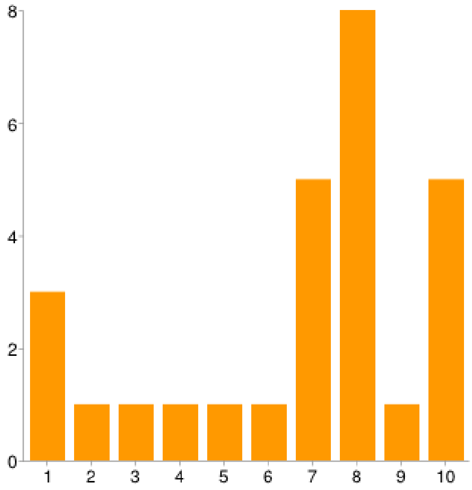
Relevance	No.	%
1	2	7%
2	2	7%
3	0	0%
4	0	0%
5	1	3%
6	0	0%
7	2	7%
8	6	20%
9	5	17%
10	8	27%

- Doors



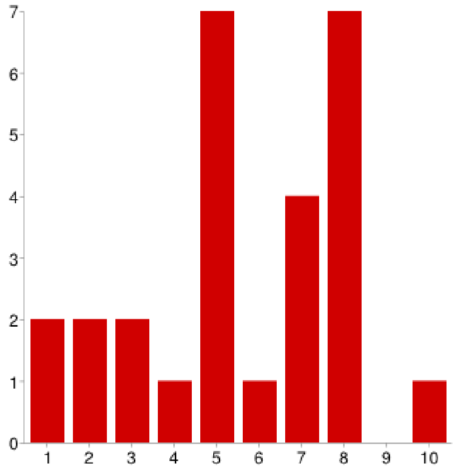
Relevance	No.	%
1	2	7%
2	2	7%
3	1	3%
4	1	3%
5	3	10%
6	2	7%
7	5	17%
8	5	17%
9	2	7%
10	4	13%

- Covers



Relevance	No.	%
1	3	10%
2	1	3%
3	1	3%
4	1	3%
5	1	3%
6	1	3%
7	5	17%
8	8	27%
9	1	3%
10	5	17%

- Floor

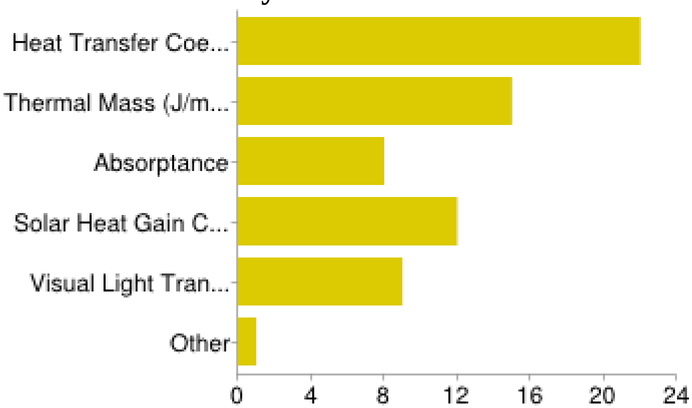


Relevance	No.	%
1	2	7%
2	2	7%
3	2	7%
4	1	3%
5	7	23%
6	1	3%
7	4	13%
8	7	23%
9	0	0%
10	1	3%

- Others
  light emmission to surroundings
  roofs: 9

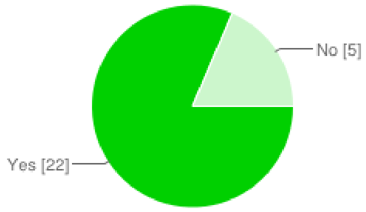
6. Components - Wall/Cover/Floor

6.1 Please Check the information that you consider relevant for Wall/Cover/Floor



Parameters	No.	%
Heat Transfer Coefficient - U (W/m2·K)	22	73%
Thermal Mass (J/m³ K)	15	50%
Absorptance	8	27%
Solar Heat Gain Coefficient	12	40%
Visual Light Transmittance	9	30%
Other	1	3%

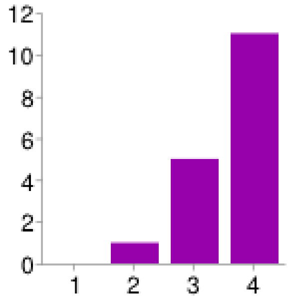
6.2 Do you think it is helpful to know the composition and layer characteristics of the Wall/Cover/Floor for a energy efficient building design?



Respones	No.	%
Yes	22	73%
No	5	17%

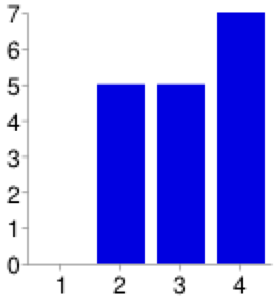
7. Layer Information of Wall/Cover/Floor

7.1 Please evaluate the importance of the MASSIVE LAYER



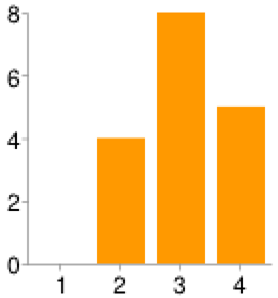
Relevance	No.	%
1	0	0%
2	1	3%
3	5	17%
4	11	37%

7.2 Please evaluate the importance of the MASSLESS LAYER



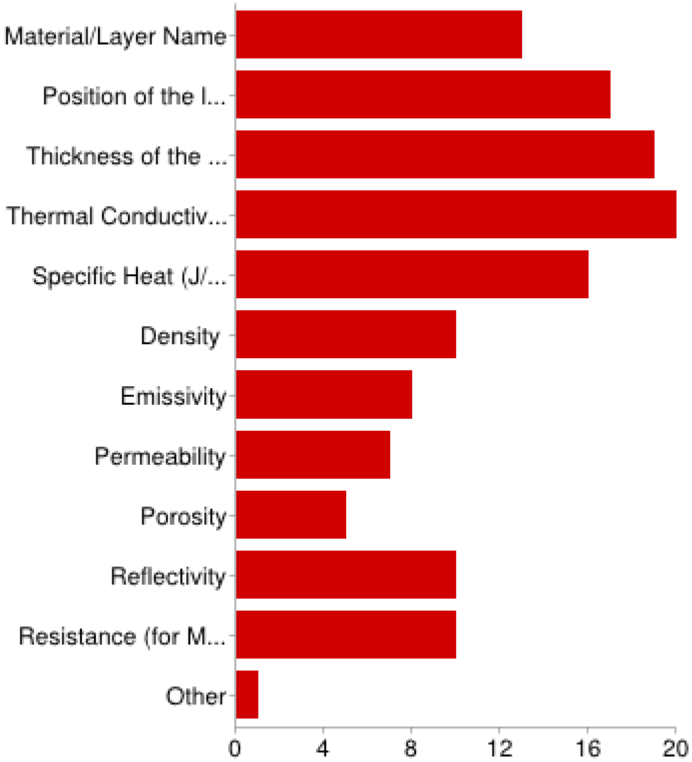
Relevance	No.	%
1	0	0%
2	5	17%
3	5	17%
4	7	23%

7.3 Please evaluate the importance of the ACTIVE LAYER



Relevance	No.	%
1	0	0%
2	4	13%
3	8	27%
4	5	17%

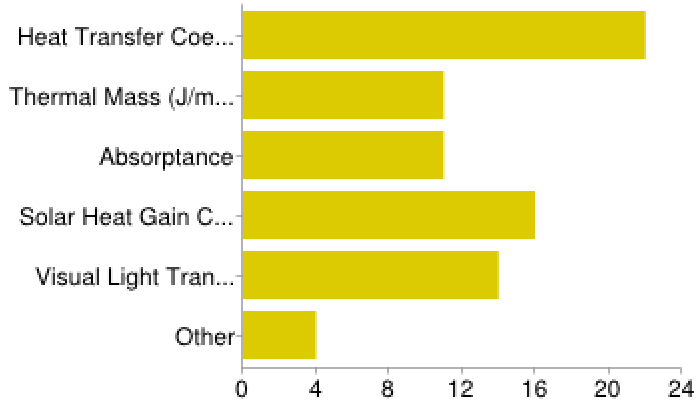
7.4 Please Check the data that you consider relevant for the LAYERs of Wall/Cover/Floor



Parameters	No.	%
Material/Layer Name	13	43%
Position of the layer in the Wall/Cover/Floor (e.g. Layer1 exterior, Layer 2.. Layer4 Interior)	17	57%
Thickness of the layer (m)	19	63%
Thermal Conductivity (W/m·K)	20	67%
Specific Heat (J/kg·K)	16	53%
Density	10	33%
Emissivity	8	27%
Permeability	7	23%
Porosity	5	17%
Reflectivity	10	33%
Resistance (for Massless layer)	10	33%
Other	1	3%

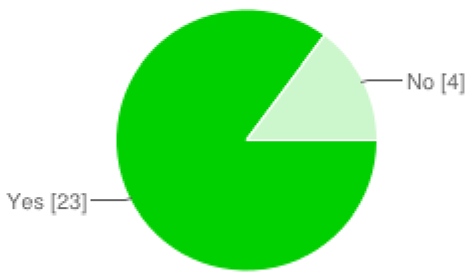
8. Components - Windows/Doors

8.1 Please Check the information that you consider relevant for the complete functions of Windows/Doors in the envelope building design



Parameters	**No.**	**%**
Heat Transfer Coefficient - U (W/m2·K)	22	73%
Thermal Mass (J/m³ K)	11	37%
Absorptance	11	37%
Solar Heat Gain Coefficient	16	53%
Visual Light Transmittance	14	47%
Other	4	13%

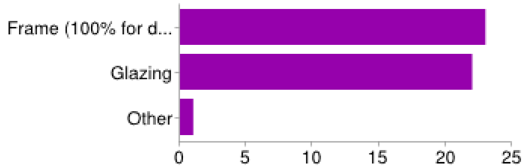
8.2 Do you think it is helpful to know the composition and its characteristics of the Window/Door for a energy efficient building design and energy performance evaluation?



Response	**No.**	**%**
Yes	23	77%
No	4	13%

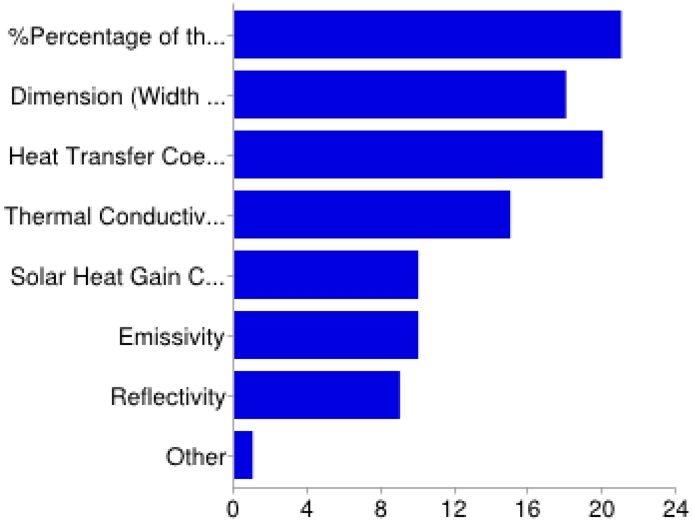
9. Composition Information and detail of the Window/Door

9.1 Components of a window/Door need to be detailed in the building design



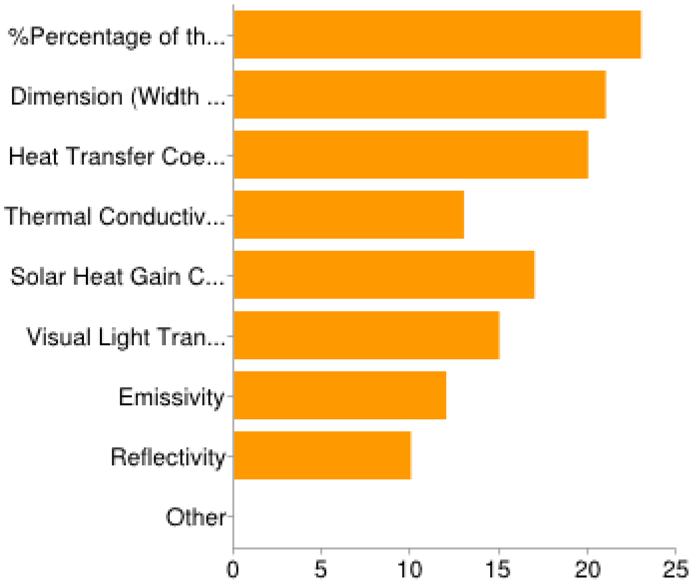
Components	**No.**	**%**
Frame (100% for doors)	23	77%
Glazing	22	73%
Other	1	3%

9.2 Please Check the data that you consider relevant for the FRAME of Window/Door



Parameters	No.	%
%Percentage of the Frame (100% for doors)	21	70%
Dimension (Width * Height)	18	60%
Heat Transfer Coefficient - U (W/m2K)	20	67%
Thermal Conductivity (W/m·K)	15	50%
Solar Heat Gain Coefficient	10	33%
Emissivity	10	33%
Reflectivity	9	30%
Other	1	3%

9.3 Please Check the data that you consider relevant for the GLAZING of Window/Door



Parameters	**No.**	**%**
%Percentage of the GLAZING (0% for Doors)	23	77%
Dimension (Width * Height)	21	70%
Heat Transfer Coefficient - U (W/m2K)	20	67%
Thermal Conductivity (W/mK)	13	43%
Solar Heat Gain Coefficient	17	57%
Visual Light Transmittance	15	50%
Emissivity	12	40%
Reflectivity	10	33%
Other	0	0%