OptEEmAL

OPTIMISED ENERGY EFFICIENT DESIGN
PLATFORM FOR REFURBISHMENT
AT DISTRICT LEVEL

Optimised Energy Efficient Design Platform for Refurbishment at District Level
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D3.1: Requirements and specification of the ECMs catalogue

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Abbreviations and Acronyms

Acronym	Description
BIM	Building Information Modelling
BPIE	Buildings Performance Institute Europe
CHP	Combined Heat – Power Plant
DBMS	Database Management System
DDM	District Data Model
DHW	Domestic Hot-Water Systems
DPI	District Performance Indicator
ECM	Energy Conservation Measures
ETICS	External Thermal Insulation Composite Systems
GBPN	Global Buildings Performance Network
HVAC	Heating Ventilation Air Conditioning
IFC	Industry Foundation Classes
IPCC	Intergovernmental Panel on Climate Change
IQ	Information Quality
OptEEmAL	Optimised Energy Efficient Design Platform for Refurbishment at District Level
PV	Photovoltaic
PVPS	Photovoltaic Power Systems
RES	Renewable Energy Source
UPS	Uninterruptible Power Supply

Executive Summary

The OptEEmAL Platform will base the formulation of candidate scenarios for energy efficiency improvement in an advanced catalogue of solutions (Energy Conservation Measures catalogue: ECMs). In this document it is presented how this ECMs catalogue affects to the different tasks in the project and how this ECMs catalogue will help to the development of all the objectives of the project.

The principal objective of this document is the development of an Energy Conservation Measures (ECMs) catalogue containing technical, operational, maintenance and cost information about existing ECMs as passives, actives, hybrid, local Renewable Energy Sources (RES) and control strategies.

For illustrating the needs of the catalogue in a holistic manner the document has been structured to cover all the aspects that are related to the catalogue, like the different requirements and data needed to develop the catalogue in a correct and useful way.

There are many types of requirements to analyse in order to create a structure for the ECM catalogue. In the next points there will be analysed different data requirements and how those affect to the application of the different ECMs and how they should be stablished in order to comply with the formulation, evaluation, optimization and completion of scenarios. To achieve the correctly function of the ECMs catalogue data quality, interoperability and implementation requirements will be described.

As said before, different types of information (energy, environmental, social, economic, etc.) will be presented in the ECM. One of the achievements of this document will be the analysis of available existing data bases. The purpose of this section is to describe where the information that will be contained in the ECM catalogue will be taken from and to initiate the next section which will deal with the connection with the selected existing databases. A state-of-the-art of existing databases will be also provided.

After the definition of the different requirements, the structure of the different refurbishment strategies will be defined taking into account the direct influence of the strategy implementation. The catalogue will be structured based on different criteria as general and technical Data or the implementation of each ECM and the calculation of each DPI.

After the analysis of requirements, several important issues and problems will be determined and as possible solution, diverse possibilities for the implementation of the ECMs catalogue taking into account the requirement analysis previously done will be presented.

The strategies stored in the ECMs catalogue should contain all the information needed by the OptEEmAL platform, it has to contain a representative quantity of refurbishment strategies and these strategies have to be complete and accurate enough to obtain a good quality in the results. The ECM catalogue is explained in the last points of this document explaining through different examples that contain technical, operational, maintenance and cost information in passives, actives, hybrid, local Renewable Energy Sources (RES) and HVAC control strategies.

For assuring the quality of the catalogue, also possible maintenance is studied in this document.

1 Introduction

1.1 Purpose and target group

The purpose of this document is the analysis of the requirements and requisites to develop an Energy Conservation Measures (ECMs) catalogue that will contain technical, operational, maintenance and cost information about existing ECMs. Among them we can find passives, actives, hybrids, local Renewable Energy Sources (RES) and control strategies. These requirements will also serve to present the expected functionalities that will serve as foundations for the realization of the catalogue itself.

1.2 Contributions of partners

The following Table 1 depicts the main contributions from participant partners in the development of this deliverable.

Table 1: Contribution of partners

Participant short name	Contributions
CAR	Part of the content of sections 2, 3, 4 and 6: -In conjunction with Acciona, ECMs catalogue objectives -ECMs interoperability and implementation requirements -In conjunction with Nobatek, analysis of available existing data bases -ECMs catalogue technology -ECMs exchange format
TEC	Part of the content of sections 3, 5, 6 and 7: -In conjunction with Cartif, ECMs data requirements -ECMs formalisation: taxonomy, strategies and structure -ECMs catalogue data insertion and data modelling -ECMs catalogue content: active strategies and RES integration
UTRC-I	Contributions to section 7 (ECMs catalogue content): HVAC control strategies
ACC	Leader of the task and deliverable Part of the content of sections 1, 2, 3, 6, 7,8 and 9: -Introduction -In conjunction with Cartif, ECMs catalogue objectives -In conjunction with Cartif, ECMs data quality control requirements -ECMs catalogue exchange format: implications of dynamic links -ECMs catalogue content: passive strategies -Initial guidelines for the maintenance of the catalogue -Conclusions

1.3 Relation to other activities in the project

The following Table 2 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the OptEEmAL project and that should be considered along with this document for further understanding of its contents.

Taking into account that D3.1 collects the requirements for the ECM catalogue, that is, what is the functionality to be covered by this element, the current document will provide the guidelines for the future analysis, design, implementation, deployment and operation of the catalogue within the OptEEmAL tool. Therefore, this document is closely related to the other tasks and deliverables in WP3, providing the key information for the future development of the catalogue. Concretely, this document interacts and/or affects the following deliverables:

Table 2: Relation to other activities in the project

Deliverable Number	Contributions
D2.1	This deliverable will define the requirement that have to be met by the District Data Model (DDM), which includes local information capturing ECMs specifications and ECMs cost
D2.2	During this document will be selected the District Performance Indicators which will be used to formulate multi-objective optimization of scenarios. The calculation of these DPIs will have a direct influence in the structure of the ECMs catalogue
D3.2	This deliverable will transform the ECMs catalogue in a wide BIM's Library that will be a collection of BIM ECMs containing the necessary information to generate the OptEEmAL scenarios by cross relation with the diagnosis data.
D3.3	In this document the ECMs catalogue data base will be developed by the use of BIM facilities with the information content that defines the product.
D3.4	For concluding the materialization of the catalogue, a testing phase will be made following the path given by this document.
D4.1	In order to define the specifications of the optimisation algorithm, will be necessary that the ECMs catalogue structure makes possible the definition of the necessary calculation parameters
D4.4	This document will provide information for the evaluation of the different retrofitting scenarios generated. These scenarios will be based on ECMs catalogue. Therefore, the connection between the simulations and ECMs catalogue will be direct

2 ECMs catalogue objectives

The OptEEmAL Platform will base the formulation of candidate scenarios for energy efficiency improvement in an advanced catalogue of solutions (Energy Conservation Measures catalogue: ECMs) compliant with the District Data Model. Conventional and innovative solutions will be integrated in a BIM data base. Technical, operational, performance, maintenance and cost requirements are included, as well as their synergies. A data imputation and integrity plan will be proposed to ensure data quality, consistency and reliability, enabling the adequate scenarios formulation and optimization.

The Energy Conservation Measures catalogue is one of the main features implemented in the OptEEmAL platform as it sets the basis for the calculation of scenarios by applying a series of conventional and innovative solutions both at building and district level. This catalogue will be fulfilled with existing data sets containing information about materials and equipment, and will include a wide range of measures to reduce the district energy demand and consumption through passive, active, local RES integration and control strategies measures.

This catalogue will provide the key information for the generation of applicable scenarios, overcoming the existing barriers in the district and being compliant with user objectives in terms of efficiency improvement, cost constraints, financial schemes, etc. The specifications about the implementation of the measures will also be included, as well as relevant information to cover the further steps within the value chain: execution, maintenance and operation. High-quality outputs (e.g. building operation and maintenance strategies, implementation schedule, etc.) are expected at the end of the design process.

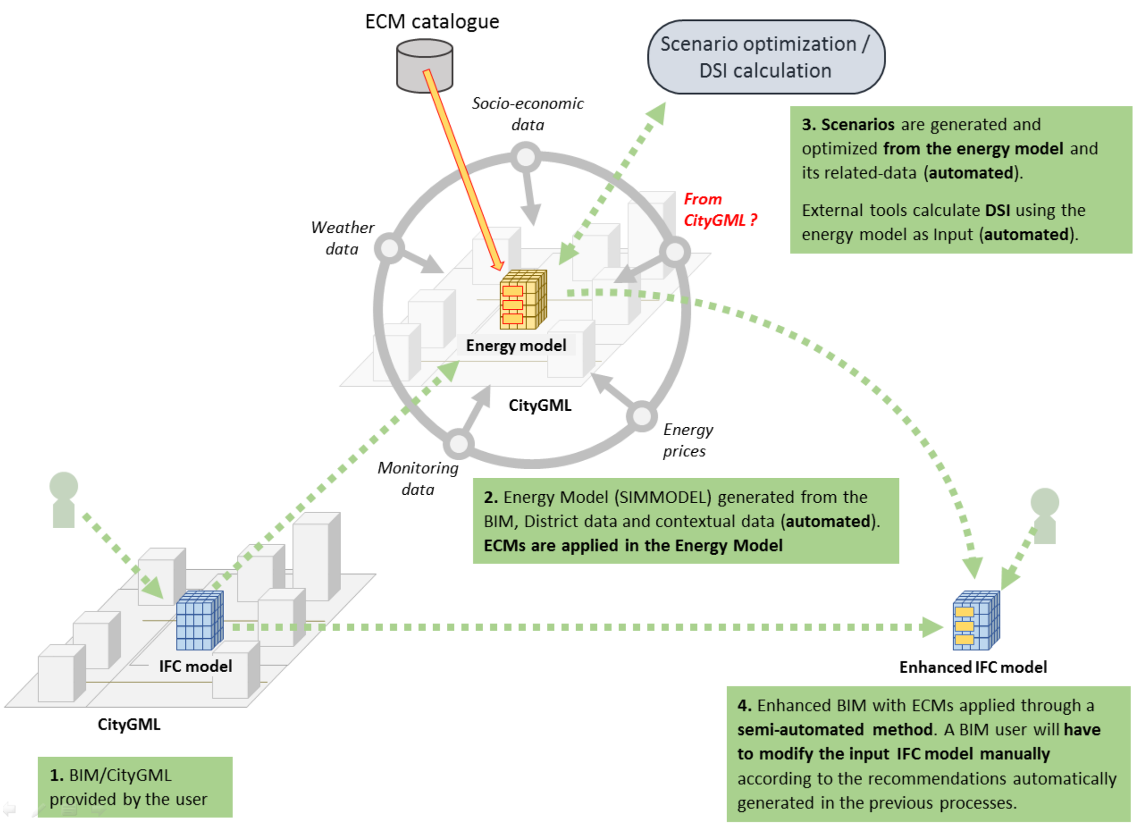


Figure 1 Scenario generation processes and optimisation

For the creation of the ECMs catalogue, a table of strategies that contains information about materials and equipment will be used. For this purpose, knowledge collection from existing projects for retrofitted district and building will support the generation of the catalogue, with measures already validated in other projects. The catalogue will include a wide range of strategies to reduce the district energy demand and consumption through passive, active, local RES integration and control strategies measures.

The ECMs catalogue will provide the most important information for the calculation and the generation of the models for the different scenarios, being compliant with the user's goals in the terms the user will define, taking into account the targets, barriers and boundaries. Due to the performance calculations of the generated scenarios that will be made in diverse levels (energy, environmental, social, economic level…) different types of information have to be included in the ECMs catalogue.

Besides, the information stored in the catalogue should cover all the aspects needed for the right operation of the platform related with the ECMs: the selection of the strategies to implement in the district to renovate, the evaluation of the different scenarios created through the implementation of EMCs (individually and combined) and the completion of the information in the final stage. In this sense, the information about each ECM will be heterogeneous and should be complete enough: general information about the strategies, technical information (energy, environmental, economic and social data) to run simulation models, and information for design purposes and for the operation of the renovated district and/or building.

In the following section 3, the technical requirements to comply with these objectives will be analysed.

3 ECMs technical requirements

During the design lifetime of a refurbishment project within OptEEmAL, the EMCs Catalogue will be queried in, at least, three different stages to comply with the different objectives of the platform. These steps will be used in order to structure the different technical requirements needed for the ECMs catalogue. Concretely the steps where the catalogue is requested are:

1. In the first query, the platform would ask for the possible ECMs that could be applied in the initial scenario, and basic information to be shown in the "check strategies" step. For this query, the targets, barriers and boundaries will be analysed in order to select the most adequate measures for the project.
2. In the second one, the platform would ask for all the parameters required to generate and run the simulation models from those ECMs previously accepted by the end-user. The simulation models include not only the energy simulation but also those with economics or environmental calculations, or any calculation needed to evaluate the performance of each scenario.
3. The third time for querying the ECMs catalogue would be in the last part of the process, when more data are required to complete the information of the finally selected scenario, to export the refurbishment design and provide the complete information to the user.

The data required in each step will be different due to the fact that the information will be used in a different way in each stage. The platform, in its queries, will ask the information needed every time. In general, the concreteness and level of detail of the information consulted to the ECM will depend on the phase of the project design, as explained before.

Within this context, this section aims to provide a list of requirements of the ECMs catalogue from different points of view. First of all, requirements related to the input and outputs of data are identified. After that, those related to the quality control data and also with data imputation are listed. The next subsection shows the necessities of the ECMs catalogue regarding the structure and the representation of the data within the catalogue. Later it is identified the list of requirement related to the communication with the OptEEmAL tool and external modules, i.e., the interoperability requirements. Finally, the implementation requirements regarding the main components of the catalogue and other non-technical requirement are exposed.

3.1 Data requirements

For this section, there is going to be used the kind of users that have been explained in the deliverable "*D1.2 - Requirements and specification of input data process to evaluate users objectives and current conditions*".

The OptEEmAL solution will query the ECMs catalogue in different steps of its operation, as for example to show chosen strategies to the end users, to create feasible scenarios, to optimise these scenarios, to modify the simulation models and to create the enhanced BIM as output of the complete design process.

In every situation the data required to the ECM catalogue is different, and in that sense different data requirements can be defined. The following table reflects these data requirements.

Table 3: data requirements

Req. Identifier	Description
R3.1.1	In the process of providing feasible strategies (applicable ECMs for the formulation of scenarios), the ECM catalogue should contain the appropriate information to define, in

	a very generic way, the specific ECM of applicability, including a general description and basic parameters showing the implications of this measurement (cost per m2, modifications required, etc.).
R3.1.2	In order to facilitate the previous search of appropriate and applicable ECMs, the ECM catalogue should contain specific information regarding boundaries and barriers (building and district level) that would help in the filtering process (i.e. if the ECM can be or not applied in an historical building). These characteristics will stand as ECM constrains (i.e. some ECMs cannot be installed or their parameters and/or quantity will be restricted).
R3.1.3	In the process of generating scenarios, the ECM catalogue should contain specific energy, environmental, economic, etc. parameters useful to create and run different simulation models. Within this context, the Scenarios Generator will query the ECMs catalogue to check the codification, the functional unit, the constraints' rules and the boundaries' rules to create feasible scenarios.
R3.1.4	In the process of optimising scenarios, the ECM catalogue should contain the previous specific energy (e.g. thermal resistance), environmental (e.g. production impact), economic (e.g. installation cost), etc. parameters needed to feed the building and district simulation models. Within this context, the Optimisation Module will query the ECM catalogue to obtain this information.
R3.1.5	In the process of exporting the final optimal scenario (chosen by the end-user), the ECM catalogue should contain the appropriate information to extend the information of each ECM in order to create the enhanced BIM for each refurbished building.
R3.1.6	In general terms, and regarding the accessibility of the information contained in the ECM catalogue, a GUI should be developed to allow to the end users checking the ECMs. This GUI must allow the visualization of all the parameters defining each ECM. Pending to define, within the architecture of the Platform, if this GUI will be accessible in all the STEPs and if it will allow modifying existing parameters or including new ECMs. At least, this GUI should be accessible to the end users to reject non-applicable ECMs and to check the optimised scenarios.

3.2 Data quality control requirements

The following section is based upon the work made by Felix Naumann, Claudia Rolker in their publication called "*Assessment Methods for Information Criteria*".[01]

When dealing with quality control, there are several difficulties. Among then you can find:

- Information Quality (IQ) criteria are often of subjective nature and can therefore not be assessed automatically.
- Information sources usually are autonomous and often do not publish useful (and possibly compromising) quality metadata. Additionally, many sources take measures to hinder IQ assessment.
- The enormous amount of data to be assessed impedes assessment of the entire information set. Thus sampling techniques are often necessary which decrease the accuracy of the assessed scores.
- Information from autonomous sources is subject to sometimes surprising changes in content and quality.

For measuring the quality of data, a common list of characteristics is represented in the next table:

Table 4 Classification of IQ Metadata Criteria, from "Assessment Methods for Information Quality Criteria"

Assessment Class	IQ Criterion	Assessment Method
Subject-Criteria	Believability Concise representation Interpretability Relevancy Reputation Understandability Value-Added	User experience User sampling User sampling Continuous user assessment User experience User sampling Continuous user assessment
Object-Criteria	Completeness Customer support Documentation Objectivity Price Reliability Security Timeliness Verifiability	Parsing, sampling Parsing, contract Parsing Expert input Contract Continuous assessment Parsing Parsing Expert input
Process-Criteria	Accuracy Amount of data Availability Consistent representation Latency Response time	Sampling, cleansing techniques Continuous assessment Continuous assessment Parsing Continuous assessment Continuous assessment

In the case of the OptEEmAL project the data quality requirements represent the specifications desired for the data to be used within the ECMs catalogue, in this case, the degree of detail, availability, accuracy, coherency, completeness and persistency of the data used in the generation, operation and maintenance of the ECM catalogue. For these data, several data quality requirements are initially identified:

Table 5: data quality control requirements

Req. Identifier	Description
R3.2.1	The input data for the ECM catalogue should be sufficiently complete and accurate before being introduced into the catalogue.
R3.2.2	The input data of the ECM catalogue should be stored in a persistent repository in order to have them available during the catalogue operation.
R3.2.3	The input data of the ECM catalogue (when numerical information with measurements units is managed) should be represented using the International Units.
R3.2.4	The same type of information should be represented in the same format (integer, float,

	double, number of decimals, separator, etc.) and using the same measurement units.
R3.2.5	The input data of the ECM catalogue should be normalised (when needed) in order to facilitate the query.
R3.2.6	The content of the ECM catalogue should be stored in a persistent repository in order to guarantee their recovery.

3.3 Interoperability requirements

The ECMs catalogue should satisfy certain interoperability requirements in order to ensure the right communication and understanding with other internal and external elements of the OptEEmAL solution.

The following table reflects the interoperability requirements.

Table 6: Interoperability requirements

Req. Identifier	Description
R3.4.1	The ECMs catalogue should take into account the District Data Model (DDM) developed in the OptEEmAL project. The DDM will be used as the common scheme to ensure the interoperability at syntactic and semantic levels. Therefore, the ECM catalogue should comply with the common DDM defined in the project
R3.4.2	The ECMs catalogue should allow the communication with the platform (element compiling a set of modules and functionalities), and offer the information required. For that aim, the ECMs catalogue should complain with the appropriate interfaces to guarantee the communication with the OptEEmAL platform. These interfaces should allow the communication with the ECMs catalogue at least in three processes during the lifetime of a refurbishment project. The processes in which the communication between the platform and the catalogue is needed are: • The *Selection of ECMs* process should be able to communicate (read access) with the catalogue. • The *Generation Scenarios* process should be able to communicate (read access) with the catalogue. • The *Completion Information* process should be able to communicate (read access) with the catalogue. For this purpose the ECMs catalogue should provide a protocol for the communication that the interfaces of these processes have to implement.
R3.4.3	The ECMs catalogue should be an element mainly passive regarding the platform: it will only offer information and it will not be able to start or launch a query to the platform by itself.

3.4 Implementation requirements

Other requirements should be also satisfied for the correct operation of the ECMs catalogue, in this case more related to how this catalogue would be implemented and what technical and non-technical considerations have to be considered, such us security requirements, access control and other non-technical requirements.

Requirements related to the implementation are specified in the following table:

Table 7: Implementation requirements

Req. Identifier	Description
R3.5.1	Security and user management: the ECMs catalogue should offer an authentication service in order to avoid non-desired queries or updates, and also to manage permissions. The ECMs catalogue should offer different access according to the privileges of a user. At least three types of users are envisaged for the catalogue: • *Catalogue administrators* should administrate the privileges of the users, thus he/she should be able to manage (create, delete, modify) users and their privileges. • *ECMs catalogue Users* should manage the catalogue, thus he/she should be able to read, write, modify and delete information about the ECMs. • *Catalogue users* should be able to read the information about ECMs.
R3.5.2	Security: the repository/repositories containing the ECMs catalogue should be physically inaccessible to non-authorized users by placing it in a secure physical environment.
R3.5.3	The ECMs catalogue should adopt and use open standards, if possible
R3.5.4	The ECMs catalogue should respond in a limited time, i.e., with a limited time response that has to be determined
R3.5.5	The ECMs catalogue should provide service near 100% of time. Two main measures are proposed in order to achieve this: • Minimize the time for certain operations that leave the system offline, like maintenance tasks, software and hardware reboots, updates, reparations, etc. For this purpose, it is necessary to plan these actions carefully. • Provide mechanisms to early detect possible failures that could crash the system.
R3.5.6	The ECMs catalogue should implement a fail-recovery mechanism for lost data and communication failures. The procedures to recover from a failure could be: • Backup service for the data executed regularly. • Usage of a UPS to save the system variables, status and data in case of power failure.
R3.5.7	The ECMs catalogue should allow adding new ECMs in an easy way, in order to extend the solutions offered by the platform. Only *ECMs catalogue User* should be authorised to add new measures to the catalogue.
R3.5.8	The ECMs catalogue should allow removing ECMs in an easy way, in order to eliminate the obsolete solutions offered by the platform. Only *ECMs catalogue User* should be authorised to remove measures to the catalogue.
R3.5.9	The ECMs catalogue should allow modifying the information of the ECMs in an easy way, in order to update the solutions offered by the platform.

	Only *ECMs catalogue User* should be authorised to modify measures to the catalogue.
R3.5.10	Taking into account the different types of information to be stored into the catalogue (and identified in the data requirements) different types of repositories should be implemented for the catalogue. For instance: - A relational database to store textual and numerical information - A BIM server to store IFC pieces of code representing different ECM - Others? The communication with the different repositories should be guaranteeing by implementing the appropriate interfaces.
R3.5.11	The catalogue does not need to be physically located in a unique and centralized data server. The catalogue can be offered as a distributed service depending on the types of repositories it needs to operate.

4 Analysis of available existing data bases

The ECM catalogue, that will be part of the OptEEmAL platform, will contain technical information about the different energy conservation measures proposed in the OptEEmAL platform. This technical information is all information needed for the calculation that will be performed in the platform and in particular the platform's DPIs. As a consequence, and as described before in this document, different types of information (energy, environmental, social, economic, etc.) will be presented in the ECM.

The purpose of this section is to describe where the information that will be contained in the ECM catalogue will be taken from and to initiate the next section which will deal with the connection with the selected existing databases. To do so, this section first presents a state-of-the-art of existing databases and then assesses the interest of the these databases for their inclusion in the OptEEmAL ECM catalogue as well as the possibility to establish direct connections between these databases and the ECM catalogue.

4.1 State-of-the-art of existing databases

The state-of-the-art of existing databases is provided in the Table 8.

Table 8: State-of-the-art of existing databases

Name	Source	Brief description	GR[1]	TR[2]	Example of data available
Facade Retrofits Database	http://facaderetrofit.org/	Using a query based on different characteristics (Country, Year, Typology, Performance Level, etc.), this database allows to get general information about renovated building, mainly regarding building envelope.	Mainly US	2015	Technology used for facade retrofitting Name of facade consultant
BPIE Data Hub for the Energy Performance of Buildings	http://www.buildingsdata.eu/	A comprehensive knowledge repository for statistics and policy information on Europe's building stock, the Data Hub introduces a data search engine that allows for cross-country comparisons, generation of customised country profiles and cost-free downloads.	EU	2016	Building stock distribution by age band per country Energy consumption levels by building types and age groups per country U-values for wall, roof, floor, windows for different building types per country Economic and market instruments per country
ENTRANZE database and web tool	http://www.entranze.enerdata.eu/	It contains an in-depth presentation of the structure of buildings and related energy systems in EU-27 (+Croatia and Serbia); some trends are given as to the dynamics of some technologies. The data-mapper is composed of five main sections, each composed of several indicators (25 indicators in total): All buildings, Residential buildings, Non-residential buildings, Heating/AC systems, Energy use.	EU	2016	Weighted average U-values per country and per building element (floor, wall, ceiling, window) Ownership distribution for residential buildings per country
EPISCOPE project database	http://episcope.eu/monitoring/episcope-tool/	The EPISCOPE tool is an interactive and user-friendly website that provides a comprehensive overview of all project results for 20 European countries (including: Bulgaria, Poland and Sweden that participated in the TABULA project). Related to the BPIE Data Hub (see above)	EU	2015	Building insulation improvements level per building elements and per countries (not available for all EU countries). Main energy carriers distribution for space heating, DHW production per countries (not available for all EU countries) [Details on used technologies available in pdf reports]

[1] Geographical representativeness

[2] Temporal representativeness

BINE Information Service	http://www.bine.info/en/topics/buildings-city/refurbishment/	BINE Information Service reports on energy research topics, such as new materials, systems and components, as well as innovative concepts and methods. The knowledge gained is incorporated into the implementation of new technologies in practice, because first-rate information provides a basis for pioneering decisions, whether in the planning of energy-optimised buildings, increasing the efficiency of industrial processes, or integrating renewable energy sources into existing systems	Mainly DE	2016	BINE information service is not a real database containing information in a standardised format. However, interesting information about retrofitting technologies can be found.
Low Energy Building Database	http://www.lowenergybuildings.org.uk/	Repository of low-energy building information created to help inform the planning and development of low energy new build and refurbishment	Mainly UK	2016	Detailed description of retrofitting strategies (qualitative). Quantitative information available in pdf reports
CONCERTO TMD	http://www.smartcities-infosystem.eu/concerto/concerto-tmd-database	The purpose of this tool is the context-oriented visualization of building and energy supply unit indicators. Through the representation of these indicators, the tool facilitates the assessment of the impact of various energy efficiency measures and building features on buildings. Buildings or energy supply units can be compared with each other with respect to their energy performance and efficiency, or with respect to the effectivity and efficiency of applied measures.	EU	2015	Economic indicators (capital cost per m^2, costs of adopted energy saving measures, etc.) Economic-environmental indicators (Emission abatement costs) Environmental indicators (CO_2 emissions) Technical indicators (final energy demand reduction per m^2)
RetScreen	http://www.retscreen.net/ang/home.php	Decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free-of-charge, can be used worldwide to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). The software (available in multiple languages) also includes product, project, benchmark, hydrology and climate databases, a detailed user manual, and a case study based college/university-level training course, including an engineering e-textbook.	CANADA, worldwide	2014	Evaluation of energy production Financial viability and risk of RES Databases of products, projects, benchmarks, hydrology and climate.

BIM object	https://BIMobject.com/en	BIM object catalogue based on real products. They work together with the product manufacturers and build the digital products as close to the physical AEC product possible both for 3D representation and with the correct product data and properties. Products from various sectors and industries are to be found, but they are all tailored to be used for BIM.	Sweden, EU	2015	Classification of materials and products and available to download in BIM, SKP files, CAD...
Mc Graw Hill Sweets	http://sweets.construction.com/	Online database which classifies materials according to several categories and is compliant with the Master Format classification of building materials proposed by CSI (Construction Specifications Institute), which aims for the standardization of construction language.	US/worldwide	2016	Comprehensive product information, CAD details, BIM objects, specs, catalogues, galleries, green product information, CEUs and more.
Arcat	http://www.arcat.com/	Leading online resource of FREE building product information. No registration is required. Most extensive and up to date specification library. ARCATgreen reports LEED credits for the building project and materials. The ARCAT BIM library has thousands of data-rich BIM objects and systems, all available in RFA, RVT, DWG, and other formats. The ARCAT e-Directory is an online publication of hundreds of building products.	US	2016	Classification of materials and products and available to download in BIM, CAD, specs, catalogues and product brochures...
SEEDs catalogue	http://www.seeds-fp7.com/documents/Deliverables//SEEDS_D1.1_Methodology_for_the_modelling_of_BEMS_r0.pdf	The project devotes its attention to improving energy efficiency in new and existing buildings, which encompasses the most diverse, largest and most cost-effective mitigation opportunities in buildings. Such an energy consumption reduction will be achieved with the development of ICT tools for the management of energy use in buildings and open spaces. Therefore, what it is to be found here are mainly control systems for technical equipment and accurate description using certain parameters (annex A-B).	EU	2015	Classification of technical equipment used in buildings.
ODYSEE-MURE	http://www.odyssee-mure.eu/	Online database that provides global information about countries in several categories: macro, industry, households, transport and services. (ODYSEE). MURE is a database that focuses on policies and measures countries have undertaken or are undertaking and their degree of success.	EU	2016	ODYSEE: Consumption per dwelling, heating consumption, energy intensity. MURE: policies whose targets are related to, for example: hot water consumption, electricity, total final consumption...

4.2 Evaluation of existing databases of interest for the ECM catalogue

Table 9: Potential interest of existing databases for the ECM catalogue and other platform aspects

Name	Source	Potential interest for OptEEmAL ECM catalogue	Possibility to create a link with the ECM catalogue	Other potential interest for the OptEEmAL platform
Facade Retrofits Database	http://facaderetrofit.org/	**Low** Verify the completeness of the ECM catalogue in term of proposed measures	No	**No**
BPIE Data Hub for the Energy Performance of Buildings	http://www.buildingsdata.eu/	**Low** Available data are not related to a technology but to a building (insufficient level of details)	No	**Medium** Can be used to assess the district current conditions
ENTRANZE database and web tool	http://www.entranze.enerdata.eu/	**Medium** Available data are not related to a technology but to a building (insufficient level of details)	**Yes**	**Medium** Can be used to assess the district current conditions
EPISCOPE project database	http://episcope.eu/monitoring/episcope-tool/	**Medium** Available data are not related to a technology but to a building	**Yes**	**Medium** Can be used to assess the district current conditions
BINE Information Service	http://www.bine.info/en/topics/buildings-city/refurbishment/	**Low** Can be used as a complementary source but not structure as a database	**No** Not a "real" database	**No**
Low Energy Building Database	http://www.lowenergybuildings.org.uk	**Medium** Interesting information but available in pdf format	**Yes – Difficult** Link with pdf where quantitative info is difficult to obtain.	**No**

CONCERTO TMD	http://www.smartcities-infosystem.eu/concerto/concerto-tmd-database	**Medium** Overall influence of different refurbishment applications	**Yes**	**Medium** Can be used to assess the district current conditions
RetScreen	http://www.retscreen.net/ang/home.php	**Medium** Detailed information available per retrofitting strategy	**Yes**	Databases related to climate, etc
BIM object	https://BIMobject.com/en	**Medium** Detailed BIM information available per some refurbishment strategies	**Yes**	**No**
Mc Graw Hill Sweets	http://sweets.construction.com/	**Medium** Detailed BIM information available per some building product and systems	**Yes**	**No**
Arcat	http://www.arcat.com/	**Medium** Detailed BIM information available per some building product and systems	**Yes**	**No**
SEEDs catalogue	http://www.seeds-fp7.com/documents/Deliverables//SEEDS_D1.1_Methodology_for_the_modelling_of_BEMS_r0.pdf	**Medium** Interesting information but available in pdf format	**Yes – Difficult** Link with pdf report where quantitative information is difficult to obtain.	**No**
ODYSEE-MURE	http://www.odyssee-mure.eu/	**Low** Can be used as a complementary source for other parts of the project but not directly ECM catalogue.	**No**	**Medium** Can be used to assess the district current conditions

5 ECMs formalisation

This section will cover the formalisation of the catalogue according to the previous requirements in section 3, in order to address them.

5.1 Taxonomy of the strategies

The taxonomy of the strategies will be defined by seven different families:

Table 10: Strategy types families

STRATEGIES	
Object of intervention	The end users determine the initial objectives of the refurbishment. Each stakeholder or end user of the platform has the option to select the DPIs to be evaluated and optimised.
Strategy	Identification number and name of the ECM According to the initial objectives, barriers of each district, potential use of the strategies... the end user of the platform has the possibility to select one or more ECM strategies.
Functional Unit	Measurement unit used to define the technical characteristic of the ECM After selecting the different strategies, OptEEmAL will define automatically the functional unit for each of them. Due to the internal calculation methodology of OptEEmAL, the end user will not have possibility to edit this unit.
Quantity	Each scenario determines the optimized quantity of the ECM This section will make possible to define the quantity of each refurbishment strategy. For this purpose, OptEEmAL proposes two possibilities. The first one, the "easy" option, makes possible the definition of the amount of that strategy manually according to its functional unit. On the other hand, through the interface, the second option proposes to select what you want to rehabilitate and automatically the platform quantifies the "quantity" of each strategy.
Ontology	According to the strategy, functional unit and quantity, OptEEmAL will generate automatically an ontology or code per each of the strategies. This ontology will harmonize the working process within the tools and applications from the OptEEmAL platform.
Properties	According to the end user profile and step of the refurbishment project, OptEEmAL platform will show different technical properties of the ECM
Geometric information (visual interface)	All the ECMs will be in BIM format. Therefore, the GUI (Graphical User Interfaces) will make possible the visualization of each ECM

5.2 Refurbishment strategies of the OptEEmAL ECMs catalogue

The structure of the different refurbishment strategies will be defined by the following criteria. First they are divided by the direct influence of the strategy implementation. Thus, three general groups are distinguished: (1) strategies that improve the thermal properties of the building envelope, (2) strategies that improve the heating, cooling and domestic hot water system. Within each group, OptEEmAL proposes different criteria of definition of refurbishment strategies:

1- The building envelope strategies are differentiated by different levels: location, kind of strategy and efficiency level.
2- Heating-cooling and DHW system strategies are differentiated by different energy generation systems (efficient and renewable), definition of distribution losses and control systems.

Detailed information for every strategy can be found in the following Table 9.

Table 11: Strategy types families

Refurbishment strategies of the OptEEmAL ECM				
Building envelope	A-Envelope	A1-External	A1.1-Ventilated facade	
			A1.2-SATE	
		A2-Internal	A2.1-Floor	
			A2.2-Wall	
			A2.3-Roof	
		A2-Internal		
		A3-Air chamber insulation		
	B-Windows			
Space Heating and Cooling / Domestic Water Heating Systems	Energy generation system	High efficient boiler (natural gas)	Different generation powers	
		Condensation boiler (natural gas)		
		Biomass boiler		
		Combined heat power (natural gas engine)		
		Combined heat power (gas turbine/micro turbine)		
		Combined heat power (steam turbine)		
		High efficient chiller (electricity)		
		High efficient heat Pump		
		Solar thermal collectors	Flat collector	
			Tube collector	
		Photovoltaic collectors	Mono-crystalline	
			Multi-crystalline	
		Geothermal		
		District Heating*		
		Energy Exchange within the district	Energy generation	High efficient boiler (natural gas)
				Condensation boiler (natural gas)
				Biomass boiler
				Geothermal
				Solar thermal collectors
				Photovoltaic collectors
			Energy Storage	Water tank
				Phase change materials units
			Distribution	Length (m or km)
	Reduction of losses	Thermal insulation of the pipes		
	HVAC Control system	Regulation of the heating and/or cooling systems	System Scheduling	
			Optimal Start-up and Shut-down	
			Optimization Based Control	Energy Based
				Cost Based
				Emission Based

5.3 ECMs catalogue structure

The following table shows the first version of the structure of the ECM catalogue. The catalogue will be structured based on different criteria. On the one hand, the rows are grouped into two different groups: General and Technical Data. Within each, different data will be defined, enabling the assessment of the impact of the implementation of each ECM and the calculation of each DPI.

Moreover, the columns provide different information about each of the data defined within the general and technical data. This information is grouped in 5 families:

1- Information related to each generic or technical data. Export to E+: In order to perform the energy calculations, part of this information will be exported to Energy Plus software. This column defines which data will be exported and which not.
2- Export to NEST: In order to perform the environmental calculations, part of this information will be exported to NEST software. This column defines which data will be exported and which not.
3- Export Optimization: In order to optimize refurbishment strategy, part of this information will be exported to optimization module. This column defines which data will be exported and which not.
4- Comment: The information of this column defines some comments related to each of the general and technical data. During this first phase there are still sections that have not been fully defined. Therefore, this column defines aspects related to the difficulty of the definition of each parameter, the calculation process, different calculation options…

Table 12: ECMs catalogue structure

				Export to E+	Export to NEST	Export Optimisation	Comment
Generic data	Description	[text]		NO	NO	NO	
Generic data	Application	[text]		NO	NO	NO	
Generic data	Limits	Historic building	[YES or NO]	NO	NO	YES	Answer "YES" --> impossible to apply in protected buildings --> direct relation with "optimization algorithm"
Generic data	Advantages	[text]		NO	NO	NO	
Generic data	Disadvantages	[text]		NO	NO	NO	
Generic data	Social acceptation	[text]		NO	NO	NO	
Generic data	Constraints	[text]		NO	NO	YES	
Generic data	nº of jobs / FU	nº		NO	NO	YES*	Export to the optimization algorithm when the objectives are related to impact indicators such as nº of jobs
Technical data	Energy data	Thermal resistance [(m2*K)/W]	[numeric value]	YES	NO	NO	Required input for "Building envelope" refurbishment strategies. This value will be exported to E+ to obtain refurbished buildings new energy demand values.
Technical data	Energy data	Energy performance [%]	[numeric value]	NO	NO	NO	Required input for "Improvement of the energy generation system" refurbishment strategies.

		Energy generation	[algorithm]	YES	YES	NO	Reflect on how it will be calculated by OptEEmAL. Options: **1**-Defining (or drawing) the inclination and orientation of collectors in OptEEmAL --> this data will be **exported to E+** --> calculate the energy generation by 1 square meter of solar thermal or photovoltaic collector in E+ **2**-Use of **NEST** to calculate these values. Due to the limitation of the information, by NEST could be only possible to quantify the energy generation value in France and Spain --> **problem** **3**-Develop an **OptEEmAL algorithm** to calculate the energy generation by 1 m² of solar thermal or photovoltaic collector
	Environmental data	Production impact (A1-3)	[X impact /unit]	NO	**From NEST**	NO	_ --> the **ontology**, due to the reference generated by OptEEmAL and the one of the NEST database **MUST be the same** _Which **life cycle stages** will be assessed into the embodied environmental impact? Only the Product stage? → According to the results obtained by the Thesis of Xabat Oregi, the environmental influence of the construction process, end of life stages and maintenance is less than 5% of the final results
		Installation impact (A5)	[X impact /unit]	NO	NEST	NO	
		Maintenance impact (B2)	[X impact /unit]	NO	NEST	NO	
		End of life impact (C1-4)	[X impact /unit]	NO	NEST	NO	
Technical data	Economic data	Production cost	[€/unit]	NO	NO	***Think calculation process***	
		Installation cost	[€/unit]	NO	NO	"	According to the results obtained by the Thesis of Xabat Oregi, the economic influence of the construction process and end of life stages is less than 5% of the final results
		Maintenance cost	[€/unit]	NO	NO	"	Directly related with the estimated service life of each refurbishment strategy. Therefore, we propose to change the unit and apply a "maintenance cost per unit and per year"
		End of life cost	[€/unit]	NO	NO	"	
		Financing information	[€/unit]	NO	NO	"	Information about different financing support policies --> due to each state member has different policies, difficult to determine general policies for Europe
	Application scale	Building level	[Yes - NO]	NO	NO	YES	Except the district heating/cooling and smart grids, all other strategies can be used at building level
		District level	[Yes - NO]	NO	NO	YES	
	Installation data	Description		NO	NO	NO	
	Maintenance data	Description		NO	NO	NO	
	Operation requirements	Description		NO	NO	NO	
	Estimated Service Life	nº years		NO	YES	NO	

6 ECMs catalogue implementation

In the analysis of requirements presented in section 3 - ECMs technical requirements, several important issues and problems were determined. At this stage of the process not all the problems have to be solved, but it is interesting to identify them and to propose different solutions for the identified issues. In this section, we present diverse possibilities for the implementation of the ECMs catalogue taking into account the requirement analysis previously done.

The ECMs catalogue is a key element of the OptEEmAL solution: it has to contain a representative quantity of refurbishment strategies and these have to be complete and accurate enough for obtaining a good quality in the results. As it was previously mentioned, the strategies stored in the ECMs catalogue should contain all the information needed by the OptEEmAL platform mainly for three processes:

- Selection of the strategies to be applied.
- Generation and evaluation of the possible scenarios after the application of the strategies.
- Completion of the design information at the final stage: data for the generation of the documentation and for the completion of the design models.

In the Figure 2 the three processes in which the platform communicates with the ECM Catalogue repository are shown.

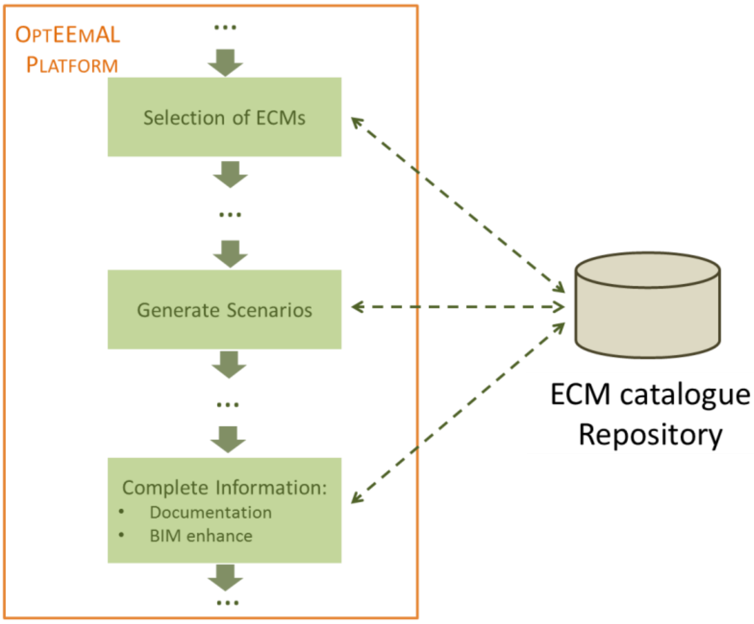


Figure 2: Queries to the ECMs catalogue from the platform during the lifetime of a refurbishment project

Obviously, the type of information needed in each one of these processes is different. In the part of the strategies selection, the data requested would be information to discriminate the strategies attending to different criteria and also general information to be shown to the OptEEmAL end-user. In the case of the information requested for the calculation, more information would be asked: specific values for the different parameters for each strategy (for the creation or modification of the different models or just for the calculation directly made by the platform) and other characteristics. When the platform would query for information to complete the design model for the scenario finally selected, more complete information is required, not only detailed parameters but also complete descriptions of the strategies and, in the case that the automatically generation of the enhanced BIM is needed, IFC code describing the strategy to be applied.

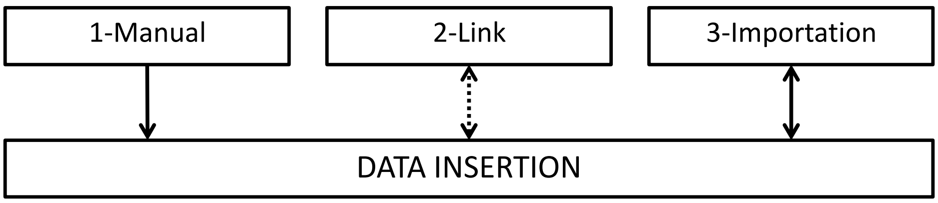
Also the way to ask for data will be different in each step. The first time, the platform has to request strategies using as searching criteria the parameters inferred from the targets of the refurbishment project (and also the barriers and boundaries defined by the platform end-user). Once the platform has identified the specific ECMs to be considered, it will ask to the ECMs catalogue requiring information directly from each strategy, due to the platform identifies the ECMs by name and unique identification in this stage.

It is important to emphasise that the information stored in the ECMs catalogue has to be consistent with the DDM developed in the OptEEmAL project, in order to guarantee the compatibility of the ECMs with the platform and, therefore, ensure that the information of the ECMs can be used by the solution without problem. Besides the information has to be coherent with the existing repositories that will be used for the population of the ECMs catalogue.

In the next subsections different topics about the implementation of the catalogue, which were reflected in the requirements capture, are analysed. Firstly, it is explained how the catalogue has to be populated with the diverse strategies. The next subsection gives some clarification about the technology to use for the implementation of the catalogue. Afterwards, more detailed data about the format used for the exchange of information are presented. Finally, a data quality control plan is exposed.

6.1 Data insertion and data modelling

The insertion of data in the ECM could be performed by different ways. In general three working methodologies are distinguished: manual insertions, link with existing data bases (see section 4) and automatic importation from other databases.



Manual	
Working process	Based on the information of different sources (existing database, other research projects, manufacturers, etc...), a member of the OptEEmAL project (to be possible the ECM manager) will insert manually the information about each ECM. To do this, firstly it will be necessary to find the right information and check their quality and accuracy. In the case that a single source will not provide all the necessary information, it will be necessary to look for more information about each strategy in other databases.
Advantages	- Control of each input data - Increment of the data quality and accuracy - Assessment of different databases and optimization of the data sources
Disadvantages	- Need to analyse a lot of data - Hard work to complete all the data for all ECMs - Difficulty to obtain all the necessary data. - Duplication of a lot of data assessed in other database and research projects - Difficulty on the maintenance of the catalogue
Link to external data base	
Working process	According to ECM typology, each family or group of OptEEmAL ECM will be linked to one or more existing databases (see section 4). This link will allow the end user to view,

	analyse and apply the information of other existing databases
Advantages	- Facility to access to the current database - Possibility to compare easily the data from different database - Optimize the quality of data for each ECM
Disadvantages	- Need to analyse more than one existing database - Difficulty to find the necessary information - Lack of information related to some parameters
Importation of data	
Working process	After detecting the different databases in section 4, it will be necessary to analyse the format, language, level of privacy, accuracy, etc … of each of them. After reviewing each and validate the quality of their data, the information of the databases that has passed the validation will be automatically imported within the OptEEmAL ECM
Advantages	- Avoid much of the work related to the definition of the ECMs - The end user has all the necessary information
Disadvantages	- Lack of information on many parameters - When the information has not been imported, difficulty to complete the ECMs - Data privacy issues for many of the existing databases - Data format problems to import many of the existing databases

In order to reduce the working process of the end user, during this first stage of the project proposes to work with options 2 (link) and 3 (importation). However, according to the information from these databases, their difficulties, their privacy level, etc. during the project it will be necessary to complete part of the information of the ECM manually (option 1).

6.2 ECMs catalogue technology

As it was indicated, the information needed for the platform about the ECMs stored in the catalogue is textual (descriptions) and numerical data (values of the parameters), so the ECM catalogue should use a database to store this kind of information.

A database is a collection of data structured following a determined data model that not only reflects the data itself, but also the relation between them. Taking into account the data model used there are different types of database: hierarchical, relational object based, object-relational, post-relational database, etc.

Currently the most used model is the relational model (actually, the SQL-relational database) because it offers a high flexibility and effectiveness. The main structure element of the databases from this category of database is "relationship". The relationships are based on the well-established foreign keys that take the reference from one primary key so as to keep the consistency of data with another selected column from a different table and also ensure that each elementary datum is only stored in one place so the insertions, updates, and deletions automatically maintain consistency.

For the implementation of the database a database management system (DBMS) is used. A DBMS is a software application that interacts with the user and the database itself to capture and organize data. The DBMSs allow the creation, administration, querying and update of the database. Attending to the way of development (licence) the DBMS can be commercial or open source. The commercial DBMS offer better performance than the open source ones, but the cost of the license is usually very high, and the performance of the free-licence system are enough in many of the cases.

In the Table 13 an assessment of the most used relational database management systems used nowadays, taking into account parameters as model, licence, operation system and others, are presented

Table 13: Comparison of databases system

Feature	Oracle	PostgreSQL	MySQL	SQL Server
License	Commercial	Open source	Open source	Commercial (limited free version)
Operating System	Multi-platform	Multi-platform	Multi-platform	Windows only
Model	Relational database	Object-relational database	Relational database	Relational database
SQL	Standard	Standard with extensions	Standard	Standard with exceptions
APIs	JDBC, .NET	JDBC, .NET	JDBC, .NET	JDBC, .NET
Stored procedures	PL/SQL and Java	User defined functions	PL/SQL	PL/SQL
Partitioning methods	Horizontal partitioning	No, but can be realized using table inheritance	---	Horizontal partitioning
Tables and views	Temporary table and materialized views	Temporary table and materialized views	Temporary table	Temporary table and materialized views
Max DB size	Unlimited	Unlimited	Unlimited	Unlimited

Very likely, the ECM catalogue will be implemented in one of the DBMS presented in the Table 13: Comparison of databases systems.

The database will not necessary be deployed in the same physical location that the other elements for the platform, meanwhile it can be remotely accessed both for the retrieval of data. The database could be available through public IP/ports with the aim of allowing data flows via remote calls.

A possible functionality that will be studied is the implementation of a different repository for IFC pieces of code, if needed. For this IFC code a BIM repository more adequate (and with more features, like BIM checker) could be used in the case of the database.

6.3 Exchange format

As it was previously said in the requirements capture, ensuring the interoperability between the ECMs catalogue and OptEEmAL solution it is a key necessity for the right functioning of the solution.

The implementation of the District Data Model (DDM) developed in the OptEEmAL project will allow to fulfil these interoperability requirements, since the DDM represents the information needed with the aim to cover the functionalities of the OptEEmAL platform related to geometry, materials, equipment, performance indicators and optimisation parameters and therefore the DDM provides the data representation framework that all the actors have to use to speak the same language, thus to guarantee the understanding among all the elements within the OptEEmAL solution.

In the next subsection, the stages where the OptEEmAL solution needs communication with the catalogue are identified.

6.3.1 Connection to the OptEEmAL platform to cover each step

The next tables show more precise information about the data exchanged between the platform and the ECMs catalogue.

Table 14 corresponds to the first part in which the OptEEmAL solution interacts with the platform inside a determined refurbishment project.

Table 14: Data exchanged in the "Selection of ECMs" stage

Process	Selection of ECMs
Description	In this phase the platform does a first query for the selection of the different strategies or ECMs attending a criteria defined by the platform end-user.
Parameter for requesting information	The information used to create the query is: • Targets of the project of district renovation project • Boundaries defined by the user • Barriers to take into account
Information requested	In this step the information requested is: • ECMs name and identifier • General information: o Short description o Application scale o Cost in general terms o Etc...
Other considerations	Not all the information about barriers and boundaries will discriminate for the selection of the strategies in the level of the ECMs catalogue. Some of the barriers and/or boundaries will be checked by the OptEEmAL platform in subsequent steps. The response has to be a set of ECMs with their respective information.

The information exchanged between the platform and the ECM catalogue in the process of scenario generation is shown in the following Table 15.

Table 15: Data exchanged in the "Scenario Generation" stage

Process	Generate scenario
Description	In this phase the platform does a query for obtaining the parameter relative to the ECMs to be added to the initial scenario and to generate the subsequent different scenarios.
Parameter for requesting information	The information used to create the query is: • ECM name (or identifier) related to the strategy

Information requested	In this step the information requested is: • Parameters (energetic, economic, environmental…): names and values • Information about limits and constraints
Other considerations	The query hast to be made, at least, once per ECM to be applied in the scenario generated. It has to be decided if with one query will be enough for all the models or a query will be needed for each model.

Table 16 shows the information exchanged between the platform and the ECMs catalogue once the end-user has selected the final scenario.

Table 16: Data exchanged in the “Complete information” stage for the documentation creation

Process	Complete information - documentation
Description	In this phase the platform asks for the detailed information about the finally selected ECMs able to cover the design purposes and standards in terms of documentation needed.
Parameter for requesting information	The information used to create the query is: • ECM name (or identifier) related to each strategy • Parameters used and values

Information requested	In this step the information requested is:
	• Information related to the design project and the operation:
	  ○ Installation data
	  ○ Maintenance data
	  ○ Operation requirements
	• Others: control strategies, economics, maintenance schedules…

Other considerations	The query has to be made once per chosen ECM to be applied in the finally selected scenario.

If finally is decided to store BIM data (in the form of IFC code) in the ECMs repository, the platform would communicate with the catalogue for this information. The exchanged data is reflected in the Table 17.

Table 17: Data exchanged in the “Complete information” stage for the BIM enhance

Process	Complete information – BIM enhance
Description	In this phase, the platform needs the information for the creation of the enhanced BIM model, if it is needed.
Parameter for requesting information	The information used to create the query is: • ECM name (or identifier) related to the final chosen strategy/strategies

	• Parameters used and values
Information requested	In this step the information requested is: • IFC code
Other considerations	The query has to be made once per chosen ECM to be applied in the finally selected scenario.

7 ECMs catalogue content examples

One important objective of the project is the development of an Energy Conservation Measures (ECMs) catalogue. This content is explained in the next point through different examples that contains technical, operational, maintenance and cost information in passives, actives, hybrid, local Renewable Energy Sources (RES) and HVAC control strategies.

OptEEmAL Platform will base the formulation of candidate scenarios for energy efficiency improvement in this advanced catalogue of solutions. In the next points technical, operational, performance, maintenance and cost requirements will be studied and included through different examples, at least one per type of strategy.

7.1 Passive strategies

In the renovation of buildings and districts there are different types of strategies. Passive strategies are used in an approach that use the architecture and static construction (non-active) elements to minimize energy consumption and improve thermal comfort within the houses.

Normally in a retrofitting project there are implemented some design passive strategies as the building form and thermal performance of its elements (including architectural, structural, envelope and passive mechanical). These elements should be carefully at first considered and optimized for interaction with the local microclimate and the conditions of each building.

A fully passive design can almost comply with comfort at all times. Some basic decisions in design as building shape, orientation and composition can improve occupant comfort by harnessing desirable site. But, in this case the OptEEmAL platform should define passive energy conservation measures to perform the situation of a non-functional neighbourhood in energy terms.

Through properly applied passive strategies, we can greatly reduce district energy requirements before we even consider mechanical systems or active strategies. Nevertheless the passive measures are applied at first at building level due to the different necessities of each building.

The next sections cover the identification of some passive building strategies with materials and space requirements ideal for substitution, covering thus the requirements and their passive properties. Different materials for building envelopes were analysed as potential candidates to be included as passive strategies in the energy conservation measures catalogue. In this sense, the efforts are focused on the next table.

Table 18: Types of Passive Strategies proposed in the ECMs catalogue

<table>
<tr><td rowspan="7">Passive strategies</td><td rowspan="6">A-Envelope</td><td rowspan="2">A1-External</td><td>A1.1-Ventilated facade</td></tr>
<tr><td>A1.2-ETICS</td></tr>
<tr><td rowspan="3">A2-Internal Insulation</td><td>A2.1-Floor</td></tr>
<tr><td>A2.2-Wall</td></tr>
<tr><td>A2.3-Roof</td></tr>
<tr><td colspan="2">A3-Air Chamber Insulation</td></tr>
<tr><td colspan="3">B- Window replacement</td></tr>
</table>

7.1.1 Ventilated Façade [02]

7.1.1.1 Introduction

This system is nowadays on the demands in architectural, because of enhancing the aesthetic image of buildings, but also, keeping energy consumption low. It provides a multilayer skin between the building and the external agents of the climate, with an internal air chamber.

Normally, the ventilated façade is fastened to an auxiliary metal structure, which is fixed to the external walls of the existing building. The continue insulation layer is fixed on the external wall to improve the thermal conditions and to avoid heat losses from the inside of the building.

There is a chamber of air between the external facade and the insulation layer to achieve the performance of the measure. The chamber removes the humidity and reduces the heat losses.

The principal objective is to create a continuous insulation layer to avoid thermal bridges. Also in summer can reduce the energy gains due to solar radiation through the ventilation chamber.

7.1.1.2 Requirements / Limitations

- **Pre-existing injuries on the façade:** Deficiencies have to be identified and rectified before implementing the façade with the new cladding. If not the façade cannot be implemented.
- **Bearing capacity of the façade and structure:** The existing wall (structure) should be able to support the weight of the external skin. If not this solution cannot be applied.
- **Other singular elements to solve:** Special pieces for the openings, corners, incoming and outgoing elements and roof connection. If not thermal bridges can appear.
- **The façade is protected by law:** In this case another measure has to be chosen.
- **Design conditions:** In some neighbourhoods with social problems is the best choose, because it changes the negative image of the buildings.

7.1.1.3 Types

There are produced standard types of ventilated facade systems that simultaneously solve two problems: optimization of the microclimate in the building and improvement of its architectural design. Depending on the purpose of the object and design requirements there is a big range of different solutions:

- **Ceramic:** It protects from adverse weather conditions. It is also resistant to aggressive environments with a high level of sound insulation; also it can be easily clean and carry.
- **Fibre cement:** It is economic, easy to install, reliable, non-flammable, shock resistant, and cold-resistant. It has also high life service.
- **Aluminium composite panels:** This material has a high strength, rigidity and elasticity. This system do not require much maintenance, lifetime is over 40 years.
- **Aluminium cassettes:** It is reliable, durable, protective, moisture resistant, corrosion resistance and ductility…
- **A polymeric siding:** They have lots of advantages because its low weight, high resolution, excellent abrasion resistance, durability, assembly, high degree of resistance.

7.1.1.4 Components / Installation

- **Support:** It is where the auxiliary structure is fixed. The support transfers the efforts to the building structure. If the wall is weak, the support should be the slabs or columns.
- **Anchorage:** It has to be adapted to the constraints of the support; the system should be design by modules and has to avoid the accumulation of humidity.
- **Cladding:** The external conditions and actions have to be resisted by this element, (Wind actions, Physical impacts, Resistance to external climate agents Thermal changes…)
- **Air chamber:** Through the chamber humidity and water is dispersed. It also reduces noise and fire transmission, it ensures drainage and ventilation.
- **Insulation:** The continuous insulation removes the thermal bridges that normally are in the façade of old buildings, are removed. It has different thickness (7, 10, 15mm). Requirements: not hygroscopic, waterproof, unalterable, continuous application.

7.1.1.5 Advantages

- **Energy saving:** Noise insulation, low heat dispersion in cold periods and low heat absorption in hot months. The average of energy efficiency is among the 30%.
- **Healthier environment:** It prevents thermal bridges, and avoids the humidity present in the building due to its air chamber.
- **Static technical and aesthetic performances:** The materials maintain all the characteristics from its installation because the large lifecycle.
- **Protection from water:** Ventilated facade stops rainwater from entering the walls, reducing decay and relevant maintenance costs at both faces of the wall.
- **Ideal for renovation work:** The system can be applied over existing plaster without the need for restoration work, it change dramatically the image of the building.
- **Maintenance:** It doesn't need much maintenance and most of the solutions are self-cleaning. It doesn´t need maintenance and service for at least 30 years after installation
- **Durability:** A copper structure has the lifetime of up to 100 or more years.

7.1.1.6 Disadvantages

- **Time:** The time of application is larger due to the structure and complexity.
- **Costs:** Costs are higher also because of the different materials needed and its quality.
- **Complication:** The measure in fact is not so complicate when it is spoken about technical issues, but the fact is that a secondary structure (scaffold) is needed.
- **Not applied in protected areas:** Because of the change of façade and image this measure cannot be applied in many historical neighbourhoods.

7.1.1.7 Costs

This cost depends on the preparation of the support layer, the installation of the anchorages, installation of the sub-structure, placement of the insulating layer, cladding material and the type of elements and the placement with the regulation system.

7.1.1.8 Conclusions

It is possible the best solutions in terms of design, durability, maintenance, protection and energy savings. The high performance of the material assumes that the ventilated façade is going to work for the building under many circumstances.

However, it cannot be implemented in protected buildings, the time of construction is longer and the cots higher than other retrofitting measures.

7.1.1.9 ECM Table example - Ventilated Façade

Table 19: ECM – Passive strategy Ventilated façade

Passive Strategy: Ventilated Façade

Generic data

Description

Ventilated façade is fastened to an auxiliary metal structure fixed to the external walls of the building. The insulation layer is fixed in between to improve the thermal conditions. A chamber of air removes the humidity of the internal wall and reduces the heat losses. The principal objective is to create a continuous insulation layer to avoid thermal bridges.

Types: • Ceramic •Fibre cement •Aluminium: • Polymeric siding

Application

-Installation of the auxiliary structure on the support constructive element. If the wall is weak, the support should be the slabs or columns.
-The module anchorage is adapted to the constraints of the support.
-There should be place enough for the air chamber.
-The insulation layer is fixed over the external layer of the wall. It is necessary to have some distance between the vertical structure.

Limits	Historic building	NO, In historic districts is normally limited Review regulation
	Injuries on the façade	YES, Injuries has to be first repaired (more cost)
	Bearing capacity	NO, If the structure is damage it cannot be added
	Ruinous state	NO
	Economic Cost	DEPEND, High cost, depends on the economics
Advantages	-Energy saving: Low heat losses in cold periods and low heat gains in hot months. -Healthier environment, Comfort: No thermal bridges, and avoid the humidity. -Aesthetic performances: It maintains all the characteristics from its installation. -Protection from water: -Maintenance: Durability: A copper structure has the lifetime of up to 100.	
Disadvantages	-Time: Application is larger than in other façades systems. -Costs: Costs are high. -Complication: Two types of structure and various materials. Colocation -Not applied in protected areas	
Social acceptation	It changes the image; it can be a social problem or an advantage.	
Constraints	Regulations: according to the architectural value, location, history, building use ... the municipal planning or regional administration may set limitations.	
nº of jobs /	-	

Technical data

Energy data	Thermal resistance [(m2*K)/W]	Depends on materials and thickness
	Energy performance [%]	30%
Environmental data	*Production impact (A1-3)*	**Import from NEST**
	Installation impact	**Import from NEST**
	Maintenance impact	**Import from NEST**
	End of life impact	**Import from NEST**
Economic data	Production cost (€/m2)	-
	Installation cost (€/m2)	250-350
	Maintenance cost (€/m2.a)	0
	End of life cost	-
	Financing information	-
Application scale	Building level	YES
	District level	YES, Individually
Installation data	It has some complication in installation because the secondary structure. But its modulation makes it affordable in a medium period of time	
Maintenance data	This time of façade does not need any process of cleaning or maintenance in the first 20 years, after that only simply revisions	
Operation requirements		
Estimated Service Life	50 years	

7.1.2 Envelope – External – ETICS [02]

7.1.2.1 Introduction

External Thermal Insulation Composite Systems can be used to improve the energy efficiency of both new and existing buildings. In existing buildings is a really affordable system in terms of economy, installation and savings.

ETICS consists of certain prefabricated components that can be applied onsite, directly to the façade. The system components, design and construction depends more in the different manuals of the installation and in the different national regulations in each country.

The quality and durability of ETICS depends on the careful choice of the system components. With more valuable material we can avoid degradation and a higher thermal and resistance capacity, but the prices of this material will make the system less economic than with less qualitative materials.

7.1.2.2 Requirements / Limitations

- **Pre-existing injuries on the façade:** As in the Ventilated Façade System, the deficiencies have to be identified and rectified before the implementation of the façade.
- **Existing bearing capacity of the façade and structure:** notice if the existing face or the structure can support the weight of the external skin. If not this solution cannot be applied.
- **Singular elements to solve**: It has to be designed special pieces for the openings, corners, incoming and outgoing elements and roof connection.
- **The façade is protected by law**: ETICS change the image of the building, so in this case another measure as the internal or cavity wall insulation has to be chosen.
- **Design conditions**: In some neighbourhoods with social problems and lack an humanity factor in the design of the buildings an external façade is the best choose because it can change the negative image of the buildings and will give an impulse to its inhabitants.
- **Lack of space in the facade**: In almost all the cases ETICS needs less space than ventilated façade system, so this solution will be used in those cases.
- **Lack of budget:** Ventilated façade is more expensive than ETICS, so in the case of a lower budget ETICS will be chosen as a more suitable solution.
- **Application:** The installation should be done in dry weather, with temperature not lower between +5 °C and +30 °C.

7.1.2.3 Types

<u>Bonded ETICS:</u>
ETICS where the connection to the substrate is ensured by bonding:

- **Purely bonded ETICS:** ETICS may be fully bonded (over the entire surface) or partially bonded in strips and/or dabs.
- **Bonded ETICS** with supplementary mechanical fixings: The load is totally distributed by the bonding layer. The mechanical fixings are used primarily to provide stability until the adhesive has dried and act as a temporary connection to avoid the risk of detachment.

<u>Mechanically fixed ETICS:</u>
ETICS where the connection to the substrate is ensured by mechanical fixings:

- **Mechanically fixed ETICS with supplementary adhesive:** The load is totally distributed by the mechanical fixings. The adhesive is used primarily to ensure the flatness.
- **Purely mechanically**: The ETICS are secured to the wall by mechanical fixings only.

7.1.2.4 Components

- **Support:** This type of solution also needs a support, normally a constructive element (wall). It has the same function than the previous passive strategy.

- **Insulation:** It is the most important material in this solution because it is directly added to the supporting wall of the building. In this case there is no air chamber. It is adhesive.
- **Reinforcement:** In order to reinforce the insulation boards a mesh made from glass fiber is applied to avoid any future crack formation.
- **Top coat:** It is in contact with all problems, such as weather, humidity, temperature changes, physical contacts with objects, corrosion, degradation… Has to be durable.

7.1.2.5 Advantages

- **Energy saving:** It makes a major contribution to reducing the amount of energy needed for heating. Near 50% reduce in U-value of 0.27 W/m²K and lower easy-to-achieve.
- **Improved comfort:** Without rapid heat loss and subsequent cycles of heating and cooling, occupants of the structure experience a more comfortable environment.
- **Condensation reduction:** It reduces the naturally occurring levels of humidity within a building and cold bridging it is remedied by external insulation.
- **Aesthetic appeal:** It has an important role in improving the external image of buildings of all kinds and ages. Indeed, it will retain a fresh, clean appearance for a long period of time.
- **Weather proofing and general repair:** It provides a weatherproofed structure, overcoming difficult or complex problems of water ingress that may be too expensive to repair.
- **Insulation performance:** Thermal conductivity of 0.039 and 0.043 W/m·K as well as a high thermal storage capacity of 2100 J/kg provide significant energy savings on heating.
- **Impact resistance:** The combination of impact resistant plaster baseboard and 8-10-mm render makes the external thermal insulation composite system really resistant.
- **Versatility:** The availability of the plaster baseboards in many different sizes means the perfect match for your specific dimensional requirements is always on hand.
- **Economy:** It is really economic when comparing to Ventilated Façade.
- **Acoustic insulation:** Soundproofing with sound transmission reduction up to 54 dB.

7.1.2.6 Disadvantages

- **Non-load-bearing:** They do not contribute directly to the stability of the wall on which they are installed. The ETICS can contribute to durability by providing enhanced protection from the effects of weathering.
- **Airtightness:** ETICS are not intended to ensure the airtightness of the building structure.
- **Not applied in protected areas:** Because of the change of façade and image this measure cannot be applied in many historical neighbourhoods.

7.1.2.7 Costs

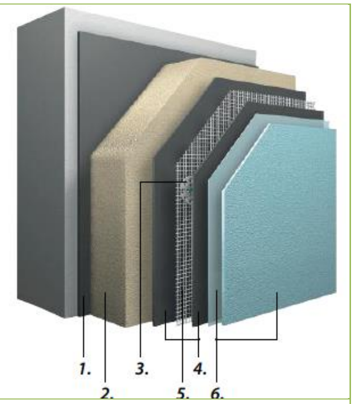
- **Economic:** The panel represents more than 50% of the overall cost of a thermal insulation system. The most economical material available is sintered expanded polystyrene (EPS) which is used in 90% of insulation systems. Natural and mineral materials are much more expensive and cost up to 4 or 5 times more, but often offer better performance levels.

7.1.2.8 Conclusions

It is one of the most economic solutions, also complies in terms of design, durability, maintenance, protection and energy savings. However, it can´t not be implemented in protected buildings.

7.1.2.9 ECM Table example - ETICS

Table 20: ECM – Passive strategy ETICS

Passive Strategy: ETICS	Generic data	**Description** ETICS consists of certain prefabricated components that can be applied onsite, directly to the façade. With more valuable material degradation can be avoid degradation and a higher thermal and resistance capacity, but the prices of this material will make the system less economic. **Application** -Support: It is the constructive element (wall). -Insulation: It is directly added to the supporting wall of the building. In this case there is no air chamber. It is adhesive. -Reinforcement: In order to reinforce the insulation boards a mesh made from glass fibre is applied to avoid any future crack formation. -Top coat: It is in contact with all problems…it has to be durable.		
		Limits	Historic building	NO, In historic districts is normally limited Review regulation
			Injuries on the façade	YES, Injuries has to be first repaired (more cost)
			Bearing capacity	YES, it can be added because of its low weight.
			Ruinous state	NO
			Economic Cost	MEDIUM-LOW, It is an affordable cost
		Advantages	-Energy saving: It reduces the amount of energy needed for heating. Near 50%. -Improved comfort: Reduces rapid heat loss and cycles of heating and cooling. -Condensation reduction: It reduces the naturally occurring levels of humidity. -Aesthetic appeal: It has an important role in improving the external image. -Weather proofing: It overcomes difficult or complex problems of water. -Insulation performance: Thermal conductivity of 0.039 and 0.043 W/m·K.. -Impact resistance: Impact resistant plaster baseboard and 8-10-mm. -Versatility: There are many different sizes. -Economy: It is really economic when comparing to Ventilated Façade. -Acoustic insulation: Soundproofing with reduction up to 54 dB.	
		Disadvantages	-Non-load-bearing: They do not contribute directly to the stability of the wall. -Airtightness: ETICS are not intended to ensure the airtightness of the building. -Not applied in protected areas: Because of the change of façade and image.	
		Social acceptation	It changes the image; it can be a social problem or an advantage.	
		Constraints	Regulations: according to the architectural value, location, history, building use ... the municipal planning or regional administration may set limitations.	
		nº of jobs	-	
	Technical data	**Energy data**	Thermal resistance [(m2*K)/W]	Depends on material 0.27 W/m²K minimum
			Energy performance [%]	30%
		Environmental data	*Production impact (A1-3)*	**Import from NEST**
			Installation impact	**Import from NEST**
			Maintenance impact	**Import from NEST**
			End of life impact	**Import from NEST**
		Economic data	Production cost (€/m2)	-
			Installation cost (€/m2)	-
			Maintenance cost (€/m2.a)	Not needed, only revisions
			End of life cost	-
			Financing information	Discounts and helps in some countries
		Application scale	Building level	YES
			District level	YES, individually
		Installation data	The installation should be done in dry weather, with temperature not lower between +5 °C and +30 °C	
		Maintenance data	It needs periodically revisions with the technical analysis of the building	
		Operation requirements		
		Estimated Service Life	25 to 30 years	

7.1.3 Comparison between passive strategies

Table 21: Comparison of different passive strategies

	CONCEPT	VENT. FACADE	ETICS	CWI Cavity wall	Internal wall
ENERGY	Less winning from solar radiation	MEDIUM	MEDIUM	NO	NO
	Elimination of thermal bridge losses	YES	YES	NO	NO
	Conservation of thermal inertia	YES	YES	YES	NO
DURABILITY	Protection against external agents	YES	YES	NO	NO
	Maintenance	LOW	LOW	LOW	LOW
	Protection to interstitial condensation	YES(*)	YES(*)	NO	NO
COMFORT	Improve of the aesthetics image	YES	YES	NO	NO
	Inconvenience to the user	NO	NO	NO	YES
	Costs	MEDIUM	HIGH	LOW	MEDIUM

(*) The protection under interstitial condensation is extend only through thermal insulation

7.2 Active strategies and RES integration

Within this group are combined two groups of refurbishment strategies: efficient technologies and renewable technologies

- **Efficient Technologies**

This kind of strategies are focused on be efficient, where fossil fuels have to make up the shortfall in energy supply this should be done as cleanly and as sparingly as possible. In the ideal situation the use of conventional fuels will be diminished to zero. Among these technologies, the most used is the replacement of energy generation systems:

- Replacement of current energy generation systems by new systems with increased performance and / or other energy sources with a lower environmental impact or lower economic cost.

- Replacement of individual systems for centralized systems.

If the rehabilitation was to be carried out at the district level, this would allow for the implementation of efficient technologies such as district heating, which is based on efficient and renewable generation systems (biomass boiler, cogeneration system or waste heat recovery system) and an optimized distribution. At the same time, if the demand for a cooling system was higher, district cooling strategies or tri-generation systems (generation of heat, cold and electricity) could be suggested.

- **Use of renewable energy**

The development of sources of renewable energy is a crucial part of the strategy to cut carbon emissions, but for these to work them also has to be economically viable. As the technology evolves and becomes more widespread the economies will improve. One of the key aspects for the success of integrating sources of renewable energy into the construction programs will be the ease with which they can be incorporated into building design. These kind of active refurbishment strategies are based in using sustainable sources of energy like wind, the sun, water and the ground to generate energy.

The second parameter that determines the type of renewable energy system is its "generation location", which differentiates between on site and off site systems.

Table 22: Options, On-site – Off-site

Option	Supply site Option	Examples
On-site	Using renewable energy sources available within the building's footprint	PV, solar hot water, and wind located on the building.
	Using renewable energy sources available at the site	PV, solar hot water, low-impact hydro, and wind located on-site, but not on the building
Off-site	Using renewable energy sources available off site generate energy on site	Biomass, wood pellets or biodiesel that can be imported from off site, which can be used on-site to generate electricity and heat.
	Purchasing off-site renewable energy sources	Utility-based wind, PV or other green purchasing options.

The implementation of such strategies (thermal solar panels, photovoltaic panels, biomass boilers or mini-wind) does not directly affect in the increment of thermal comfort of the inhabitants. However, their influence will be directly in aspects such as:

- Environmental: reduction of consumption of the non-renewable sources energy.

- Economical: generation of "free" energy (except the initial investment and the maintenance cost).

Table 23: Types of Active Strategies proposed in the ECMs catalogue

<table>
<tr><td rowspan="18">Space Heating and Cooling / Domestic Water Heating Systems</td><td rowspan="16">Energy generation system</td><td>High efficient boiler (natural gas)</td><td rowspan="8">Different generation powers</td></tr>
<tr><td>Condensation boiler (natural gas)</td></tr>
<tr><td>Biomass boiler</td></tr>
<tr><td>Combined heat power (natural gas engine)</td></tr>
<tr><td>Combined heat power (gas turbine/micro turbine)</td></tr>
<tr><td>Combined heat power (steam turbine)</td></tr>
<tr><td>High efficient chiller (electricity)</td></tr>
<tr><td>High efficient heat Pump</td></tr>
<tr><td rowspan="2">Solar thermal collectors</td><td>Flat collector</td></tr>
<tr><td>Tube collector</td></tr>
<tr><td rowspan="2">Photovoltaic collectors</td><td>Mono-crystalline</td></tr>
<tr><td>Multi-crystalline</td></tr>
<tr><td colspan="2">Geothermal</td></tr>
<tr><td rowspan="3">Energy Exchange within the district</td><td>Energy generation</td></tr>
<tr><td>Energy Storage</td></tr>
<tr><td>Distribution</td></tr>
<tr><td>Reduction of losses</td><td>Thermal insulation of the pipes</td><td></td></tr>
<tr><td>Control system</td><td>Regulation of the heating and/or cooling systems</td><td></td></tr>
</table>

7.2.1 Photovoltaic (PV) solar Technology

7.2.1.1 Introduction

Photovoltaic (PV) solar technologies generate electricity by exploiting the photovoltaic effect. Light shining on a semiconductor such as silicon (Si) generates electron-hole pairs that are separated spatially by an internal electric field created by introducing special impurities into the semiconductor on either side of an interface known as a p-n junction. This creates negative charges on one side of the interface and positive charges are on the other side. This resulting charge separation creates a voltage. When the two sides of the illuminated cell are connected to a load, current flows from one side of the device via the load to the other side of the cell. The conversion efficiency of a solar cell is defined as a ratio of output power from the solar cell with unit area (W/cm2) to the incident solar irradiance. The maximum potential efficiency of a solar cell depends on the absorber material properties and device design. (Ref: IPCC, Intergovernmental Panel on Climate Change)

7.2.1.2 Types

In general, cells can be classified as either wafer-based crystalline (single crystal and multi-crystalline silicon, compound semiconductor) or thin film.

Wafer-based crystalline

- **Single-crystalline silicon cells** (or monocrystalline): The active material is made from a single crystal without grain boundaries; those cells have the highest efficiencies (13-18%).
- **Multi-crystalline (polycrystalline) silicon cells**: The cell material consists of different crystals with different orientation. This type of cells has a lower efficiency, but it is cheaper in production. This kind of cell has an efficiency of about 11-16%.
- **Ribbon silicon technologies** use the available silicon more efficiently. The wafers are directly crystallized from the silicon melt. Ribbon cells have an efficiency of about 10-14%.

Thin films

Those modules are constructed by depositing extremely thin layers of photovoltaic materials on a low cost backing such as glass, stainless steel or plastic. Individual 'cells' are formed by then scribing through the layers with a laser. Thin film cells offer the potential for cost reductions. Those types of cells have in general a lower efficiency.

7.2.1.1 Components / Installation

There are two general types of PV systems, isolated (OFF) and grid connected (ON). Isolated systems provide electricity independently from the electricity grid and grid connected systems are connected to the electricity grid and displace power that would otherwise be drawn from the grid. Grid-connected PV systems use an inverter to convert electricity from direct current (DC) as produced by the PV array to alternating current (AC), and then supply the generated electricity to the electricity network. Compared to an off-grid installation, system costs are lower because energy storage is not generally required, since the grid is used as a buffer. Off-grid installations in return need a storage battery to provide energy during low-light periods and a regulator is used to maintain the battery at the highest possible state of charge and provide the user with the required quantity of electricity while protecting the battery from deep discharge or overcharging.

The Figure 3 shows the time evolution of the ratio of off-grid and grid-connected systems in the Photovoltaic Power Systems (PVPS) Programme countries. The principal applications for PV systems are two: OFF grid applications and ON grid applications.

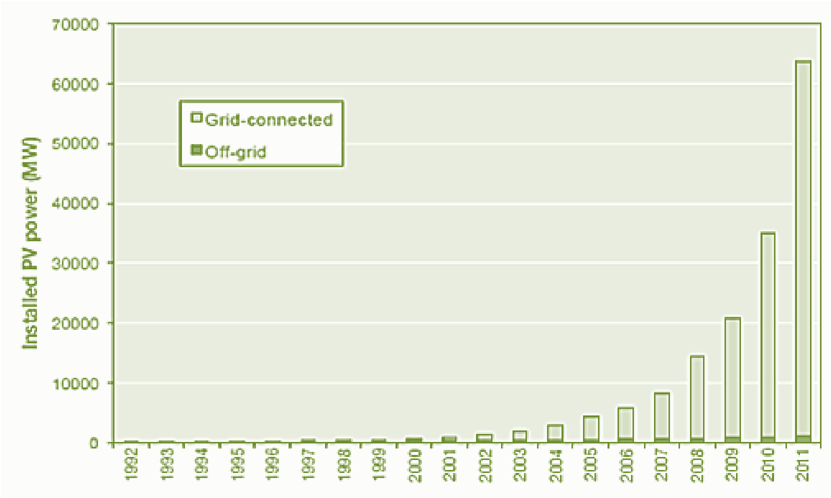


Figure 3 Cumulative installed grid-connected and off-grid PV power. [04]

OFF grid applications: Isolated systems provide electricity independently from the electricity grid.

- **Off-grid domestic**: systems provide electricity to households and villages where the cost of connection to the electricity network is high.
- **Off-grid non-domestic:** installations were the first commercial application for terrestrial PV systems. PV systems are usually used for power supply for remote services such as lighting, water pumping, etc.
- **Off-grid centralized PV mini-grid systems:** this kind of systems are increasingly used as an alternative power supply system for diesel generators usually used for isolated village electrification, villages where houses are not separated too much between each other. Although they may have a diesel generator set as an optional balancing system or operate as a hybrid PV-wind-diesel system.

ON grid applications: these systems are connected to the electricity grid and displace power that would otherwise be drawn from the grid.

- **Grid-connected distributed systems:** are systems integrated into buildings, into the customer´s premises or in the built environment that provide power to a grid connected customer or directly to an electricity grid that is configured to use the energy generated in the distributed system to supply energy for a number of customers. A wide range of mounting structures has been developed especially for building integrated PV, including PV facades, sloped and flat roof mountings, integrated glass-glass modules and 'PV roof tiles'.
- **Grid-connected centralized systems:** are usually ground mounted installations that perform the functions of centralized power stations. The mission of those systems is the supply of bulk power.

7.2.1.2 Advantages

- **Solar energy**: It is renewable and the total solar irradiation of the sun to the earth surface is about 5.6.1012 TJ per year.
- It allows applications in many orders of magnitude, from some milliwatts to several megawatts. Combining cells to reach different capacities.
- **No emissions:** the conversion of solar energy has any emissions during operation, only the visual impact in the buildings.
- **Radiation transformation:** Direct and diffuse radiation can be transformed to electricity.
- **Silicon:** It is the second most abundant element on earth and is not toxic.
- **Buildings integration:** Integration in buildings in a responsible way is possible.

7.2.1.3 Disadvantages

- Low convertible energy density.
- **Weather:** Electricity production depends on weather conditions and irradiation.
- **Storage:** There is no good storage facility developed yet.
- **Silicon:** It is the second most abundant element on earth and is not toxic.
- **Buildings integration:** Integration in buildings in a responsible way is possible.
- The purification of the silicon is an energy intensive (and expensive) process. This increases the embodied energy of the product.
- **Space needed**: Large areas are necessary.

7.2.1.4 Trends in photovoltaic applications[03]

The evolution of photovoltaic technology has been very strong during the last 50 years (see Figure 4). This improvement is based in laboratory prototype cells, developed through successful R&D.

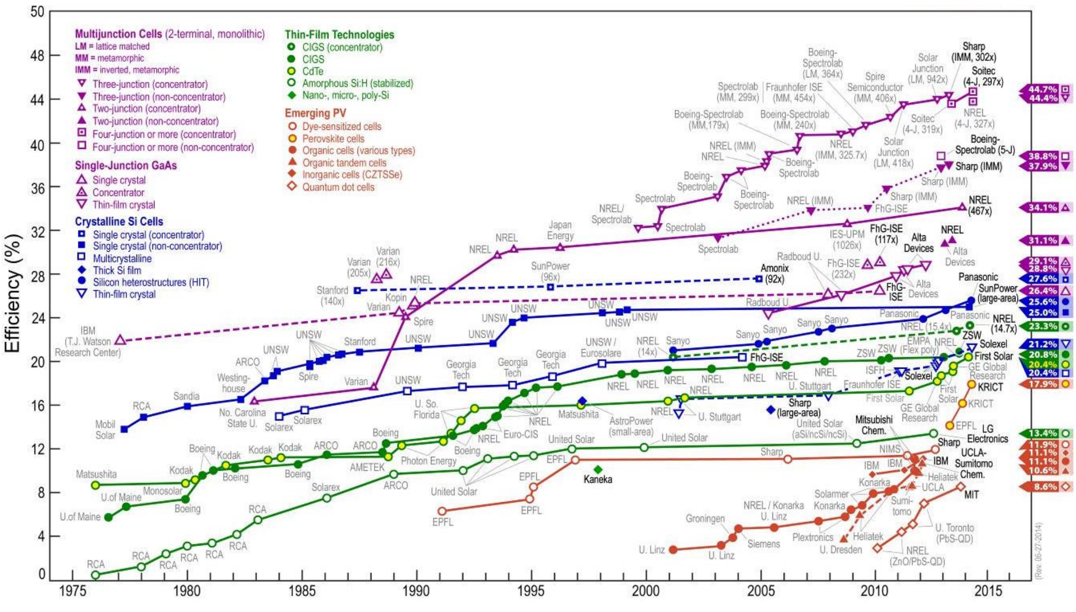


Figure 4 Laboratory Best-Cell Efficiencies evolution for various PV Technologies

Currently, more than 80% of PV modules are based on wafer-based crystalline silicon but c-Si PV systems will decline after 2020 promoting thin film technologies in the medium term and in favour of novel technologies in the long-term. The next figure shows how the PV market will change until 2050 [06].

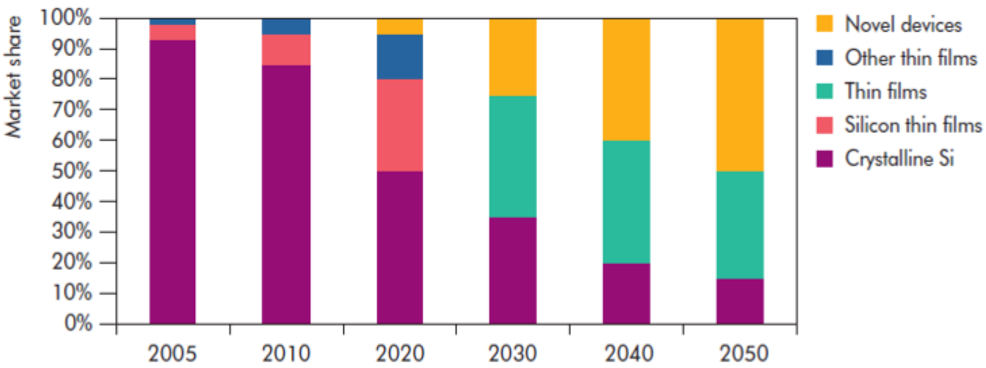


Figure 5 PV market

Therefore, depending on the time-line, three main types of PV devices can be distinguished, the existing PV technologies, the emerging photovoltaic technologies and the novel technologies. One of the main problems with the *existing photovoltaic technologies* is that Silicon for solar cells needs a high purification grade and the production plants are responsible of the main economic costs and energy consumptions of the process. Therefore, the mayor improvements strategies in the sort-term are the improvement regarding the cell efficiencies, the reduction of silicon consumption per KWp, increasing the recycling of silicon and the improvement of the purification technologies.

The *emerging photovoltaic technologies* are based on very low-cost materials and processes. Those technologies are still under development. The *novel PV technologies,* the aim of this kind of technology is not to minimize cost but is to reach very high efficiencies by optimizing the use of the entire solar spectrum. Those technologies represent high-risk but also high-potential because they consider new materials, devices and new conversion concepts.

7.2.1.5 Cost

The investment cost for PV systems was high in 2010, but is expected to decrease during the next years with the increasing penetration in the market of thin film modules, with the development of the production processes and with the mass-scale integration in building that will reduce costs related to mounting structures. The next figure shows the forecast presented by the European Photovoltaic Industry Association (EPIA) for the costs of a Wp generated by photovoltaic technologies [07].

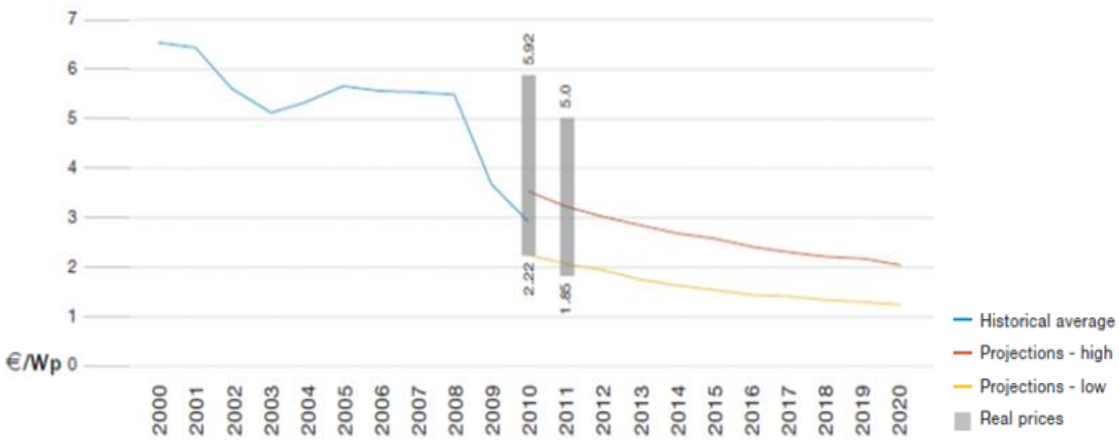


Figure 6 Costs of a Wp generated by photovoltaic technologies

The studies developed by EPIA suggest that the PV prices will decrease through to 2020 with average prices falling by around 3-5% each year.

7.2.1.6 ECM Table example - Photovoltaic

Table 24: ECM – Active strategy Photovoltaic

Passive Strategy: Photovoltaic	Generic data	**Description**		
		Photovoltaic (PV) solar technologies generate electricity by exploiting the photovoltaic effect. Light shining on a semiconductor such as silicon (Si) generates electron-hole pairs that are separated spatially by an internal electric field created by introducing special impurities into the semiconductor on either side of an interface known as a p-n junction. 1m2 of monocrystalline photovoltaic panel connected to the grid		
		Application		
		Two kind of applications: On grid and Off grid -ON Grid: Grid connected systems are connected to the electricity grid and displace power that would otherwise be drawn from the grid. -OFF Grid: Isolated systems provide electricity independently from the electricity grid (Off-grid domestic systems, Off-grid non-domestic installations or Off-grid centralized PV mini-grid systems)		
		Limits	Historic building	NO, In historic districts is normally limited. Review regulation
			Economic Cost	DEPEND, High cost, depends on legislation
		Advantages	-The solar energy conversion has no emissions during operation -Applications in many orders of magnitude (from some MW to several MW). -Direct and diffuse radiation could be converted in electricity -Silicon is the second most abundant element on earth and is not toxic. -Integration in buildings is possible.	
		Disadvantages	-Low convertible energy density. -Electricity production depends on weather conditions and irradiation. -There is no good storage facility. -The purification of the silicon is an energy intensive (and expensive) process.	
		Social acceptation	Normally there are not any problems related to the social acceptance.	
		Constraints	-Geographic: according to the urban morphology or the climatic zone where the district is located, the solar incident radiation on the PV panel could be too low. -Regulations: architectural value, location, history, building use ..., municipal planning or regional administration may set limitations on its use.	
		nº of jobs / MW installed	6,96 - 11.01	
	Technical data	**Energy data**	Thermal resistance [(m2*K)/W]	(Not necessary)
			Energy performance [%]	15%
			Energy generation	Internal algorithm
		Environmental data	*Production impact (A1-3)*	**Import from NEST**
			Installation impact	**Import from NEST**
			Maintenance impact	**Import from NEST**
			End of life impact	**Import from NEST**
		Economic data	Production cost (€/m2)	250
			Installation cost (€/m2)	13,6
			Maintenance cost (€/m2·a)	2,2
			End of life cost	Information not available
			Financing information	Information not available
		Application scale	Building level	YES
			District level	YES
		Installation data	Colocation of PV panels in an aluminium substructure located on different surfaces: roof or facade of a building (building scale) or large surfaces (district electricity generation scale)	
		Maintenance data	It doesn't need much maintenance and most of the solutions are self-cleaning. It doesn´t need maintenance and service for at least 30 years after installation	
		Operation requirements	Receive enough solar radiation on the collector and make a proper system installation	
		Estimated Service Life	30 [08]	

7.2.2 District Heating Technology

7.2.2.1 Introduction

District heating is a system for distributing heat generated in a centralized location for residential and commercial heating requirements such as space heating and water heating. A district heating plant is often a combined heat and power plant (CHP). By co-producing heat and power in the same process, the heat that would otherwise be wasted in electricity production is utilized. This leaves tremendous energy savings of up to 30%. The heat is often obtained from a cogeneration plant burning fossil fuels but increasingly biomass, although heat-only boiler stations, geothermal heating, waster heat recovery systems and central solar heating are also used, as well as nuclear power[09].

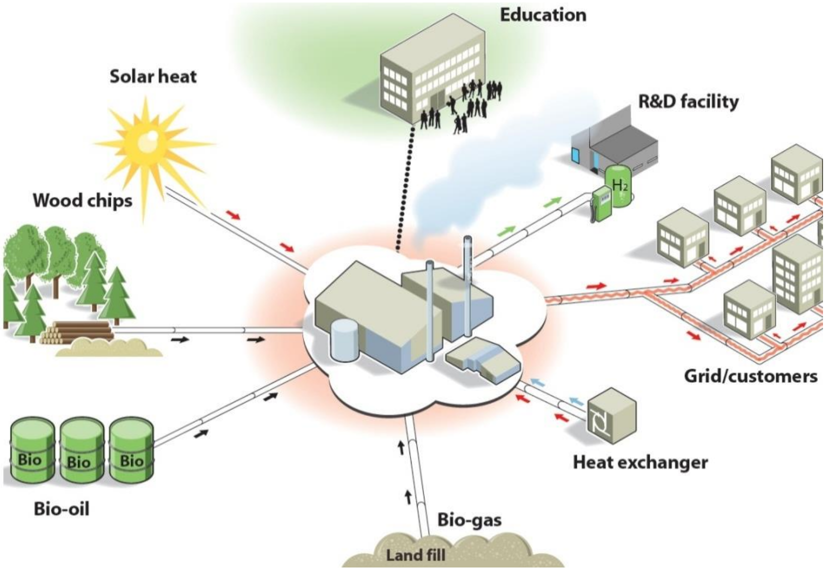


Figure 7 District heating scheme [10]

District heating plants can provide higher efficiencies and better pollution control than localized boilers. According to some research [11], district heating with combined heat and power (CHPDH) is the cheapest method of cutting carbon emissions, and has one of the lowest carbon footprints of all fossil generation plants. Also, is one of the most interesting strategies to improve (refurbishment project) the energy performance of a city or a district.

Through a district heating network, the heat producing plant pumps heated supply water to consumers where it is used as room-/floor-heating and to generate domestic hot water. The domestic hot water gets heated in a heat exchanger in which the heated supply water transfers its heat to the water coming out of the taps.

For room heating, the supply water might be used directly. Alternatively, a heat exchanger could also transfer the heat to an internal circulation. The supply water – which is now cold because the heat has been transferred to domestic hot water and room heating – then returns to the district heating plant. The district heating supply water circulates endlessly in a closed pipeline.

Some district heating systems use steam as medium for heat distribution instead of water. This is to achieve higher supply temperatures, which are often necessary for industrial processes. A disadvantage of steam is that it has higher heat losses than water.

7.2.2.2 Components

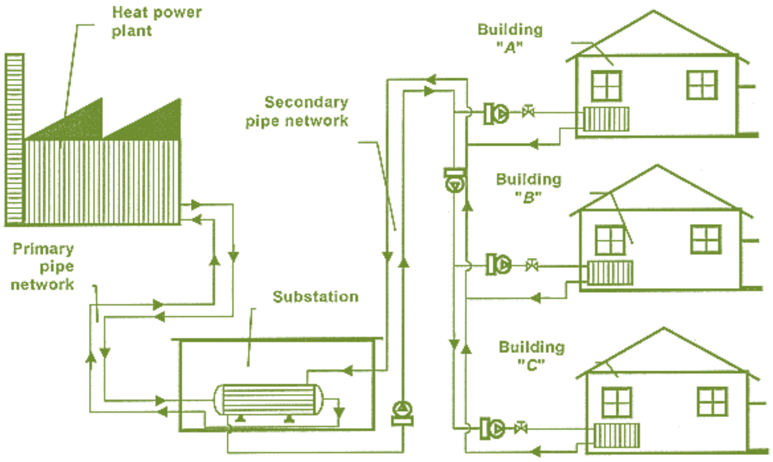


Figure 8 District heating/cooling elements

- **Thermal generation plant**: Centralised heat and / or cold production in a large installation that generates thermal energy required to meet the demand of all users. Thermal energy can be generated by turbine engines, biomass thermal plant, cogeneration system, waste heat recovery system and / or solar plants. The most important is that the energy is generated at a single point, optimizing performance of the entire system
- **Distribution pipe network:** The distribution pipe network enables the supply of fluids (hot and/or cold) and is formed by isolated pipes to minimize heat losses. Usually the pipes are distributed in underground drains that follow the layout of streets in urban areas.
- **Substations:** The heat transfer between the distribution network and consumers (buildings or homes) is done through a substation. It consists on a heat exchanger, the elements that regulate and control the correct operation and the measuring elements to bill the energy.

7.2.2.3 Advantages

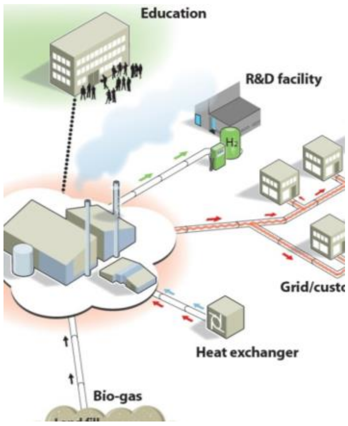
- Enables the use of renewable energy, waste, local and more efficient technologies such as cogeneration.
- **Space**: It saves useful space in buildings because it's not necessary to have energy production systems.
- **Cost savings for users:** Bill reduction and any need to invest in equipment, maintenance and / or renovation.
- **Energy efficiency**: Installations are more energy efficient because of the centralized management and maintenance. It reduces environmental impact and primary energy.

7.2.2.4 Disadvantages

- Efficiency depends on critical parameters.
- **Temperature of the network**: if the water temperature is lower the net energy efficiency of the system is higher.
- **District density**: increasing the density of the built area, the implementation of district heating systems is more favourable.
- **High Investment cost** to be discounted in a long period.
- **Heat demand**: for very low heat demands (new buildings), district heating is not viable.

7.2.2.5 ECM Table example – District heating technology

Table 25: ECM – Active strategy District heating Technology

Passive Strategy: District Heating Technology	Generic data	**Description**		
		This generation and distribution system is composed by 3 elements: -Thermal generation plant: Centralised heat and / or cold production that generates thermal energy required. Thermal energy can be generated by turbine engines, biomass thermal plant, cogeneration system, waste heat recovery system and / or solar plants. - Distribution pipe network. It enables the supply of fluids (hot and/or cold) and minimizes heat losses. Usually is placed underground. - Substations. It consists on a heat exchanger; it controls the correct operation and the measuring elements to bill the energy.		
		Application		
		District heating/cooling is a system for distributing heat/cool generated in a centralized location for residential and commercial requirements such as space heating/cooling and water heating. This system is one of the most interesting strategies to improve (refurbishment project) the energy performance of a district or a city.		
		Limits	Historic building	NO, In historic districts is normally limited. Review regulation
			Economic Cost	DEPEND, High cost, depends on the economics
		Advantages	-It saves useful space in buildings. Energy production systems are not necessary. -Enables the use of renewable energy, waste, local and cogeneration. -Cost savings for users. -Installations are more energy efficient because of the centralized management and maintenance. It reduces environmental impact and primary energy.	
		Disadvantages	-Network temperature: the efficiency of the system is higher in low temperature -District density: increasing the density of the built area, the implementation of district heating systems is more favourable. -District size: a number of users connected to the net must be guaranteed. -High Investment cost to be discounted in a long period. -Heat demand: for very low heat demands, district heating is not viable.	
		Social acceptation	Normally there are not any problems related to the social acceptance.	
		Constraints	-Technologic: difficulty to integrate in the energy system due to the low energy demand of the assessed district -Geographic: difficulty to integrate in the energy system due to the urban morphology or location (distance between generation and energy consumption points) of the energy generation	
		nº of jobs / MW inst		
	Technical data	**Energy data**	Thermal resistance [(m2*K)/W]	Necessary
			Energy performance [%]	High efficient boiler, natural gas -> 0,95
				Biomass boiler -> 0,8
			Energy generation	Internal algorithm
		Environmental data	*Production impact (A1-3)*	**Import from NEST**
			Installation impact	**Import from NEST**
			Maintenance impact	**Import from NEST**
			End of life impact	**Import from NEST**
		Economic data	Production cost (€/m2)	Boiler --> (according to the power)
			Installation cost (€/m2)	Distribution pipes --> 150 €/m
			Maintenance cost (€/m2.a)	Information not available
			End of life cost	Information not available
			Financing information	Information not available
		Application scale	Building level	NO
			District level	YES
		Installation data		
		Maintenance data	Check the appropriate performance of the system: reduce losses, regulate the energy generation performance system, control of the energy demand…	
		Operation requirements	Optimize the energy generation system	
		Estimated Service Life	50	

7.3 HVAC control strategies

Control methods described in this section are system-level control strategies which apply to all systems where it is possible and advantageous to coordinate multiple supply sources with energy storage to fulfil building and district energy demand. This includes micro-grids and HVAC systems installed in buildings as well as district heating & cooling systems and networks. Typical control goals are reduction of energy consumption, reduction of energy cost and reduction of environmental pollutions, while maintaining the thermal comfort.

Table 26: HVAC Control Strategies

HVAC Control Strategies	*B-System Level Control*	*B1-System Scheduling*	
		B2-Optimal Start-up and Shut-down	
		B3-Optimization Based Control	*B3.1-Energy Based*
			B3.2-Cost Based
			B3.3-Emission Based

We consider more in detail the case of district heating system introduced in section 7.2.2. In this section, we refer to figure 19 which illustrates the schematic of a system including relevant data acquisition and control blocks. Configuration and size of a district heating system is often determined by the shape of the annual energy demand curve. Usually, the district level supply is sized to fulfil the base-load whereas backup boilers are included to balance the energy demand fluctuations and supply the demand peaks. Moreover, a further demand balancing action can be performed by the energy storage – where installed. The adoption of energy storage units enables to partially decouple the energy supply from the current demand. In this way, oversizing of the backup equipment can be avoided and a better exploitation of the base-load supply is achieved, since they can run for a longer period of time closer at maximum efficiency operating conditions.

The most relevant examples of system-level control strategies are Scheduling, Optimal Start and Stop and Optimization-Based Control. Most sophisticated strategies enable the coordination of different energy supply systems as well as thermal storage for variable grid energy tariffs.

The *Scheduling-based control* is a basic – yet quite powerful – function of an energy management system (EMS) enabling the control of systems using a table with a start/stop time and related set-points. The scheduling function included in modern building management systems enables the control of individual zone temperatures thereby maintaining the environmental comfort while guaranteeing that the system is not operated during unoccupied hours.

The *Optimal Start and Stop* is a control strategy that takes into account zone temperatures and the thermal inertia of the building to anticipate the start or the stop of the controlled system such that the thermal comfort requirements are met at the beginning of the occupied period and until its end. Anticipated start of heating or cooling system enables it to meet the temperature set-point when occupants come into the building. Anticipated stop shuts down the system prior to the normally scheduled time such that the shut-down effect is not felt before the occupants have left.

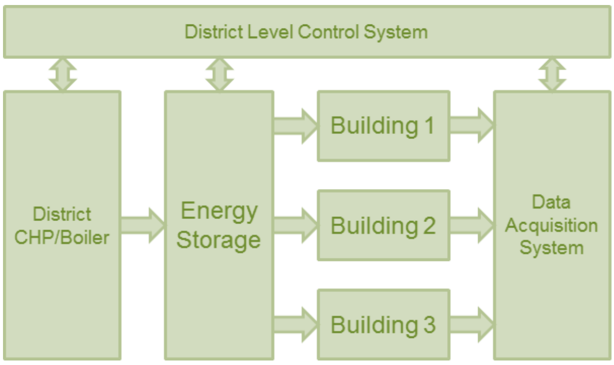


Figure 9 District heating/cooling control system elements

In the next section, we will consider in more detail the *Optimization-Based Control* and its application to energy system control at building and district level.

7.3.1 Optimization Based Control [12][13]

7.3.1.1 Introduction

The Optimization-Based Control considered in this section is a predictive control method that enables the scheduling of one or more energy supply systems and/or storage components such that a conveniently chosen objective function is minimized [1-2]. Typical objective functions are related to predicted energy cost or deviation from temperature set-point. Prediction of system schedules is obtained over a convenient time horizon exploiting forecasts of electrical and/or thermal load consumption and/or inputs such as external temperature and building internal heat gain. Typically, a day ahead time horizon is considered when the grid energy tariff is included in the predictive control algorithm.

7.3.1.2 Requirements / Limitations

In this section, we consider high level requirements to determine the hardware and software infrastructure needed to implement the optimization-based control strategy.

First of all, application of the Optimization-Based Control Method described in the previous section requires the computation of a number of forecasted profiles as well as availability of an optimization engine including a relevant mathematical programming solver.

Relevant historical data about building/district energy consumption, environmental data (for example: outdoor air temperature, wind speed, solar irradiance) and building operation (for example: building occupancy) need to be gathered from relevant sensors and data acquisition systems and stored in a data-base for subsequent processing.

After processing the raw data to determine forecasted profiles and actual optimization of the system operation, information can be directly sent to the controlled subsystems (such as CHP, Boiler and Batteries) via a relevant middleware or sent to a facility manager who will take the responsibility of implementing the optimized schedules.

7.3.1.3 Types

There are different types of optimization based control depending on the objective. Furthermore, objectives can be combined in a weighted sum. Typical objectives are:

- **Energy based:** The controller aims at minimizing the energy supplied to the building while ensuring that the comfort of occupants is guaranteed in the occupied period.
- **Cost based:** The energy required by the building (including electrical and thermal) is supplied in the most cost-effective way – possibly including load shifting (by means of energy storage) – from a time of the day when energy purchased from the grid is more expensive to a time of the day when it is cheaper.
- **Emission based:** It aims at supplying the required amount of energy such that the emissions are minimized to reduce the environmental impact and/or to avoid penalties

7.3.1.4 Components / Installation

Implementation of the described strategy requires the installation of a number of hardware and software components:

- Sensors and Data Acquisition Systems
- Data-Base System to store and retrieve building and environmental data
- Mathematical Software for Data-Driven Modelling and Forecasting (for example, System Identification, Neural Networks)
- Mathematical Software for Mixed Integer/Linear/Nonlinear Programming

- Middleware and Actuation Devices (Optional).

7.3.1.5 Advantages

- **Energy savings:** the benefits include a reduction in the energy consumption for the system/building/district under maintaining the comfort of building occupants.
- **Cost savings:** energy savings are likely to yield cost savings as well but energy cost based optimization can independently yield savings as well. In this case, cost savings are obtained by supplying the load in the most cost effective way selecting different energy sources and shifting the load by means of storage. In general, savings on the order of 10% have been previously demonstrated at the district level.
- **Healthier environment:** for emissions based optimization, the benefits commonly include reductions in CO_2 and other emissions which can impact the environment. Previous investigations have demonstrated district level CO_2 emissions savings are achievable by means of improved exploitation of local resources.

7.3.1.6 Disadvantages

Optimization based control has great potential for energy, cost and emissions reductions, but there are some limitations to the approach including:

- **Commissioning effort:** with the present state of the art, such solutions often need to be customized to each particular component of the system, incorporating in the optimization algorithm the proper component models and parameters.
- **Scalability:** Most of the work on optimization based control refers to centralized solutions applicable to a single building. Scalability to a district-level has been investigated and more recent work shows that hierarchical optimization algorithms can tackle the problem of energy management for the multi-building case accounting for energy cost and CO_2 emissions. Scalability of such technologies up to large districts poses requires adequate ICT infrastructures, for example Cloud-based [1].
- **Expertise:** development and implementation of optimization based controls requires a level of technical expertise higher than classical, standard controls when applied to new systems/buildings/districts.
- **Costs:** Some of the computing requirements for implementation of the approach can require some additional software components not commonly found in existing building management systems.

7.3.1.7 Costs

Of the components required for implementation of optimization based controls, the sensor and data acquisition system as well as the data storage system are likely to be found in many installations. Therefore, these two components would not represent an additional cost for using this approach. On the other hand, the mathematical software component gives an additional cost in the order of €3000. The optional middleware cost is more difficult to estimate, being that a customized, proprietary, solution.

7.3.1.8 Conclusions

In conclusion, optimization based controls offer the potential for energy, cost and emissions reductions using the existing HVAC or district heating systems and advanced computing capabilities.

It is important to note that while optimization based controls often focus on energy, cost and emissions reductions, an important constraint that must be considered in all cases is the need to maintain the comfort level of the occupants (if not improve it) to meet the accepted standards for each application.

7.3.1.9 ECM Table example – Optimization Based Control

Table 27: ECM – Active strategy Optimization Based Control

Strategy	Data	Field	Item	Value
Passive Strategy: Optimization Based Control	Generic data	**Description**	It is a predictive control method that enables the scheduling of one or more energy supply systems and/or storage components such that a conveniently chosen objective function is minimized. It accounts for energy grid price and forecasted electrical and thermal energy demand. Typical objective functions are related to predicted energy cost or deviation from temperature set-point.	
		Application	It needs the application of hardware and software components: -Sensors and Data Acquisition Systems -Data-Base to store energy consumption and environmental data -Math Software for Data-Driven Modelling and Forecasting -Math Software for Mixed Integer/Linear/Nonlinear Programming	
		Limits	Historic building	NO, In historic districts is normally limited. Review regulation
			Economic Cost	DEPEND, High cost, depends on the economics
		Advantages	-Energy savings: Reduction in the energy consumption for the building or district. -Cost savings: Cost savings are obtained by minimizing the predicted energy cost. -Healthier environment: Reductions in CO_2 and other emissions which can impact the environment by means of improved exploitation of local resources.	
		Disadvantages	-Commissioning effort: solutions need to be customized to each particular application of the concept to a particular system (building, district). -Scalability: Most of the work on optimization based control refers to centralized solutions applicable to a single building. Deployment on large districts requires adequate ICT infrastructures. -Expertise: Technical expertise required. -Costs: It may require expensive software not found in existing building management systems and also a personal computer for their implementation.	
		Social acceptation	Normally there are not any problems related to the social acceptance.	
		Constraints	-Computation of a number of forecasted profiles as well. -Availability of an optimization engine including a relevant mathematical programming solver. -Relevant historical data needed about building/district energy consumption, environmental data and building operation for subsequent processing.	
		nº of jobs / MW inst	-	
	Technical data	**Energy data**	Thermal resistance [(m2*K)/W]	Insulation data and weather conditions used to estimate building thermal demand.
			Energy performance [%]	>10% - Internal algorithm
		Environmental data	*Production impact (A1-3)*	**Import from NEST**
			Installation impact	**Import from NEST**
			Maintenance impact	**Import from NEST**
			End of life impact	**Import from NEST**
		Economic data	Software cost (€)	€3000
			Installation cost (€/m2)	-
			Maintenance cost (€/m2.a)	Information not available
			End of life cost	Information not available
			Financing information	Information not available
		Application scale	Building level	YES
			District level	YES
		Installation data	-Optimization software used to run the control algorithm on a computer. -Dedicated software functions or middleware to read data from sensors and apply optimized set-points and control actions.	
		Maintenance data	-No maintenance required other than keeping the software licenses updated.	
		Operation requirements	Presence of building/district manager required to restore the normal operation of the system after a fault or maintenance operations or to implement the optimized set-points where this functionality is not implemented automatically.	
		Estimated Service Life	Same lifecycle of other installed components.	

8 Initial guidelines for the maintenance of the catalogue

For assuring the quality of the catalogue along the time, it will be needed a periodic maintenance. A common system for doing this maintenance should be described in a guideline that will take into account the requirements of control quality described in the section 3.1.

The first step to develop the future guide for the ECMs maintenance will be the description of some steps to follow in order to stablish an initial guideline; the next recommendations are examples of possible actions to follow in order to maintain the catalogue:

- The catalogue could be reviewed in a certain period of time (this period of time will fluctuate with the different technological innovations, but should be around 1 year) during the demonstration of the OptEEmAL project.
- The catalogue could be also updated each certain period of time (this period of time will fluctuate with the different technological innovations, but should be around 1 year) because of the possible modifications in each measure.

The maintenance should be done from a specific user of the catalogue (the ECM catalogue user) that will be in charge of eliminating, replacing or crating new entrances in the catalogue. These first recommendations for the maintenance of the catalogue should be much related to the identification, modification and elimination of out-of-date measurements, and their substitution by up-to-date ones. In the next image some ideas can be taken for the future guide of maintenance.

Figure 10 http://websupportindia.com/catalog-management

9 Conclusions

The results from this document have as main purposes to:

- **Make possible the formalization of the ECMs.** For accomplishing this, there has been described the technical requirements that the catalogue has to comply with. Then it has been described the taxonomy of the set that gave us the structure of the catalogue itself. With all this information and also adding details about the implementation of the catalogue in the platform, it was possible to give some specific examples of the information the measure has to contain and thus it was also possible to specify the structure and content that the measures are going to have.
- **Identify how the ECMs in the catalogue have to be developed.** Having the requirements (functional and non-functional) and the structure developed, the development of the measures has a clear path to follow.

From the document content we can foresee that:

- **One of the main issues that the ECMs catalogue has to face with is the fact that it is going to work inside an "Energy model"** so that it will be easier the closer to that model the instance will be defined.
- **Probably the solution will be database agnostic.** The only constraint will be to use one with the capability of using SQL (simple query language and thus, relational).
- The implementation has to be deeply made because **the catalogue is going to have a huge impact** in the whole platform.
- **The maintenance of this catalogue will be based on the data quality control requirements** in order to stablish a future guideline for the maintenance.
- OptEEmAL needs more developments performed within WP2 and WP4 to continue improving the content and format of the ECMs catalogue according to developments in D4.1 (intermediate version), partners can value different requirements for the ECM catalogue

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