OptEEmAL

THE SOLUTION FOR DESIGNING YOUR ENERGY EFFICIENT DISTRICT RETROFITTING PROJECT!

OPTIMISED ENERGY EFFICIENT DESIGN PLATFORM FOR REFURBISHMENT AT DISTRICT LEVEL

OptEEmAL Final Booklet

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680676.

PROJECT ID

Duration: 42 months (September 2015 – February 2019)

Partners: 13 partners from 8 countries
(France, Germany, Greece, Ireland, Italy, Spain, Sweden, Turkey)

Coordinator: CARTIF Technology Centre

Call identifier: H2020-EeB-2014-2015 / H2020-EeB-2015

Topic: EeB-05-2015 Innovative design tools for refurbishment at building and district level

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1 PREFACE

The design of retrofitting projects for existing buildings still suffers from needless fragmentation, long processes and uncertainties. This hinders the building stock from becoming more sustainable and contributing to the EU's ambitious targets of 40 % emissions reduction by 2030. This is reflected in the current renovation rates of ~1.5 %, which are still too low. Therefore, new solutions that facilitate collaboration and improve the whole process are demanded by the retrofitting sector.

The fragmentation of the retrofitting market with multiple stakeholders with different and often conflicting interests is mirrored in the communication among them. Traditional collaboration methods provoke inefficiencies in the process of modelling, evaluating and selecting retrofitting alternatives. New paradigms are therefore required, such as the implementation of Integrated Delivery Methods (IPD), in order to reinforce collaboration and ensure the appropriate involvement of stakeholders from the beginning of the process.

Evaluating candidate alternatives poses also a big challenge for the stakeholders of the process, and the time required to define, model and simulate them is too time-consuming to consider a good range of solutions. This limits the space of alternatives and sometimes hinders the implementation of combinations of technologies that could benefit the project in a greater manner. Furthermore, the use of different tools to model and simulate the retrofitting scenarios obliges to create ad-hoc models due to the lack of interoperability among tools.

The above is prone to errors in modelling and, added to the lack of information about some technologies and their related costs or benefits, turns into increased uncertainties along the process. This lack of credible information results in an increased risk that prevents, in most cases, investments in retrofitting.

Acknowledging these challenges, OptEEmAL has been working during 42 months to deliver a platform that aims at solving these issues through offering stakeholders with functionalities that automatically perform a diagnosis of the district, propose candidate scenarios, evaluate and optimise them, and provide the required data for an improved design of a retrofitting project, using the necessary tools for each step. The integration of such tools, interoperability mechanisms and catalogues of technologies to improve energy efficiency and optimisation methods has been our working field leading to a successfully integrated platform and a number of progresses beyond the state of the art that will have a big impact on the scientific community and the society.

Preface

In summary, we have worked towards reducing fragmentation, time and uncertainties of the process in order to become THE solution for designing your Energy Efficient District Retrofitting project.

OptEEmAL Kick-Off Meeting, 6-7 October 2015, Valladolid, Spain

Our consortium has worked with great efforts towards these objectives in an unbeatable environment of trust, mutual support and continuous learning, which we hope is reflected in these pages you now have in your hands. Enjoy reading!

Miguel Á. García-Fuentes   Susana Martín-Toral

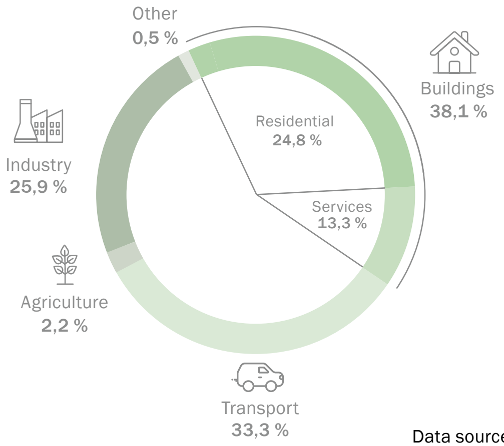
OptEEmAL Project Coordinators

CARTIF Technology Centre

2 INTRODUCTION

ENERGY EFFICIENCY IN BUILDINGS AND RETROFITTING: FACTS & FIGURES

Cities across Europe are growing and continue to consume increasing amounts of energy. Among often neglected sources of emissions responsible for climate change are buildings. EU statistics still find buildings are responsible for approximately **40 % of energy consumption** and 36 % of CO_2 emissions **in the EU[1].**



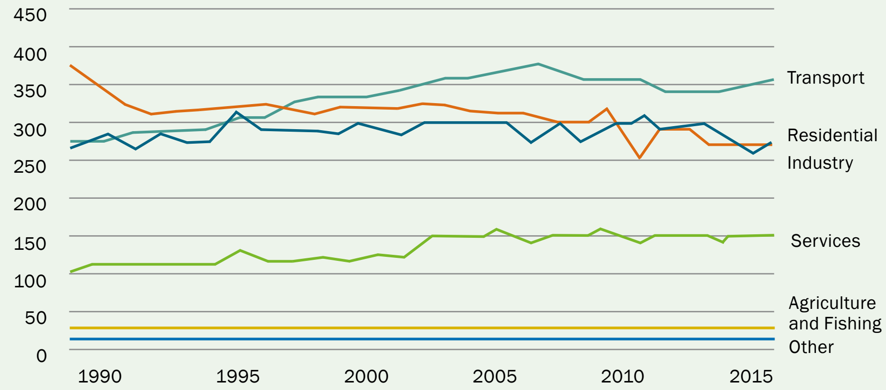
Data source: Eurostat, 2014

ENERGY EFFICIENCY AND EU POLICY[2]

Until today, the 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive are the EU's main legislative instruments promoting the improvement of the energy performance of buildings within the EU and providing a stable environment for investment decisions. Member States needed to transpose them into national legislation.

On 19 June 2018, **Directive (2018/844/EU)** amending the Energy Performance of the Buildings Directive was published. It entered into force on 9 July 2018. The new amendments aim at accelerating the cost-effective renovation of existing buildings, with the vision of a decarbonised building stock by 2050 and the mobilisation of investments. Member States will have 20 months to transpose its provisions into national law (namely by 10 March 2020).

Under the current Energy Efficiency Directive, for example, EU countries had to draw up long-term national building renovation strategies which can be included in their National Energy Efficiency Action Plans. Under the **new, revised Energy Performance of Buildings Directive (EPBD)**, EU countries must establish stronger long-term renovation strategies, aiming at decarbonising the national building stocks by 2050, and with a solid financial component.



Final Energy Consumption by Sector

Source: European Commission (2017). EU Energy in figures. Statistical Pocketbook 2017, 85.

The **2010 Energy Performance of Buildings Directive** has made it possible for consumers to make informed choices that will help them save energy and money, and has resulted in a positive change of trends in the energy performance of buildings. Following the introduction of energy efficiency requirements in national building codes in line with the directive, today, new buildings consume only half as much energy as typical buildings from the 1980s.

However, about 35 % of the EU's buildings are over 50 years old and almost 75 % of the building stock is energy inefficient, while only 0.4 – 1.2 % (depending on the country) of the building stock is renovated each year. Therefore, more renovation of existing buildings has the potential to lead to significant energy savings – potentially reducing the EU's total energy consumption by 5 – 6 % and lowering CO_2 emissions by about 5 %.[3]

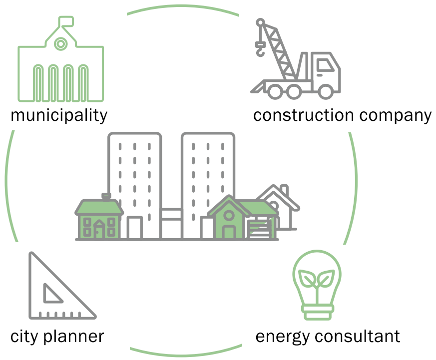
WHILE NEWEST KNOW-HOW AND TECHNOLOGIES CAN BE INTEGRATED INTO NEW BUILDINGS AND CONSTRUCTION PROCESSES, WE STILL NEED BETTER SOLUTIONS TO REDUCE ENERGY CONSUMPTION IN EXISTING BUILDINGS AND CITY INFRASTRUCTURES, WHICH STILL MAKE UP THE LARGEST PART OF THE CITY INFRASTRUCTURE ACROSS EUROPE.

RETROFITTING CHALLENGES AND THE OPTEEMAL SOLUTION

The OptEEmAL Platform will change energy efficient design of retrofitting projects. Improving the energy efficiency of buildings not only generates economic, social and environmental benefits. Better performing buildings also provide higher levels of comfort and wellbeing for their occupants, and improve health by reducing illnesses caused by a poor indoor climate. They also have a major impact on the affordability of housing and on energy poverty.

Investments in energy efficiency also stimulate the economy, in particular the construction industry, which generates about 9 % of Europe's GDP and accounts for 18 million direct jobs. SMEs would particularly benefit from a boosted renovation market, as they contribute more than 70 % of the value added in the European building sector.

In retrofitting projects, municipalities, city planners, energy consultants, construction companies and many other stakeholders need to work together. They all use different planning tools and concepts, making it hard to communicate. With the OptEEmAL Platform, they have the chance to collect all their data in one place and translate it into one language and thus, overcome those challenges to provide customised and high-end solutions for the retrofitting of buildings and entire districts.



To develop and implement the best possible refurbishment solutions for existing buildings, all stakeholders need to be involved from the start to reduce costs and increase the relevance and impact of the refurbishment projects. The social and economic contexts of urban planning have to be considered to reach better and more holistic energy efficiency solutions across Europe.

The OptEEmAL Platform allows its users and stakeholders to create an optimised, integrated and systemic design for their retrofitting projects of buildings or entire districts. It automatically calculates the "OptEEmAL" retrofit scenario and helps choose the best retrofit solution in terms of costs and benefits. OptEEmAL is based on a cloud system and latest construction modelling tools, which makes its results most accurate. Involving all stakeholders during all project phases, the platform helps to avoid conflicts and reduces time and resources needed, thus saving at least 19 % of the retrofitting costs. OptEEmAL makes retrofitting easier and more profitable for all people involved.

3 OPTEEMAL PROJECT

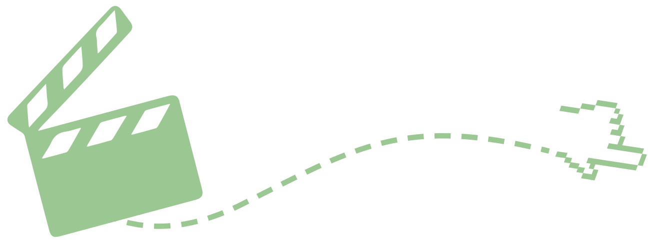
3.1 MISSION AND OBJECTIVES

OptEEmAL explained: An Integrated Solution to design your Energy Efficient District Retrofitting Project

OptEEmAL is a project, funded under the European Union's Horizon 2020 research and innovation programme, in which 13 partners from 8 countries are working on delivering an optimised, integrated and systemic design tool for building and district retrofitting projects based on an Integrated Project Delivery approach.

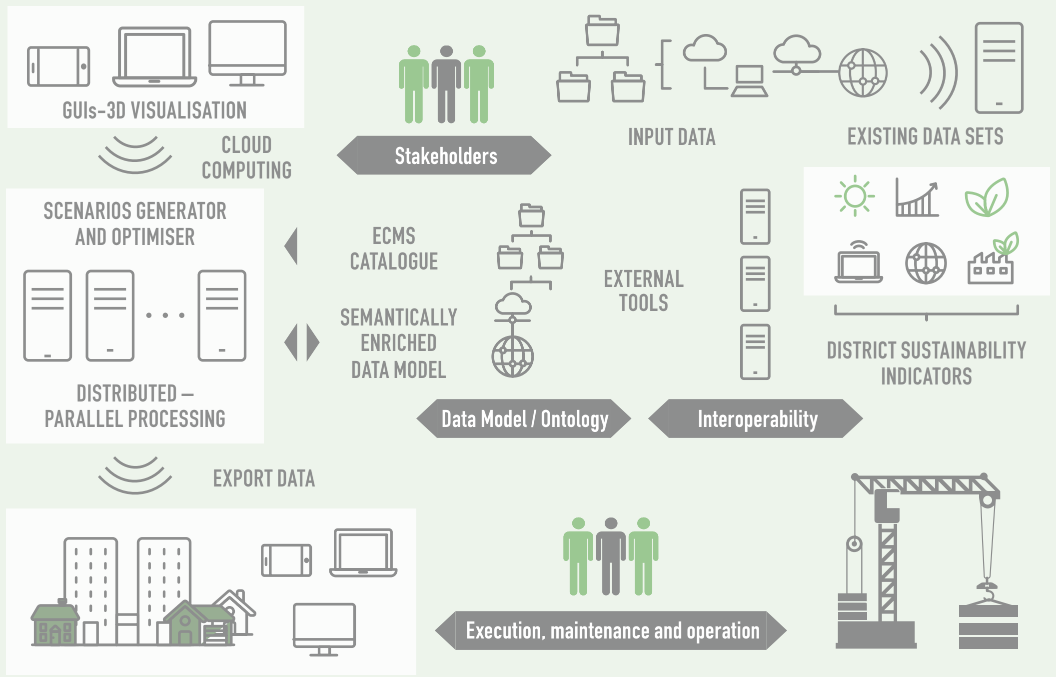
This Optimised Energy Efficient Design Platform was developed to design energy efficient retrofitting projects that are based on different **energy conservation measures** to improve the energy performance of buildings and districts. The tool will reduce time delivery and uncertainties and result in improved solutions when compared to business-as-usual practices. The platform will provide automatic and accurate calculation of the best possible scenarios for district retrofitting projects.

Watch our introductory **OptEEmAL video** here.



Our main objective is being achieved through a **mix of development and testing activities**, including:

- Developing a **holistic and automated services platform**, integrating interoperable modules and tools for diagnosis and generating optimised district energy retrofit scenarios according to user preferences.
- Reinforcing the **commitment of all stakeholders involved** through an Integrated Project Delivery approach allowing them to articulate their needs through a collaborative and value-based process.
- Creating an integrated ontology-based **District Data Model** containing key information on energy, comfort, environment, economic and social well-being and urban morphology.



Concept of the OptEEmAL project

- Cataloguing **Energy Conservation Measures** including technical, operational, maintenance and cost information providing valuable and consistent outputs for design, district operation and maintenance stages.
- Developing a **bio-inspired optimisation module** based on evolutionary computing that automates the decision-making process for an optimal energy efficient retrofitting plan at district level.
- **Externally connecting the OptEEmAL Platform** to relevant entities, i.e. existing Building Information Modelling (BIM) and CityGML tools, enabling the calculation of indicators to generate and optimise the retrofit scenarios.
- Strategic **dissemination, training, exploitation and market deployment** of the project's developments and results.

3.2 IMPACT OF THE OPTEEMAL PLATFORM

The OptEEmAL Platform provides stakeholders with an optimised, integrated and systemic design for their retrofitting projects of buildings and entire districts.

This leads to the following impacts:

- **High economic impact** through the reduction of costs by 19 % during the design phase compared to business-as-usual. Promotion of holistic solutions reduces costs of the operational phase by 25 % and leads to a higher return on investment.
- **Greater market competitiveness** through the utilisation of energy efficient solutions in a holistic integration and the improvement of the contractual processes.
- **Boost of the European construction sector** through the creation of new jobs and strengthening SMEs in the sector.
- **Promotion of social impacts** by involving the inhabitants in the decision-making process. This ensures that their expectations are met and increases user acceptance of the activities carried out, ultimately leading to an improvement of social well-being.
- **Dissemination of new knowledge at professional level** through specific information channels and trainings targeting relevant stakeholders and user groups.

TO HELP YOU UNDERSTAND HOW THE OPTEEMAL PLATFORM CAN SUPPORT YOU IN FINDING YOUR BEST RETROFIT SOLUTION, WE OFFER GENERAL AND TECHNICAL TRAININGS IN OUR DEMO CITIES.

Our trainings and consultations show you how the OptEEmAL Platform works and how it can help you get the job done. The trainings are organised in cooperation with our demo site partners in Lund (Sweden), San Sebastián (Spain) and Trento (Italy) and present the OptEEmAL project and its benefits to all stakeholders and potential users.

You are guided through the IPD implementation and trained on how to collect your input data, use the platform and make YOUR district retrofitting project work.

For more information on our OptEEmAL General and Technical Trainings, please contact our Coordinator (opteemal_contact@cartif.es) or Communication and Dissemination Secretariat (opteemal@steinbeis-europa.de) or visit www.opteemal-project.eu

3.3 OPTEEMAL PROJECT PARTNERS

The OptEEmAL consortium consists of 13 partners from 8 countries (Spain, France, Italy, Greece, Turkey, Germany, Ireland and Sweden), each one contributing specific knowledge to meet OptEEmAL objectives, according to their skills and role in the project.

The project partners represent key stakeholders within the value chain of the retrofitting design process of buildings and districts: research institutions, large industries, small and medium-sized enterprises, including technical offices representing the final user, public authorities, and an exploitation and dissemination/communication expert partner.

• **CARTIF Technology Centre** Spain	Project Coordinator of OptEEmAL and in charge of the overall platform design, ECO Tool and Evaluator Development
• **Fundación TECNALIA** Spain	Definition and Development of the Energy Conservation (ECMs) Catalogue, Development of the Optimisation Module
• **NOBATEK** France	Environmental Simulation, Platform Validation and Demonstration on Technical and Societal Levels
• **Fundació Privada Universitat i Tecnologia** Spain	Definition and Development of the Ontologies-based District Data Model (DDM) and Data Repository
• **Technical University of Crete** Greece	Development of District and Building-Level Performance Indicators, and Tools and Interfaces with Simulation Software
• **ACCIONA Construction** Spain	Stakeholders' Involvement and Retrofit Scenarios; Integrated Delivery Approach (IPD)
• **United Technologies Research Centre** Ireland	Energy Conservation and HVAC Simulation
• **Expert System** Italy	Main platform developer and integrator of Data Insertion and Data Exportation Modules
• **ARGEDOR Information Technologie Ltd.** Turkey	Graphical User Interfaces (GUIs)
• **Distretto tecnologico trentino per l'energia e l'ambiente** Italy	Demo site, Software Testing of Retrofit Analysis of existing Buildings in different Districts
• **Fomento San Sebastián** Spain	Demo site, Coordinator of smart activities in San Sebastián
• **City of Lund** Sweden	Demo site where the Calculation Tool is tested and implemented
• **Steinbeis-Europe-Zentrum** Germany	Dissemination, Communication and Exploitation of project results

4 PLATFORM FOR ENERGY EFFICIENT DISTRICT RETROFITTING DESIGN

4.1 STAKEHOLDER INVOLVEMENT

Pursuing energy-efficient buildings and districts is not only a challenge in terms of the complexity of the design and the analysis required, but also regarding the number of stakeholders involved. Moreover, each project is specific and it is not easy to identify the necessary stakeholders for all district retrofitting plans. EU-wide, each country has its own structural organisations.

The most common stakeholder involvement schemes based on a review of numerous district retrofitting plans in Europe are classified into three main categories:

- executive group,
- operational group and
- interest group

The **executive group** includes politicians, city planning and study departments, as well as developers or investors and building stock owners and managers. They are in charge of the direction in which a district retrofit should evolve and of the main objectives or constraints to be set. They are also influenced by the main regulations, including the energy directives. The second group is the **operational group**, which includes contractors, builders, service providers, network managers and planning, design and engineering offices. They hold the technical knowledge to carry out a district retrofit, as well as the main interest in terms of efficiency in the process and cost reduction. Finally, the **interest group** is represented by inhabitants and NGOs, which are in the end the beneficiaries of such energy retrofits.

The adequate communication among stakeholders as well as their representation in the decision-making process is crucial to avoid modifications in the project in future stages that may result in a cost increase. It is necessary to bear in mind that whereas in the retrofit of a building, the decisions to be taken are numerous and have a great impact on the results and final costs of the retrofit, in district retrofitting, this impact becomes exponential due to its complexity and dimensions.

OptEEmAL is a tool to support the decision-making process in district retrofitting. The two main groups of stakeholders represented in the project are the executive group and the operational group. The communication among them, as well as their confirmation in every relevant decision of the design of the project retrofit is granted within OptEEmAL. To do so, the Integrated Project Delivery approach, as it will be explained later, has been implemented. To this end, three actors have been defined to represent the different stakeholders (owner, prime designer and prime constructor) and mandatory interactions have been set at specific and relevant stages of the project. In addition, a chat has been integrated into the platform to assure the constant communication if required by the users.

4.2 MODULES AND TOOLS

INTEGRATED DELIVERY APPROACH

INTEGRATED PROJECT DELIVERY (IPD) IS A PROJECT DELIVERY APPROACH THAT INTEGRATES PEOPLE, SYSTEMS, BUSINESS STRUCTURES AND PRACTICES INTO A PROCESS THAT COLLABORATIVELY HARNESSES THE TALENTS AND INSIGHTS OF ALL PARTICIPANTS TO OPTIMISE PROJECT RESULTS, INCREASE VALUE TO THE OWNER, REDUCE WASTE AND MAXIMISE EFFICIENCY THROUGH ALL PHASES OF DESIGN, FABRICATION, AND CONSTRUCTION.[4]

One main difference to other project delivery approaches relates to the workflow boundaries. An Integrated Delivery implies a very high team involvement in the early phases of the design, determining what the project goals are, who will build and how the design will be realised.

Inputs from the broader integrated team coupled with BIM tools to model and simulate the project, bring the design to a higher level of completion before the documentation phase is started. Thus, the conceptualisation, criteria design and detailed design phases involve more effort than their counterparts in the traditional flow.

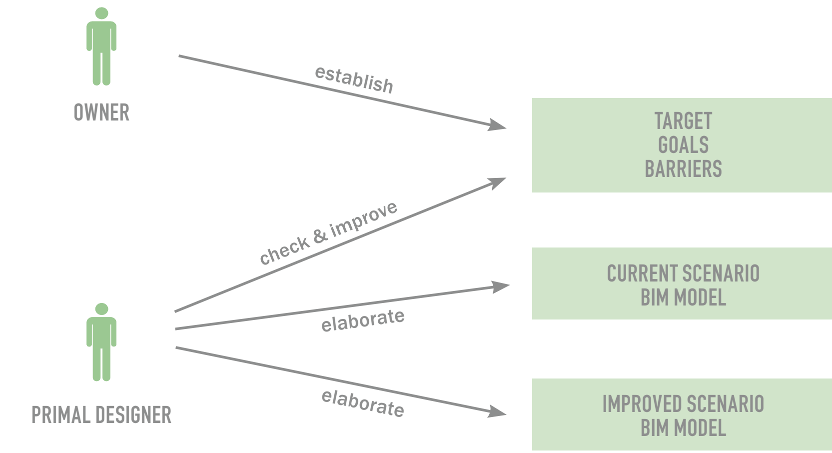
The implementation documention phase will be shorter than the traditional construction document phase, and the early participation of regulatory agencies, subcontractors and fabricators allows for a shortening of the agency review and buyout phases. As a result, the project is defined and coordinated to a much higher level prior to construction start, enabling a more efficient construction and a shorter construction period.

Traditional Project Delivery		Integrated Project Delivery
Fragmented, assembled on "just-as-needed" or "minimum-necessary" basis, strongly hierarchical, controlled	TEAMS	An integrated team entity composed by key project stakeholders, assembled early in the process, open, collaborative
Linear, distinct, segregated, knowledge gathered "just-as-needed", information hoarded, silos of knowledge and expertise	PROCESS	Concurrent and multi-level, early contributions of knowledge and expertise, information openly shared, stakeholders trust and respect
Individually managed, transferred to the greatest extent possible	RISK	Collectively managed, appropriately shared
Individually pursued, minimum effort for maximum return, (usually) first-cost based	COMPENSATION/ REWARD	Team success tied to project success, value-based
Paper-based, 2 dimensional, analog	COMMUNICATIONS/ TECHNOLOGY	Digitally based, virtual, Building Information Modeling (3,4 and 5 dimensional)
Encourage unilateral effort, allocate and transfer risk, no sharing	AGREEMENTS	Encourage, foster, promote and support multi-lateral open sharing and collaboration, risk sharing

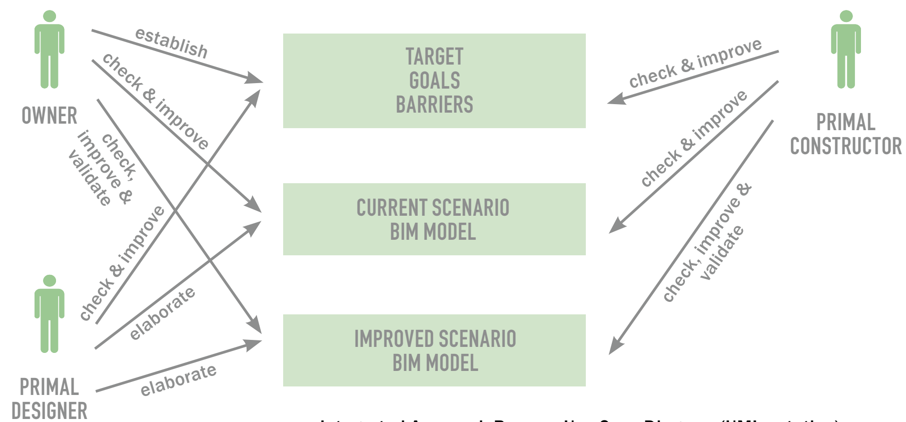
Project elements in Traditional and Integrated Project Delivery Approaches (Source: AIA / AIA California Council, 2007)

The changed conceptualisation of the elements is due to different ways of interaction between the different actors in the project. In a traditional approach, it is the owner who sets the goals, targets and barriers to the project without interaction or exchange with the prime designer who has to elaborate the actual and the optimised models depending on the information given by the owner – nor with the prime constructor.

In an integrated process, all the main actors (owner, prime designer and prime constructor) work together on the definition of the goals and targets. Together, they asses the actual scenario of the project and look for an improved scenario together.



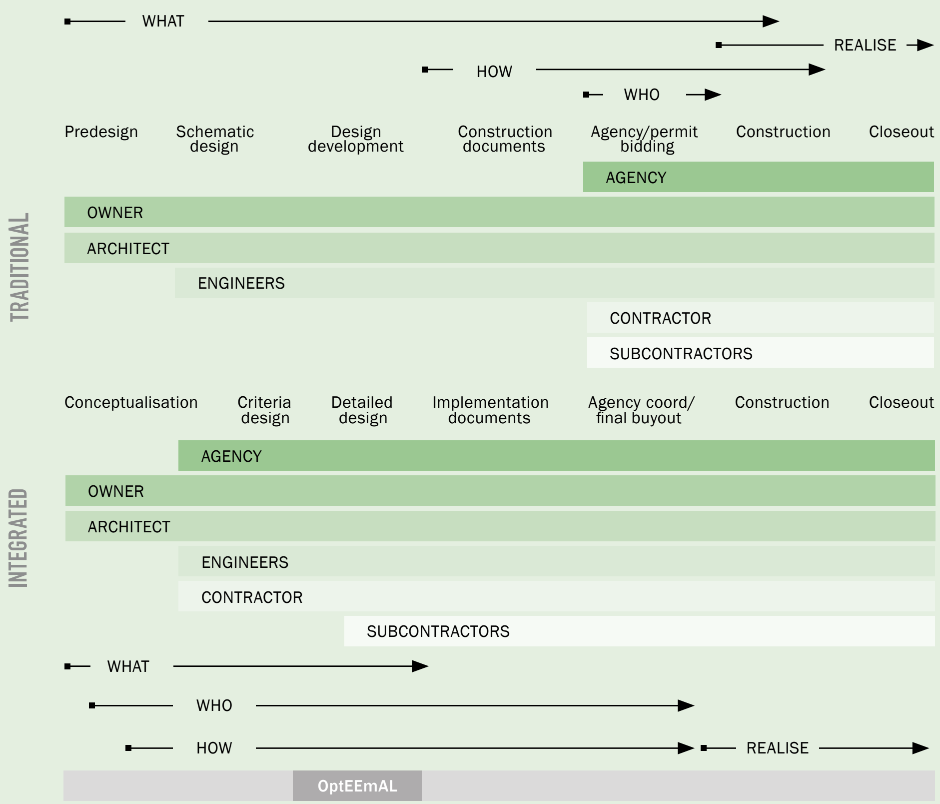
Traditional Approach Process Use Case Diagram (UML notation)



Integrated Approach Process Use Case Diagram (UML notation)

In OptEEmAL, the IPD approach is applied in the first phases of the project during which the conceptualisation, criteria setting and detailed design are carried out.

This process will provide all the documentation needed for the project implementation prior to the permission and bidding processes inherent to the project.



Traditional Delivery vs. Integrated Delivery. Edited from source: AIA / AIA California Council, 2007

> "The OptEEmAL project has drawn attention to the possibilities BIM offers. It has also shown how important it is to have a holistic approach to energy efficiency measures in which multiple actors' interests must be balanced."
>
> City of Lund, Sweden – OptEEmAL Project Partner

DATA INSERTION MODULE

This module is responsible for collecting input data from the user (e.g. login information) and project data, e.g. project name, description, CityGML and Industry Foundation Classes (IFC) files, which will be used in the optimisation phase. It also allows for preliminary checks and/or validation of such data, excluding CityGML and IFC file validations.

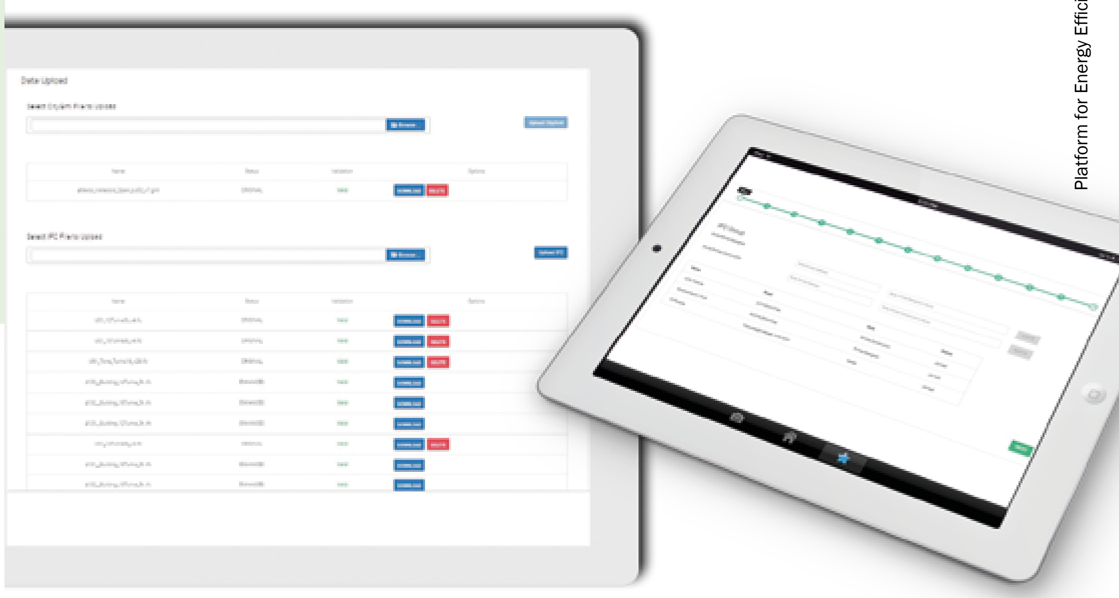
The inputs for the module are data related to the project such as:

- user's buildings data
- district data
- weather
- economic data
- targets and boundaries
- barriers and prioritisation criteria

The user is guided in every step of the data entry.

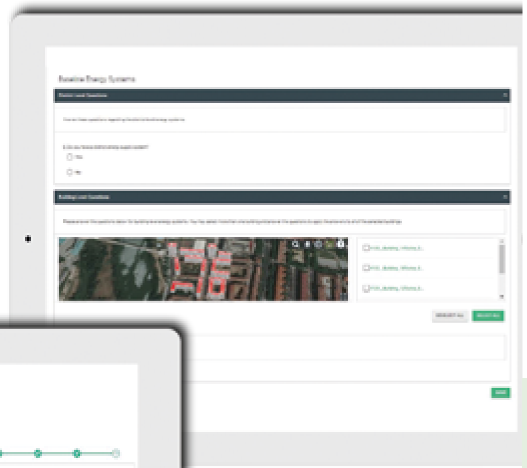
MAIN PROJECT DATA

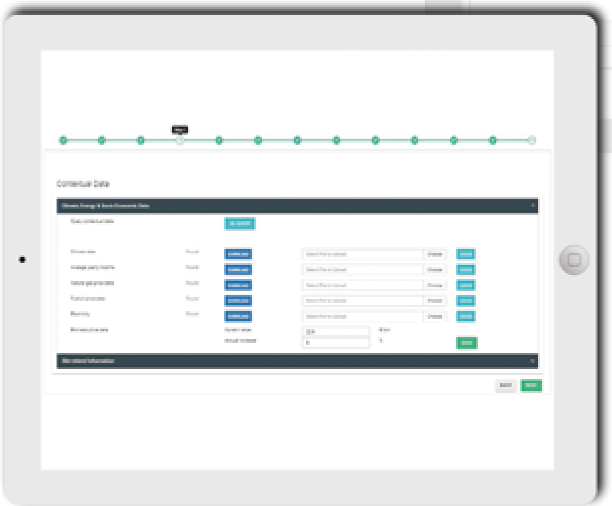
The user introduces general information on the project:



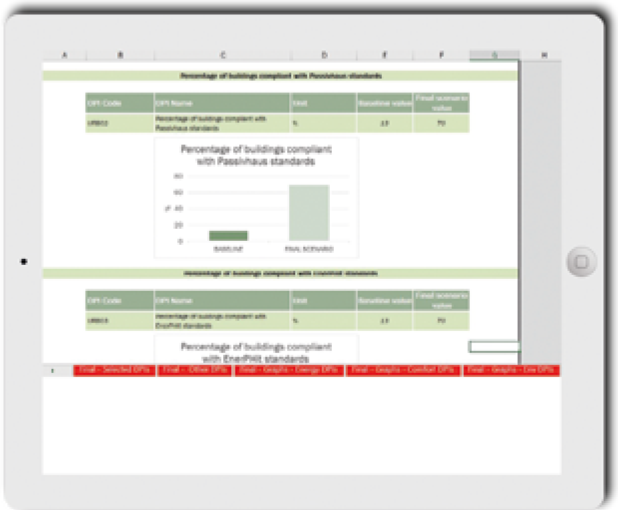
CityGML Upload

Baseline Energy Systems





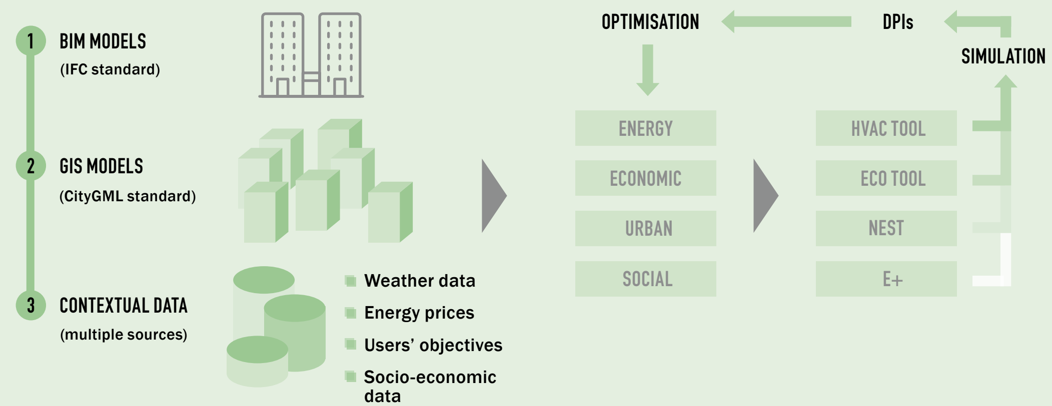
Contextual Data



Final Scenario for
Your Refurbishment Project

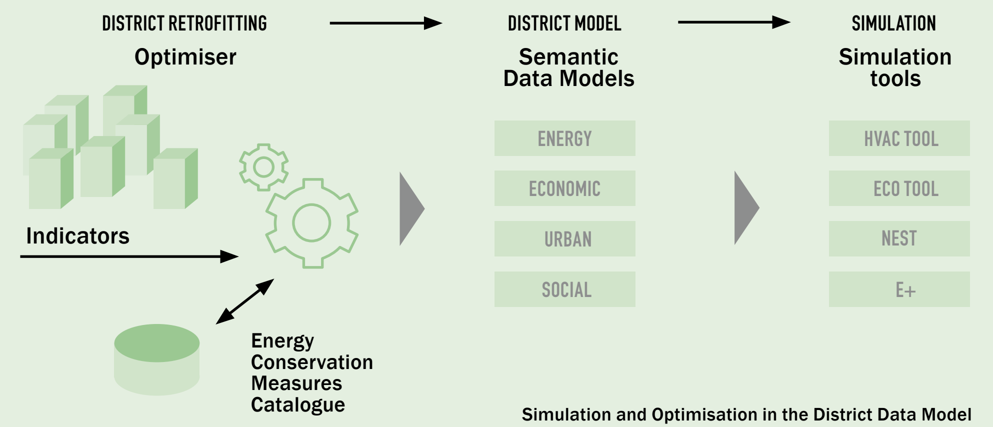
DISTRICT DATA MODEL

As a basis for calculating the district performance indicators of a district in different domains, the OptEEmAL District Data Model (DDM) collects information from different sources, such as BIM / Geographic Information System (GIS) models and contextual information (energy prices and weather conditions among others). The DDM ensures the interoperability between the data sources and a set of simulation tools that calculate district performance indicators.



From a Retrofitting Plan to a District Data Model

The DDM has been conceived as a unified multi-level data model based on semantically enriched existing standards such as IFC and CityGML. The data model is organised in different domains (e.g. energy, economic, social etc.) in which a vocabulary, i.e. ontology, has been implemented for each of the domains including all the terms and properties to model the data required as input for a simulation tool of a particular domain. This makes it easier to develop specific connectors for the simulation tools. For example, unique interfaces based on standardised communication protocols have been implemented to generate any input required by simulation tools (e.g. EnergyPlus, HVAC tool, NEST).



Simulation and Optimisation in the District Data Model

The DDM is populated following a set of data transformation and integration processes based on Semantic Web technologies. This makes the transformation processes transparent and enables the community to maintain them and create new ones. The transformation and integration processes take into account the semantic and structural heterogeneity between the data sources making the DDM an interoperability solution for the architecture, engineering and construction (AEC) industry.

> "An accurate and reliable generation of the initial BIM model (based on IFC) and CityGML file feeding the OptEEmAL Platform is mandatory for the success of their use. In order to help the experts to generate these IFC and CityGML files properly, IFC and CityGML guidelines have been generated in the scope of the OptEEmAL project as a contribution to the experts' community."
>
> CARTIF Technology Centre, Spain – OptEEmAL Project Coordinator

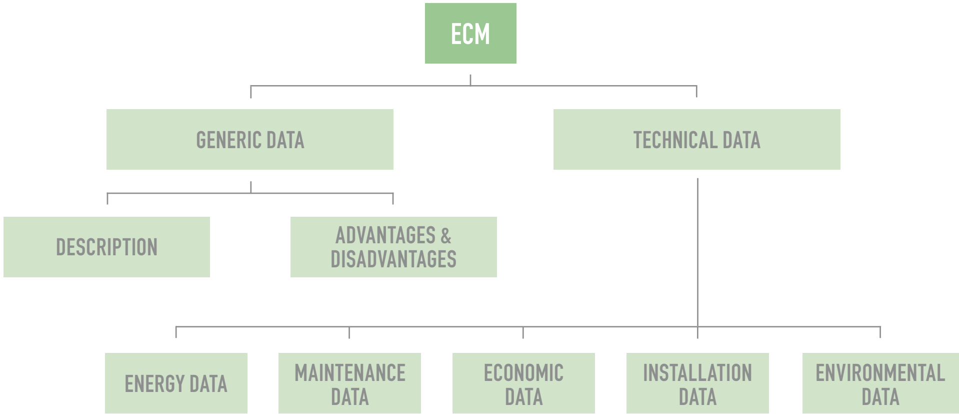
ECM CATALOGUE

The Energy Conservation Measure (ECM) catalogue is one of the main features of the OptEEmAL Platform. It sets the basis for the calculation of retrofit scenarios by applying a series of conventional and innovative renovating solutions, both at building and district level. This catalogue contains information about materials and equipment – for a wide range of measures – to reduce the district energy demand and consumption through Passive, Active, Control and Renewable Energy Source (RES) integration measures.

- **Passive ECMs** aim at achieving a significant reduction of the energy demand for heating and cooling.
- **Active ECMs** use traditional energy sources in the most efficient way possible.
- **Control ECMs** optimise the implementation and integration of active and control ECMs.
- **Renewable ECMs** use sustainable sources of energy like wind, sun and geothermal energy to meet the building's energy demand.

The ECM catalogue data model or structure is composed by numerous parameters that accurately define each renovating measure and allow for the calculation of different scenarios formed by a single or a combination of EMCs.

- Informative parameters will inform the user of the advantages, disadvantages, necessary maintenance and installation requirements of each ECM.
- Optimisation parameters will determine the barriers, targets and application scale of the ECMs. These parameters will be used by the optimisation module of the platform to determine the feasibility of each measure.
- Technical, economic and environmental parameters will be used to calculate the impact and reach of the renovating actions.



ECM Catalogue Data Structure

Additionally, the end user of the OptEEmAL Platform and the equipment manufacturers will have the possibility to include new personalised or commercial ECMs and components, widening the range of application of the OptEEmAL Platform by adapting it to specific refurbishment projects and commercial equipment.

> "Obtaining an Energy Conservation Measure (ECM) Catalogue containing all the information useful for the involved stakeholders in refurbishment projects is complex.Hence, a dynamic, active and updated ECM catalogue is essential to succeed in the kind of solution proposed by the OptEEmAL project."
>
> CARTIF Technology Centre, Spain – OptEEmAL Project Coordinator

MULTI-SCALE INTEGRATION FOR DISTRICT SIMULATION

The Simulation module, aiming at certain District Performance Indicators (DPIs) calculations, is supporting two key processes in the OptEEmAL platform: the data insertion and diagnosis process; and the scenarios generation and optimisation process. In both processes, data retrieved from proper Data Models (Energy, Energy Carrier, Urban, etc.) comply with certain groups of transformation rules to generate the required simulation input files:

- an XML file for every building of interest to be used as input to NEST[5] for the environmental DPIs calculation;
- ECO tool inputs for the economical DPIs calculation;
- Input Data Files (IDF) files for every building of interest, to be used as input to EnergyPlus[6] for the building envelop thermal simulation and computation of its energy loads; and
- multiple configuration files to be used as input to the HVAC tool for the energy and comfort DPIs calculation. Note here that within OptEEmAL, SimModel[7] has been chosen as the Energy data model.

> "To achieve functions like data retrieval, data transformation, execution of the simulation tools and computation of DPIs, new and existing, but modified components have been developed. The need for most of these components was stipulated in the design of the simulation module, while the need for others, like the BIM exporter modifications, became apparent later when the quality of data obtained from commercial tools was not acceptable."
>
> Technical University of Crete, Greece – OptEEmAL Project Partner

> "However, further data quality issues have to be solved and there is always room for improvement. Regarding the HVAC data, for instance, instead of a short OptEEmAL's BES catalogue, IFC and its translation to Building Energy Performance (BEP) simulation input data files could be implemented, despite limitations in the description of HVAC systems. Commonly, HVAC modeling in BEP simulation engines requires further information than the one included in an IFC file and can be captured within an IFC scheme. A thorough documentation of such missing information and recommendations on how to deal with this drawback would be preeminent."
>
> Technical University of Crete, Greece – OptEEmAL Project Partner

Energy Simulation

Concerning the Energy simulation, a set of components has been developed to support the Data Insertion and Graphical User Interface functionalities:

- a document of **BIM Guidelines** provides the modeler with design rules to be followed towards generating a consistent BIM model;
- a modified version of the **Revit IFC Exporter** enables exportation of information which could not be exported by its original version (e.g. material thermal properties);
- the **model checker** (BIM checking component) checks, using a static set of rules, whether required data are present in the IFC file, while
- the **Geometry Error tool** checks for geometry errors that may affect other tools (e.g. Common Boundary Intersection Projection (CBIP) tool).

Related to data management and simulation functionalities, the components that have been developed are the following:

- the **CBIP tool**[8] enriches the IFC file with geometry information that is required for Building Energy Performance simulations (BEPs) (namely, generates the 2nd-level space boundary information);
- the **DNS tool**[9] retrieves information from the CityGML and generates a set of surfaces that have shading effect to the buildings under investigation (these buildings define the district);
- the **Automatic Zoning tool**[10] aims at generating zoning information if this is not available from the supplied IFC file — these three supporting tools belong to the enrichment layer and interact with the Data Management Module;
- the **SimModel Enrichment tool** retrieves the output of the ETL2 process (a mapping process from IFC RDF to SimModel RDF) and enriches the energy data models with additional information required for energy simulations;
- the **Simulation Input Model Generator Module** retrieves data from the Instance Creator (Data Management Module), generates input files for specific simulation tools (e.g. EnergyPlus), and submits these files to the Cluster Computing tool for simulation, results of which are retrieved by the DPI Calculation tool, and after some aggregation operations, DPIs values are computed and stored at the project repository.

HVAC Simulation

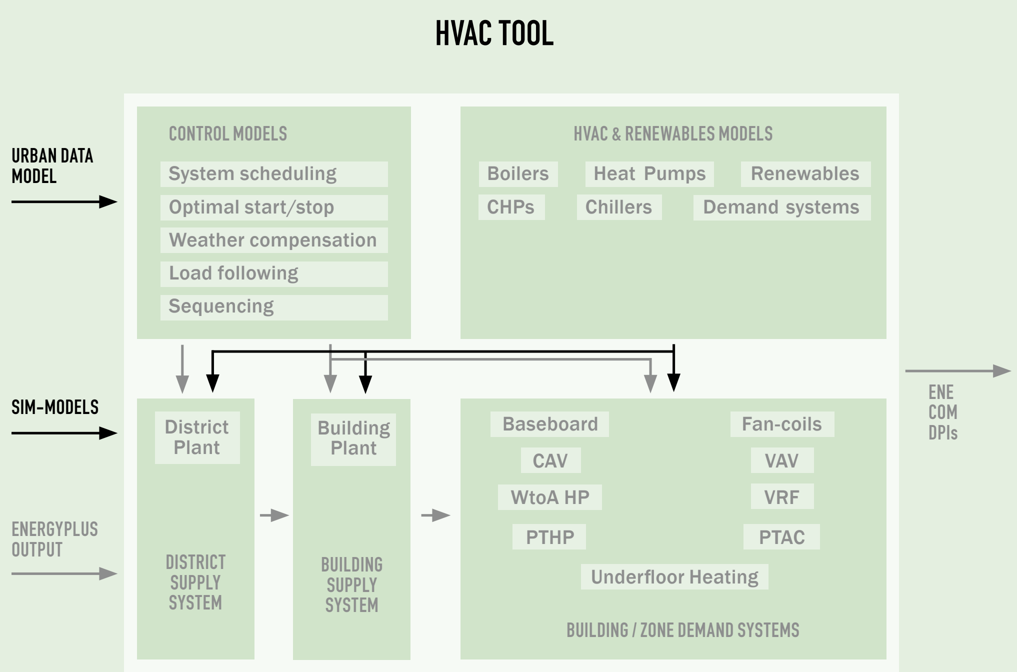
The optimisation platform includes a tool that simulates HVAC (Heating, ventilation, and air conditioning), Controls and Renewables, providing the basis for a complete simulation of the retrofit scenario. The output of the tool is used by the platform to determine the energy and comfort District Performance Indicators (DPIs). The tool chooses one or more units out of the ECM catalogue such that the thermal demand can be fully supplied. In case the considered refurbishment scenario includes more than one HVAC unit, the system-level control logic is taken into account to determine how the HVAC units share the load and the final consumption of each unit given the variable efficiency models included in the tool. Additional control models are available in the tool to enable the estimation of the variation in the total energy demand when the system schedules (start and stop times) are varied with respect to the reference values. In this way, scenarios can be investigated where the energy consumption is reduced and thermal comfort maintained or improved.

Compared with other simulation tools developed in other research efforts, this tool can assess the actual costs and energy performances of commercial HVAC units (whereas existing tools usually take into account only costs per kW) and use a comprehensive set of high-fidelity simulation models and tools to determine DPIs.

The layout of the tool is shown on page 28 depicting a complete set of supply and demand systems at building and district level. The supply systems include hot water boilers (condensing and non-condensing), combined heat-power-units, solar-thermal panels, electric reciprocating chillers, air to water heat-pumps and more. The models of demand systems are efficiency-based models applicable to different building demand systems, namely: baseboard heating systems, fan-coil systems, constant air-volume (CAV) systems, variable air-volume systems (VAV), variable refrigerant flow (VRF) systems, packaged terminal heat pumps (PTHP) and air conditioning units (PTAC), water to air heat pump systems (W2A HP), underfloor heating systems. The models include zone-level consumption of water circulation pumps and fans.

In addition, the tool includes a set of simulation models enabling the user to address a group of system-level controls, which are applicable to the energy supply systems. These are: system scheduling, optimal start-up & stop, thermal load following, weather compensation for hot and chilled water loops and sequencing control for boiler and chiller plants.

Once the proper system is selected and sim-xml models are linked to the tool, the simulation engine runs and reports a complete set of energy and comfort DPIs to the platform, which will be used in scenario selection and determination of the Pareto optimal points according to user objectives and targets from the refurbishment project.



All Levels of the HVAC Tool in the OptEEmAL Platform

Environmental Simulation

One objective of the OptEEmAL project was to create links between existing tools. In this sense, and in order to perform the requested environmental simulations, the existing NEST[11] tool has been integrated into the platform, within the simulation module.

Initially, the NEST tool was developed in order to apply the life cycle assessment methodology to new or to be retrofitted districts. The objectives of the tool are to identify environmental hotspots associated with urban systems using a quantitative assessment methodology and thus, ease decision-making while integrating environmental aspects. In this way, NEST considers not only the environmental impacts of buildings, but also of other urban elements such as roads, green areas, mobility networks etc.

Developed as a plugin for SketchUp, the NEST tool has been turned into a web service in the frame of the OptEEmAL project. The developed web service has to be connected to the rest of the platform through the simulation module using xml files. In order to match with the OptEEmAL philosophy, the tool has been "simplified" compared to the commercial version, with only two indicators considered among the eight available and with consideration of buildings and energy networks solely as components of urban systems.

Web-based NEST tool by NOBATEK/INEF4

Using the developed web service, all environmental DPIs considered by the platform are calculated with the NEST tool using the life cycle assessment methodology. To make these calculations, NEST is using input data provided by the user, but also by other simulations - in particular energy simulations performed using EnergyPlus, highlighting the links created between the different already existing tools.

For more information on EnergyPlus, please visit: https://energyplus.net/

Economic Simulation

In the context of the OptEEmAL project, one specific tool (ECO tool) has been developed in order to calculate the indicators needed for the economic evaluation of the scenarios generated. This software, developed using JAVA programing language, is able to calculate different economic indicators, such as operational energy cost, investment, life cycle cost, return on investment and payback period.

In order to calculate these DPIs, ECO tool needs different types of data as input: information about the cost of the ECMs implemented in the scenario, information about the units of the ECMs applied or the surface covered by the ECMs, the surface to be refurbished, and also the values of other DPIs calculated in other steps. The information of the energy prices and their increment is automatically collected in a previous step, during the data insertion (five values are gathered corresponding to the last five years together with the type of units, e.g. Kilowatt-hour). The DPIs needed are diagnosis DPIs from the baseline situation and evaluation DPIs (specifically final energy consumptions of different sources: electricity, natural gas, gasoil and biomass) from the scenario that is being evaluated for the calculation of the Economic DPIs in the evaluation process.

With all the described information, the ECO tool is able to calculate the economic indicators that will be the basis of the economic evaluation of each scenario.

"Capturing the reality of retrofitting a district is a big challenge in terms of modeling and solving in a semi-automatic manner, a problem that requires multiple interactions between data, stakeholders and tools. To address this challenge appropriately, different and complementary knowledge fields have been integrated resulting in a tool that supports the retrofitting design process and that allows for the reduction of time, errors and costs for stakeholders."

CARTIF Technology Centre, Spain – OptEEmAL Project Coordinator

SCENARIO EVALUATOR

Each one of the scenarios is automatically evaluated analysing the result of the most significant District Performance Indicators (DPIs). Specifically, 18 DPIs have been selected for the evaluation. These DPIs, calculated in previous simulation stages, have been classified into two main groups: those which imply a cost and those which represent a benefit:

- The **cost group** contains the DPIs that indicate the environmental (Global Warming Potential – GWP, primary energy consumption and energy payback time) or economic (investments, life cycle cost and payback Period) cost for the scenario.
- The **benefit group** involves the DPIs that could show a benefit for the scenario: reduction of energy demand or consumption, increase of the energy demand covered by renewable sources, increase of the comfort, energy used from district heating, and also, this group takes into consideration the benefits obtained when increasing the contribution of renewable energies: photovoltaic, solar thermal, hydraulic, mini-eolic, geothermal and biomass etc.

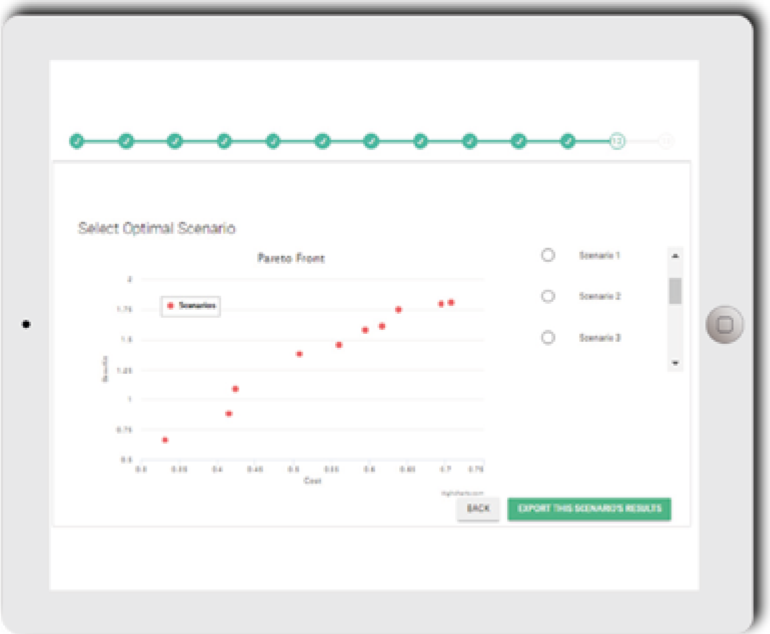
The DPIs are normalised in order to be able to make a comparison between them. After calculating and normalising the DPIs, they are aggregated following a dynamic weighting scheme that varies according to user priorities. The user can define his/her priorities introducing the prioritisation criteria through two different mechanisms:

- objectives can be inferred from the pairwise comparison of the 18 indicators, performed by the user, indicating the importance of each DPI over the others or
- the user can select one scheme from the pre-defined schemes, which are based on possible objectives to be pursued according to directives, such as having a "nearly Zero Energy District" or "generation through renewables". In this step, a cost value is obtained, calculated as the weighted aggregation of the normalised DPIs belonging to the cost group and the benefit value generated as the weighted aggregation of the normalized DPIs belonging to the benefit group. The results of the cost and benefit analysis are used by the optimisation module in order to compare and rank the different scenarios.

OPTIMISATION MODULE

The optimisation module is a key element within the OptEEmAL Platform, as it enables the generation of feasible retrofit scenarios to be evaluated, with the final aim to look for optimal retrofit scenarios along the Pareto frontier. The multi-objective algorithm is based on the Multi-Objective Harmony Search (MOHS) that simultaneously optimises cost and benefit fitness functions at district level. The proposed multi-objective algorithm does not converge towards a unique solution. Therefore, a set of solutions is proposed, which represent the best trade-off scenario (related to the bi-objective optimisation) in form of the Pareto optimal front.

This module comes into action at the second and third stages of the platform process (scenarios generation and optimisation process), after the user has inserted all relevant data of the project and after this data has been checked and stored. Diagnosis DPIs, which correspond to the baseline scenario and represent the initial status of the district, have also been calculated at this stage.



Optimal Scenario Selection Interface – Pareto Front Curve

The prioritising criteria, specified in the data insertion and diagnosis process, is introduced in the optimisation module (**scenario generator**), which will generate scenario vectors by means of combining the applicable ECMs. In the first iteration, the scenarios proposed will be random, whereas in the following iterations, the scenario generation will be based on the outcomes of the optimisation algorithm. Once the simulation data models have been created, the scenario's DPIs will be calculated and directed to the data management module to be stored in the project repository.

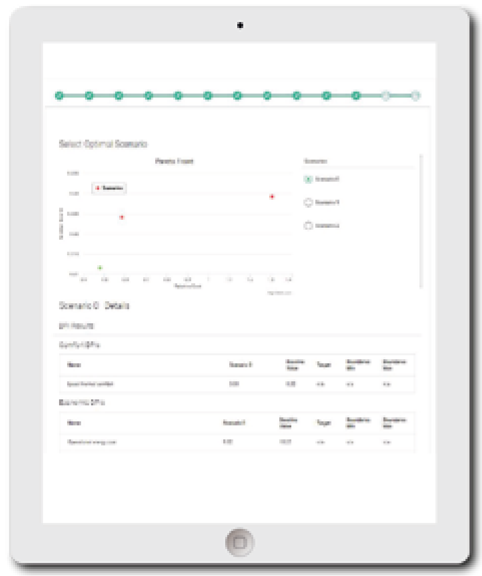
Once DPIs are stored, these can be retrieved by the optimisation module (**evaluator**) in order to have two unique, understandable and easy-to-handle values for each scenario to be ranked by the optimisation module: cost and benefit functions. With the result of the objective function, the optimisation module (**optimisation algorithm**) will either generate more combination rules and continue the iterative process or finish the iteration process if the stopping criteria is met. In this last case, the optimiser output data would be stored in the OptEEmAL repositories.

DATA EXPORTATION MODULE

The data exportation module provides two typologies of output through its components: Scenario Selector and Data Exporter. The output of the first component is the desired scenario chosen by the users among the ranking of scenarios generated in the optimisation process.

Scenario Selection

After this step, the Data Exporter will enable the user to export the files with the information generated in the platform, using different file formats: IFC, CityGML, PDF and XLS.



Optimal Scenario Selection Interface – DPI Results

Example of Baseline Results

Among the exported data, this tab presents the District Performance Indicators (DPIs) of the final scenario of the examined district. It reflects the performance of the district after retrofitting and compares it with the baseline scenario. In this tab, only the results for the selected DPIs are presented.

District Performance Indicators (DPI) of the final scenario

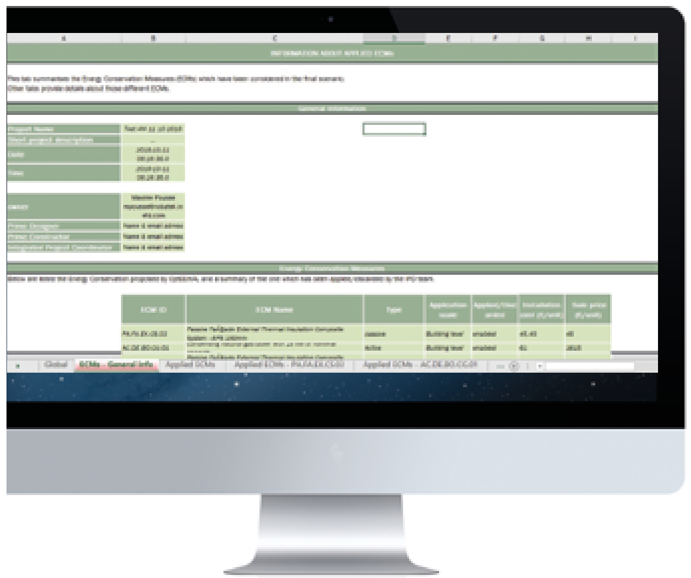
Problem Definition

The following part of the report presents the data introduced in order to define the problem formulation.

Data Input for Problem Definition

ECM General Information

This entire file summarises the Energy Conservation Measures (ECMs) which have been considered in the final scenario.



Energy Conservation Measures (ECMs) considered in final scenario

4.3 DEVELOPMENT STRATEGY FOR RETROFITTING DESIGN PROJECTS

The design of energy efficient retrofitting projects, in this case at district scale, is a challenging problem that requires a multi-scale and multi-domain evaluation and a constant interaction among stakeholders, data and tools. An appropriate interaction of stakeholders as data providers and decision-makers turns essential in order to achieve the expected goals more effectively and to deliver projects that are financially and technically sustainable.

OptEEmAL integrates processes in order to allow generating and evaluating the candidate retrofit scenarios integrating an optimisation and evaluation core tackling the diverse domains and scales that this problem poses and also integrating the data models and tools for this aim.

Capturing and representing the reality of the retrofitting value chain has been a cornerstone of OptEEmAL since the platform was conceived and, as such, it provides four main processes as a strategy to design a retrofitting project, guiding the user through the steps that allow transforming input data into a solution to the requirements and priorities of the stakeholders.

These four core steps are:

- **Problem statement:** a set of interactions allow the users to insert all data required by OptEEmAL in a friendly manner through models created outside OptEEmAL and through the interfaces of the tool.
- **Problem mapping:** OptEEmAL takes the data inserted by the users and transforms it into a problem that can be interpreted by the tools that will evaluate the current conditions and the proposed retrofit scenarios. The problem is conceived as a set of data models that allow representing the energy, comfort, economic, environmental or urban performance of the district as well as integrating information about the users, inhabitants, boundary conditions, expected targets or prioritisation criteria.
- **Problem solving:** once the baseline models are generated, OptEEmAL proposes a set of candidate retrofit scenarios automatically through selecting and combining Energy Conservation Measures from the catalogue that represents them. Thus, the optimisation loop is launched where sets of scenarios are generated, evaluated and optimised until the stopping criteria are achieved.
- **Solution exporting:** as a last step, the user is presented with the set of best scenarios against the prioritisation criteria inserted at the beginning of the process and the exportation documents are generated to be downloaded by the user.

Therefore, OptEEmAL automates the processes of generating the multi-domain and multi-scale models, the generation of candidate retrofit scenarios as combinations of Energy Conversation Measures and the evaluation and optimisation of these scenarios through the appropriate ecosystem of tools. This turns into a reduction of time, errors and costs related to this process while the interaction among stakeholders is deepened and reinforced.

"The jump needed to be able to design refurbishment projects at building level to entire district level projects exponentially increases the complexity of the developed platform. For that reason, the concept of scalability has to be taken into account from the early beginning of the project to mitigate the risk of complicating the problem to be solved."

CARTIF Technology Centre, Spain – OptEEmAL Project Coordinator

"We have seen an incredible knowledge generation and transformation of this knowledge into a real product in three and a half years. The use of BIM models for retrofitting projects in an "automated" manner is a great breakthrough and offers new possibilities in the building sector.

OptEEmAL has brought web technologies knowledge and their application to retrofitting projects to a new level!"

NOBATEK, France – OptEEmAL Project Partner

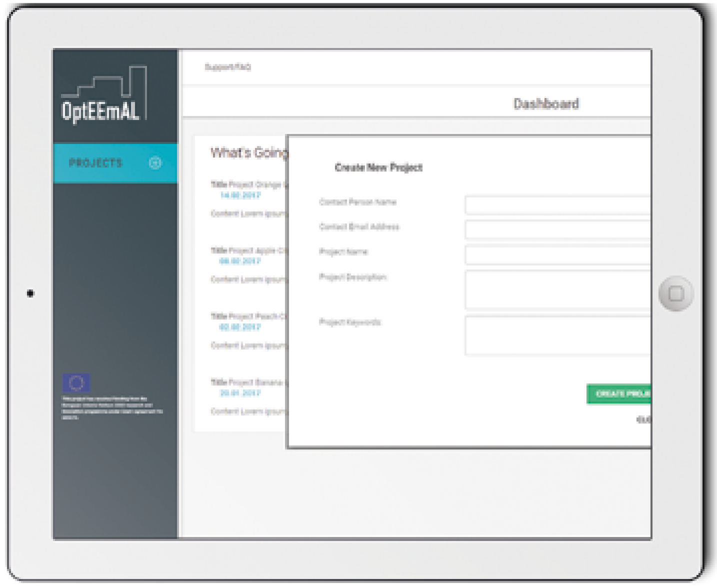
Platform for Energy Efficient District Retrofitting Design – Development Strategy for Retrofitting Design Projects

4.4 PLATFORM PROTOTYPE

First of all, the user has to log in to the platform. If the user does not have an account yet, a register form is shown. After that, the user has to follow the next steps to complete a project in the OptEEmAL Platform:

Step	Name	Phase
0	New Project	PROBLEM STATEMENT
1	IPD Group Creation	
2	Data Upload and CityGML-BIM Matching	
3	Baseline Energy Systems	
4	Contextual Data	
5	Energy Conservation Measures	
6	Check Strategies	PROBLEM MAPPING
7	Baseline Performance	
8	Targets and Boundaries	
9	Prioritisation Criteria	
10	Problem Summary	PROBLEM SOLVING
11	Optimisation Progress	
12	Select Scenario	SOLUTION EXPORTING
13	Export	

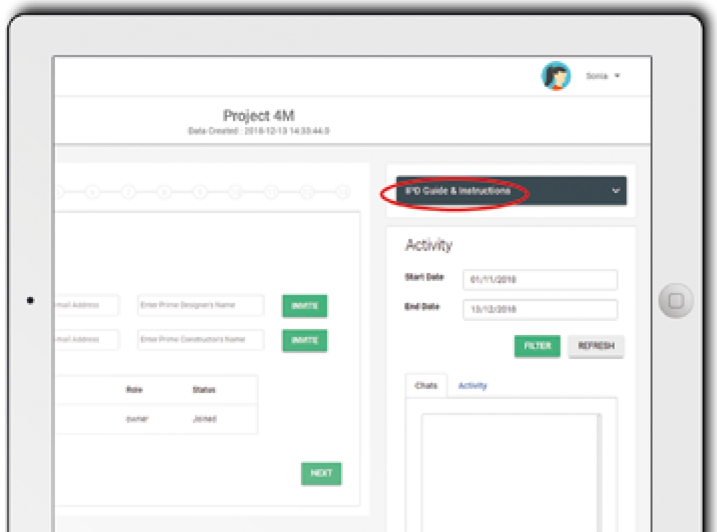
0 NEW PROJECT



Create New Project

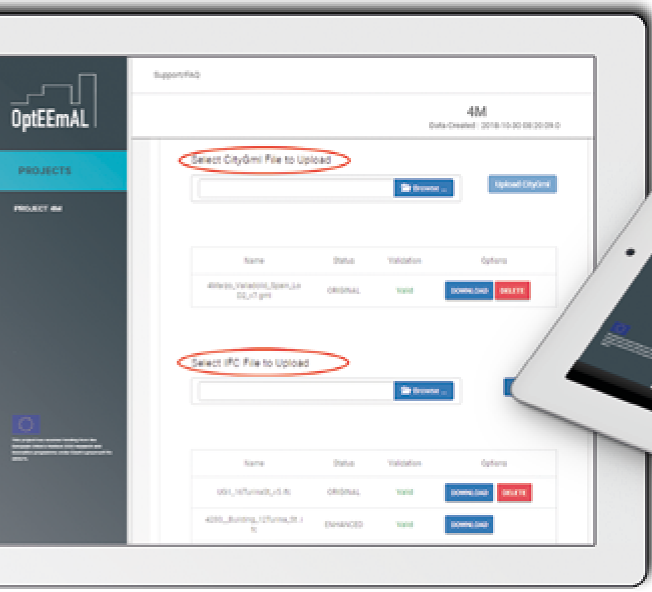
1 IPD GROUP CREATION

IPD Group Creation: The three profiles involved in this step are: the Owner, the Prime Designer and the Prime Constructor. In this step, you can download the IPD guide



Platform for Energy Efficient District Retrofitting Design – Platform Prototype

2 DATA UPLOAD AND CITYGML-BIM MATCHING



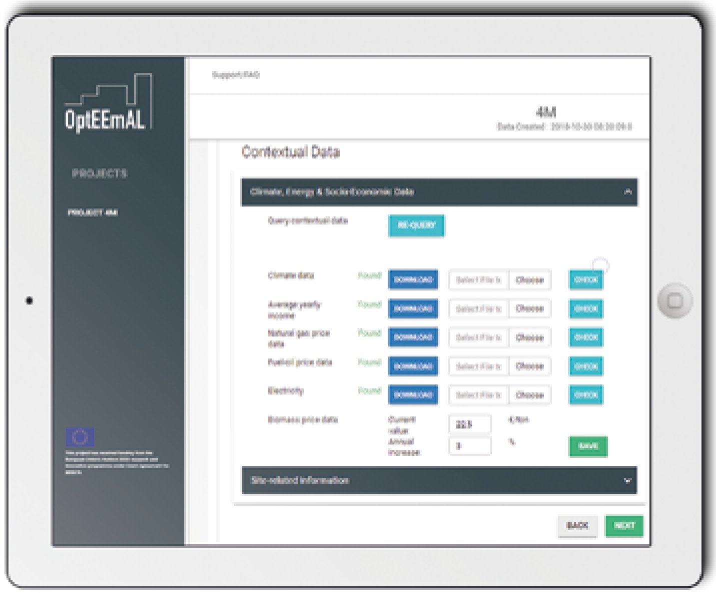
Upload CityGML and IFC files

Matching BIM in CityGML

3 BASELINE ENERGY SYSTEMS

Complete the questionnaire related to the Baseline Energy Systems

4 CONTEXTUAL DATA

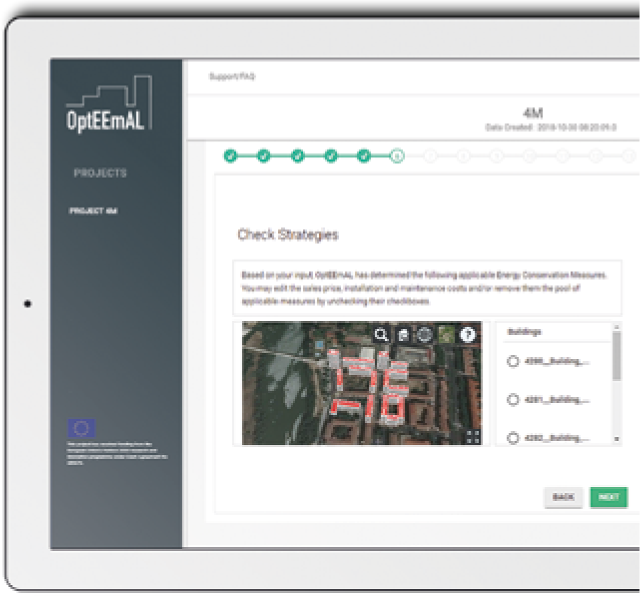


Contextual data is collected by the platform through accessing public data sources such as EUROSTAR or E+. The user can also upload and validate his/her own contextual data files

5 ENERGY CONSERVATION MEASURES

Select the Energy Conservation Measures

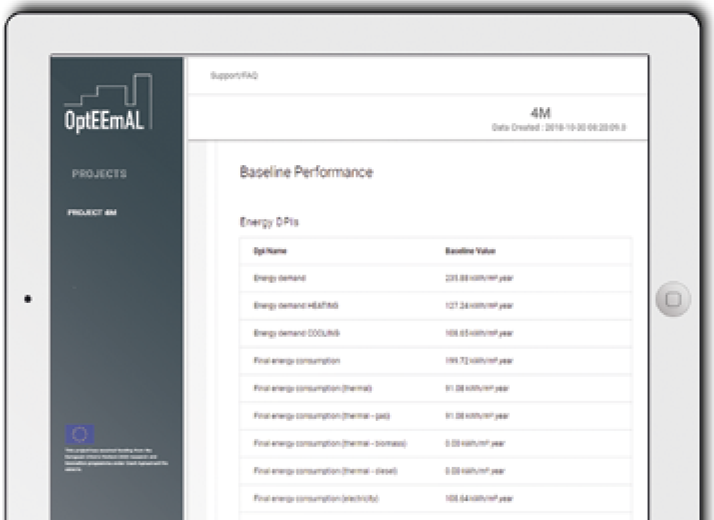
6 CHECK STRATEGIES



Select “Check Strategies” and edit measures

7 BASELINE PERFORMANCE

The OptEEmAL Platform shows the result of the diagnosis of the current state for the retrofitting project



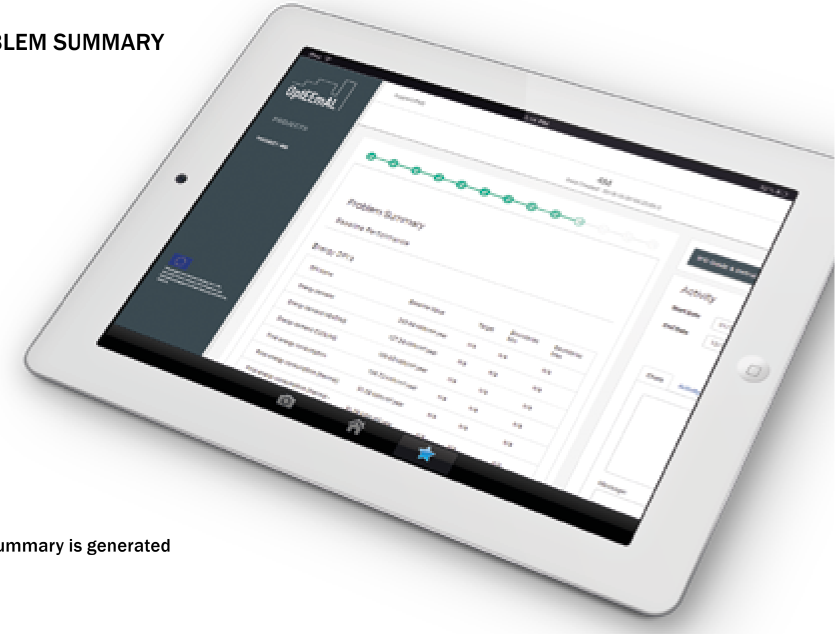
8 TARGETS AND BOUNDARIES

The user selects the most suitable set of targets for the district or for a specific building typology

9 PRIORITISATION CRITERIA

The user defines the prioritisation criteria for his / her refurbishment project

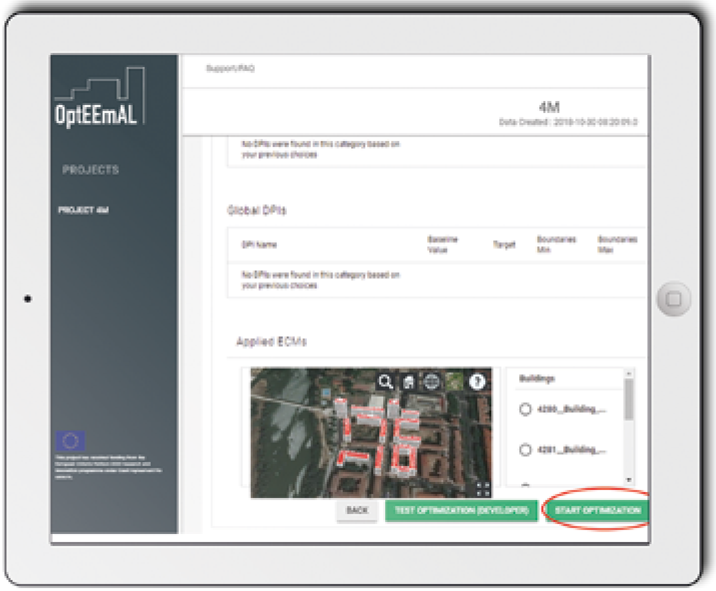
10 PROBLEM SUMMARY



A problem summary is generated

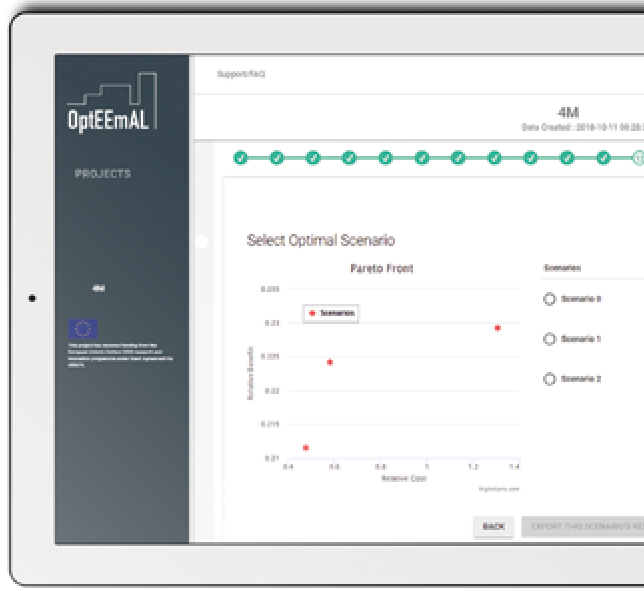
11 OPTIMISATION PROGRESS

Select "Start Optimisation"



12 SELECT SCENARIO

Best scenarios are shown within the Pareto front where the user has to select the preferred one



13 EXPORT

The documents to export are generated and downloadable by the user

4.5 OPTEEMAL CASE STUDIES

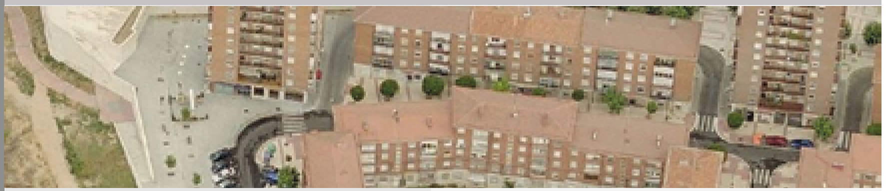
The first important step, in order to validate the OptEEmAL Platform and move from TRL 5 to TRL 6 demonstration of the platform, was to **test the platform prototype in existing EU-wide energy efficient retrofitting projects at district level.** Specific case studies were selected to ensure the platform performance is tested under different conditions including climate aspects, boundary conditions, uses, building typologies, intervention levels, conservation conditions, existence of specific barriers, consideration of historical buildings and other aspects.

The OptEEmAL consortium decided to use already performed retrofitting projects. The idea was to compare the results provided by the platform with already performed projects where data related to the performance of the district before and after retrofitting was available. Most of the case studies have been taken from past or on-going EU projects.

The following three case studies had been pre-selected.

CASE STUDY 1

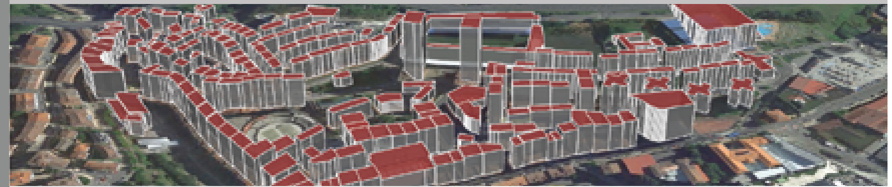
Cuatro de Marzo, VALLADOLID – Spain


© City of Valladolid

Year of construction / retrofitting	1960 / 2015 (planned)
Climate zone	D2
Main retrofitting strategies	External insulation, change of windows, biomass-based district heating, ICT systems
Retrofitted conditioned area / use	Residential: 21,000 m²
Achieved energy savings / use	Residential: 60 %
Specific features (e.g. historic buildings, regulation issues)	n.a.
Funding scheme	Public funds: 2.100.000 € Private investment: 1.300.000 €
More information	http://r2cities.eu/demos/valladolid/case_study_in_short.kl

CASE STUDY 2

Mogel, EIBAR – Spain


Map data ©2018 Google

Year of construction / retrofitting	1949 / 2014
Climate zone	C1
Main retrofitting strategies	Envelope upgrade (wall + roof insulation, window change), solar thermal
Retrofitted conditioned area / use	Residential: 9,450 m² 15 buildings, 150 dwellings
Achieved energy savings / use	Estimated 60 % in residential buildings
Specific features (e.g. historic buildings, regulation issues)	Heritage protected builidings
Funding scheme	Public funding 60 % (EU, local government) Building owners 40 %
More information	http://zenn-fp7.eu/demonstrationsites/mogel-spain.4.3d71f8313d6a4ffc793240.html

CASE STUDY 3

Polhem, LUND – Sweden


© Lunds Kommun

Year of construction	Depending on the building (1914, 1961, 1985, 1975, 1982, 1991)
Main retrofitting strategies	n.a. (retrofitting project not defined yet)
Retrofitted conditioned area / use	26,987 m²
Achieved energy savings / use	n.a. (retrofitting project not defined yet)
Specific features (e.g. historic buildings, regulation issues)	Historical protection of building n° 3
Funding scheme	Public (Lund municipality)
More information	https://www.opteemal-project.eu/files/opteemal_d1.2_requirementsspecification inputdataprocess.pdf

4.6 THE OPTEEMAL DESIGNS FOR OUR DEMONSTRATION CITIES

In a second step and as ambitious final stage for the validation procedure, OptEEmAL was used by three important stakeholders to carry out real energy efficient retrofitting design projects for three districts.

The three different stakeholders in charge of designing retrofitting projects at district level were essential as test-beds for validation: A municipality, a private consortium of technical offices and a municipal company. Each stakeholder heads the demonstration of the performance, usefulness and user friendliness of the tool for developing Integrated District Energy Efficient Retrofitting Plans in real environments.

The three demonstration cases are described below and their results focus on the generation of intervention plans. However, the real implementation and execution will not take place in the scope of the OptEEmAL project.

MAIN TASK OF THE DEMONSTRATION SITES

- Provide a city vision and perspective for the development of the platform, as well as an analysis of available information at city level to define the demo case strategy
- Support the validation of the platform in a real environment in the respective district to identify the main interventions that could bring benefits to the building units and the entire district in terms of energy efficiency and energy performance
- Organise workshops and trainings with local stakeholders to test the platform and gather feedback for its development

"The multi-scale and multi-domain evaluation of design alternatives for retrofitting a district poses a challenge to the integration of tools and their related data requirements which needs the implementation of a scalable and interoperable data model making this data also available for future integrations of new tools."

CARTIF Technology Centre, Spain – OptEEmAL Project Coordinator

SAN SEBASTIÁN, Spain

The building retrofitting project in Txomin Enea is part of a larger and ambitious project towards a smart city model for the Urumea Riverside district. San Sebastián has an integrated strategy aiming for a smart district in the Urumea Riverside with the particular objective of getting a nearly zero district: district branding in sustainability. This district has a surface area of approximately 200 hectares, which is made up of the Txomin Enea residential neighbourhood, the Ametzagaina Natural Park, which acts as a carbon reserve, and the Industrial Estate 27 with over 350 companies and almost 4,500 people.

The retrofitting project is an opportunity to improve the quality of life of the neighbours of Txomin Enea. The aim of the retrofitting is to achieve both a reduction in energy demand of dwellings around 35 %, as well as reducing the energy cost for residents and, therefore, the CO_2 emissions. Currently, these households do not have insulation on facades or roofs, so an action of refurbishment in these elements will substantially improve the thermal conditions and comfort.

OptEEmAL helps to propose different solutions and scenarios that meet all the objectives of the retrofitting project, taking into account the needs of residents in order to improve comfort and reduce the energy cost. In the same way, the interests of other stakeholders such as the promoters and the constructors in the districts are addressed. Thus, the final refurbishment proposal guarantees the optimal solution from several points of view such as interior comfort, reduction of CO_2 emissions, decrease of energy demand and more competitive cost.

LUND, Sweden

Lund's role in the project is to test the platform, both in the case study phase and in the demo case phase. The municipality has chosen a group of buildings to work with; the Polhem school, which is a high school near the city center. The buildings are in various ages, shapes and conditions. The construction years range from 1914 to 1991 and the total building area is approximately 24,000 m^2. The buildings are heated with district heating that is 100 % renewable. However, the municipality sees many other advantages with energy efficiency measures.

A consultant has developed 3D-models of all the buildings to meet the platform's demands. Lund has no energy efficiency measures planned for the buildings at the moment, but the platform results might start a retrofitting process further on. The project provides the municipality with valuable knowledge for facilitating the process of bringing several stakeholders together, as well as for the prioritisation of sustainability parameters. Lund contributes to the project by giving the perspective of a building owner taking into account the specific conditions in the north of Europe with different building standards and large regions being covered by heating systems mostly based on renewable fuels.

TRENTO, Italy

The district of San Bartolameo in Trento is one of the biggest public residential districts devoted to the living of both students and professors: the area of approximately 20,000 m^2 is divided in different buildings with varying types of utilisation serving different needs: dorms, a board with gymnasium, an auditorium, a bar and offices.

Despite the fact that the buildings have been recently constructed, the owner has the objective to verify which could be the main interventions that could bring energy benefits to the buildings. The retrofitting project is an opportunity to, on the one hand, improve the quality of life of the inhabitants of the buildings, and, on the other hand, to reduce the energy consumption and verify which technologies – software and hardware – will support this goal.

The OptEEmAL Platform will identify and figure out the best retrofit scenario that will give some concrete indications to be followed and the real optimal solution for the whole district, to help define the best interventions that will take in consideration different aspects: improve the energy efficiency and energy performance of the buildings, the sustainability of the district and of the surroundings, and of course economic advantages and savings.

Platform for Energy Efficient District Retrofitting Design – The OptEEmAL Designs for our Demonstration Cities

5 CONCLUSION AND WHERE TO GO FROM HERE

After three years and a half of project execution, we are proud to present a solution able to help in the design of retrofitting actions towards the improvement of the energy efficiency and performance at district scale. The work carried out by the OptEEmAL partners has been focused on developing an Optimised Energy Efficient Design Platform able to design energy retrofitting projects that are based on different energy conservation measures to improve the behaviour of a district. To reach this objective, the OptEEmAL consortium has created a tool able to reduce time delivery and uncertainties resulting in improved solutions when compared to business-as-usual practices. Using this tool, the main output of the project has been to demonstrate and validate the correct functioning of the platform for three demonstration districts located in San Sebastián (Spain), Lund (Sweden) and Trento (Italy).

The work executed in the different work packages, and materialised in the modules and tools previously presented, has been based on the integration of five main pillars essential to obtain a novel solution:

- Integration of a BIM-based information exchange approach to enhance collaboration between stakeholders and improve information flows within the design process.
- Integration of an IPD-based retrofitting design approach to facilitate communication, knowledge sharing and consensus among interested stakeholders.
- Integration of a catalogue of Energy Conservation Measures (ECMs) considering the scale of implementation and providing all needed data for the evaluation of the design alternatives.
- Integration of a Multi-Criteria Decision Analysis (MCDA) approach for decision-making integrating the interest of the stakeholders and making use of well-established indicators at different scales.
- Integration of a semantic data model and data mapping processes to ensure interoperability among the platform components and consistency of communications.

Thus, the OptEEmAL Platform provides the user with a holistic tool aimed at reducing time and costs in the design phase, and improving the whole process in terms of management, information flows and design quality.

On the other hand, the OptEEmAL approach has contributed to progressing in several areas of innovation beyond the current state of the art:

- OptEEmAL integrates relevant issues and stakeholders so that important information for the design of district retrofitting plans are taken into account in a single framework, providing a support for the implementation of a holistic and integrated approach, which is not possible in currently available tools. The project is providing extensive guidelines on participation.
- OptEEmAL allows the definition and evaluation of refurbishment scenarios of districts taking into account environmental, economic and social indicators.
- OptEEmAL takes advantage of geo-clustering techniques providing automatic answer to climate and energy price queries with the creation of a specific geospatial information database.
- OptEEmAL takes advantage of the experience of its consortium partners to provide a wide catalogue on energy efficient measures at both building and district level.
- The OptEEmAL Platform integrates a multi-objective optimisation module based on Evolutionary Algorithms, to define and evaluate automatically refurbishment scenarios at district level.
- OptEEmAL combines and integrates multidisciplinary and diverse data sources. The Semantic Web technology implemented enables the transformation of the captured data into meaningful information.
- The outputs of the whole OptEEmAL tool are planned to be part of the decision-making/best-alternative-selection optimisation process to identify the best retrofitting configuration while respecting stakeholder requirements.

Finally, the project impacts can be classified in several categories. The economic impact reflects a reduction of costs during the design phase by about 19 % compared to business-as-usual, and the operational phase cost could be reduced by 25 % through promoting holistic solutions, leading to a Return on Investment (RoI) increase of over 50 %. The market competitiveness can increase through the enhancement of the utilisation of energy efficient solutions in a holistic integration and improvement of the contractual processes. The European construction sector could grow tremendously by creating or adapting about 24,885 jobs and improving the work of three million SMEs in the sector within the next 10 years.

Social impacts can be obtained by the involvement of inhabitants in the decision-making process to achieve compliancy with their expectations and increasing user acceptance and improvement of social wellbeing. And finally, OptEEmAL fosters the dissemination of the new knowledge at professional level through specific information channels and actions targeting the identified stakeholder groups.

	CONCEPT	OPTEEMAL IMPACT
	Reduction of districts energy consumption Reduction of global energy consumption Reduction of overall CO_2 emissions	25 % 0.94 M MWh / year 0.68 $MtCO_2$ / year
	Creation or improvement of direct jobs Creation or improvement of indirect jobs Improvement of inhabitants' quality of life	24,885 34,839 6.7 million people
	Reduction of costs during the design phase Economic energy saving Economic direct growth Indirect economic growth RoI increase with holistic district designs	19 % 140M € / year 166M € / year 600M € / year + 50 %

In this context, OptEEmAL has contributed to the PPP EeB Roadmap targets in the overall challenge related to the design of energy/resource efficient retrofitted buildings and districts (including those with historical value), particularly in the three main identified targets:

- a multi-scale cross-disciplinary approach fostering interactions among players (including software suite and training),
- offering an optimised design for an affordable sustainability framework platform that supports refurbished construction projects which minimise building GHG emissions and their cost of ownership, and
- an improved collaborative building tool covering not only the design phase but also providing valuable information for the execution, maintenance and operation stages, integrating relevant sets of the whole district life cycle information.

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