Final Report

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1. EXECUTIVE SUMMARY

Design4Energy project developed an innovative integrated evolutionary design methodology that allows the stakeholders to analyse the energy efficiency of buildings and make better informed decision in optimising the energy performance at building life cycle level.

Based on the methodology, a series of guidelines, 3D online gaming for training, technology database, interoperability suite, eeBIM connected with EnergyPlus, lighting simulation & gbXML viewer and decision support tool were developed and integrated to the Design4Energy Platform, the Collaborative Virtual Workspace.

The Collaborative Virtual Workspace, as an integrated platform, is a complex, multi-functional, collaborative platform that could support integration of both advanced web-based and non-web based tools, workflow services, and coordination among design activities to ensure seamless flow of knowledge sharing during the whole project life cycle is developed. It is an interactive workspace that allow various actors to collectively simulate and assess the impact of various energy solutions within a visual space, with a view of achieving optimum energy efficiency at building level and/or neighbourhood level. This virtual workspace offers a 'Simulated Reality' of the energy performance of buildings as close as possible to the physical reality. Development of the Collaborative Virtual Workspace was achieved through integrating a new methodology to improve current practice utilising performance-based process with a set of Key Performance Indicators (KPIs) from early design stage. The new methodology was supported with integration of a database library of components and energy systems, energy simulation tools as well as maintenance and operational data.

Design and implementation of Design4Energy methodology, platform and tools was structured around the three scenarios developed in the project, focusing on neighbourhood, new build and retrofit. The first scenario considers neighbourhood energy matching in building design. The second scenario focuses on holistic energy design optimisation during early design phase while the third one focuses on the use of operational and maintenance data in retrofit.

The research outcomes were evaluated through the use of the tools on the three buildings: a single family detached house in Spain for retrofitting, a new residential building in German for new design and an office building in Poland for new design. The evaluation was done through a comparative assessment and qualitative analysis, by comparing the design process and building performance of the designs done with traditional design methodology and Design4Energy methodology. The evaluation shows the great potential of Design4Energy methodology and tools in improving building performance, impacts on the architectural sector and influence on the way of communication between architects and their clients. In the evaluation, with the limited options generated for the retrofitting building case study, 18.70 % of consumption reduction can be easily achieved compared to the actual building consumptions. 21.15 % of consumption reduction is simulated for the office building designed with Design4Energy platform in comparison with traditional process. The benefits by using Design4Energy platform are far beyond the energy performance improvement and the corresponding CO_2 reduction, with the methodology and tools, the end user can integrate building performance optimization in early design phase, reduce investment and time in green building design, facilitate the conversation with the clients in energy efficiency issue and provide them more information for decision making.

Design4Energy solution empowers the end user in energy efficient building design and enhancement of competitive advantage.

2. PROJECT CONTEXT AND MAIN OBJECTIVES

The EU Building Sector is a major energy consumer. More than 40% of the total energy consumed in the EU is used to cover the needs for heating, cooling and electricity of residential, commercial and public/institutional buildings. Commercial and residential buildings consume in fact an amount of 2843 TWh/a and about 70% of the electricity in EU, producing approximately 839 Mt CO_2/a. As the major part of this energy (61%) is produced from the combustion of oil and natural gas, the EU Building Sector is highly depended on imported fossil fuels. Moreover, the EU Building Sector, with a share of 20%, is also a major contributor to the EU Green-House Gas (GHG) emissions. To address all these issues concerning EU security of energy supply, EU contribution to climate change and in line with the low-carbon economy roadmap.

Energy-related retrofit rates beyond 3% are nevertheless possible in the short or medium term when refurbishments have not taken place for a large part of the stock for some time (e.g. in some eastern EU countries) and could be tackled in a condensed timeframe. However, in the longer term the full coupling of energy-related renovation to average refurbishment cycles sets a ceiling at 3%. Energy efficiency is no longer an optional extra in buildings - it has now become a basic requirement to reach the ambitious low-carbon economy roadmap.

There is an urgent need to improve current methodologies for a better adaptation of future retrofitting and building design.

Generally, primary responsibility for building energy performance is ascribed to the design team, and it is true that the features and systems designed into the building have a critical role in overall building performance. The design team is responsible for determining the characteristics of these systems and thus sets the stage for the long-term performance of the building. But many of the features designed into the building must also be operated and maintained properly, so there is overlap between design variables and operational impacts. Maximizing energy performance, however, has proven elusive to industry for many years. The greatest opportunity to reduce energy consumption lies in the concept design phase, when orientation, massing, materials, components, and systems and their properties are defined. Thus, the feedback loop between design, including the goals, decision, and assumptions made, and operation is rarely closed, prolonging inefficient practices and slowing the pace of performance improvement and adoption of appropriate innovations. Design decisions that typically impact the entire life cycle of the building need to consider the energy savings under different usage scenarios of buildings. The biggest challenge is to increase the comfort and to reduce the energy use at the same time. Traditional thinking is dominated by occupant satisfaction and sophisticated HVAC systems, often at the expense of energy use. The pressure of economic and ecologic considerations is mounting to invent new concepts to satisfy occupant requirements with substantial reductions in energy use. This requires new ways of evaluating systems and informing design teams to make optimal design decisions.

Latest advances in modelling and optimisation techniques should enable improvements in buildings design and control in order to facilitate decision-making before the construction stage. To improve the reliability of modelling tools, main challenge is to ensure their interoperability and connectivity with other information systems used during the building life-cycle. Knowledge in the fields of modelling and computation should be applied to ensure the interoperability between tools from various domains and different scales in order to propose solutions adapted to collaborative multi-disciplinary work.

The development of sustainable solutions for energy-efficient buildings properly integrated in their neighbourhood and their corresponding construction processes requires major innovations in design tools, construction methods and management practices.

Design4Energy project developed an innovative Integrated Evolutionary Design Methodology that allows the stakeholders to analyse the energy efficiency of buildings and make better informed decision in optimising the energy performance at building life cycle level.

The methodology was implemented on a sophisticated technology platform, namely the Collaborative Virtual Workspace, it enables actors to manipulate different building components, energy solutions, current usage parameters of the tenants, energy related parameters (weather, external light, temperature, airflow, etc.) to explore "what-if" scenarios to understand the impact of their decisions within a broader design context. These exploratory features offer an interactive design space for design teams to make validated and qualified choices as early as possible, offering considerations on the regulations, user comfort, constraints, and future evolution of the building's energy performance over time. In this platform, the consortium implemented an integrated workflow to visualise the various phases within the whole project's life cycle, the activities within each phase and the set of tools required to perform such activities.

In specific, the main objectives are:
- Develop Information platform to connect Design process with neighbourhoods information, predicting relevant information for energy matching and performance optimization.
- Work with current building context and creation of evolutionary scenarios in adjacent energy systems.
- Creation of evolutionary scenarios that take into account the technological evolution of building materials, components and energy systems and the future user behaviour changes.
- Development of an information platform that supports the optimized design of integrated energy-efficient buildings using a holistic approach to estimate energy consumption in buildings from the initial sketch of the building until the end of its service life.
- Deep analysis of the perception of the users of the building about comfort and user behaviours, facilitate the target setting will a KPI framework.
- Development of a decision support tool that will suggest the most accurate design options to increase the building energy efficiency.
- Creation of a virtual workspace that will allow the actors to interact with the buildings and explore "what-if" scenarios to create energy efficient buildings.
- Development of an interoperable data exchange protocol among design platform, the energy model module, and other information systems used during building life cycles.
- To validate the Design4Energy methodology in three demonstration buildings with different use and different climate conditions.
- To develop a virtual e-learning environment, based on the gaming technology that can allow people to learn how to design green buildings taking a more holistic view of the building life cycle.
- To train different stakeholders and offer easy-to-use guidelines for architects, SME builders and decision makers to enhance the use of integrated solutions.

- To contribute to bridge barriers for implementing of collaborative virtual workspace as a main instrument to fulfil with the EPBD as one of the main European Policies.
- Dissemination Plan and its deployment to facilitate the social acceptance.
- To develop new business model considering the innovative schemes based on Energy Efficient Buildings and Low Carbon Urban District concepts and the emerging innovative technologies including Design4Energy outputs.

3. MAIN S & T RESULTS/FOREGROUNDS

3.1 Design4Energy methodology and guideline

In Design4Energy project VTT was responsible for developing a methodology for designing energy efficient buildings, including the neighbourhood context. It started by defining the scenarios presented as visionary stories of future situations. Finally, a future vision for potential holistic energy efficient design solutions is created.

Ten visionary scenarios were defined and formulated with details. They cover the whole product life cycle to design energy efficient buildings with consideration of their neighbourhoods. Most of scenarios focus on energy aspect. A framework of new dedicated KPI indicators was developed to provide metrics for quantifying energy matching and exchange activities on the neighbourhood level.

Aiming to raise the energy efficiency dialog and streamline the communication between the client and architect / energy designer in early briefing stage, selected Design4Energy visionary scenarios have been elaborated into usage scenarios with tangible Key Performance Indicators (KPIs) for economic, environmental criteria as well as for building's performance in use and its impact on neighbourhood performance. In the holistic framework presented, all these criteria in different categories can be addressed in a uniform and consistent manner. This is possible already at the strategic definition stage (target setting) and subsequently in all design stages (assessing design solutions against targets), as well as during operation stage (assessing renovation need and options). To improve current building design practice, process maps were also developed based on the advance process integrating energy efficiency improvement actions, thus forming key components of the design methodology, usage scenarios and guidelines.

As a proof of concept, two new tools were developed, which added to defining the underlying methodology, is a considerable step beyond the state of the art and beyond the DoW. The work carried out in this workpackage of the project was reported in nine published papers and presentations at the large-scale conferences.

The research approach for development of Design4Energy methodology is utilising scenario development as an instrument for re-engineering. This includes visionary scenarios, focused usage scenarios with process flow and requirements and business processes, finally ending up at validation scenarios.

The 8 key building blocks for the Design4Energy methodology were introduced during the final task. The Design4Energy methodology is 1) holistic, 2) evolutionary, 3) energy efficient oriented and 4) adaptable to design approaches and methods. It is (5) serving the decision making process with information, using key processes: 6) Integrated modelling process (BIM) with EE-simulations and analyses and advanced visualisation, 7) Performance based design process and (8) Collaborative design process. Further the 8 building blocks were closely defined with their main principles and linking methods, process activities and tools which had been developed during the Design4Energy project.

Towards the completion of the workpackage, guidelines were developed to help in the use of the concept of sustainability and related language, including the use and meaning of established indicators, in order to guide on how to assess and report performance.

The guidelines were structured in 4 groups: Design guidelines, Guidelines for analyses, Collaboration guidelines and Assessment guidelines. Guidelines contents were developed including the following types:

- To-Do lists (as part of the Design guideline)
- Overall Design Advisory (as part of the Design guideline)
- Checklists (as part of the Collaboration guideline)
- Design Advisory (as part of the Collaboration guideline and the Assessment Guideline)
- Storyboards of the tools (as part of the Guideline for Analyses and the Assessment Guideline)

To support BIM process planning, a process description map with symbols for BIM models and analyses was developed. The content of all guidelines was finally presented in a Facilitator tool, to be used for overall training to Design4Energy process and for the design management.

3.2 Collaborative Virtual Workspace

The University of Salford developed a complex, multi-functional, collaborative platform that could support integration of both advanced web-based and non-web based tools, workflow services, and coordination among design activities to ensure seamless flow of knowledge sharing during the whole project life cycle.

The Collaborative Virtual Workspace was developed as an interactive workspace to allow various actors to collectively simulate and assess the impact of various energy solutions within a visual space, with a view of achieving optimum energy efficiency at building level and/or neighbourhood level. This virtual workspace offers a 'Simulated Reality' of the energy performance of buildings as close as possible to the physical reality. Development of the Collaborative Virtual Workspace was achieved through integrating a new methodology to improve current practice utilising performance-based process with a set of KPIs from early design stage. The new methodology was supported with integration of a database library of components and energy systems, energy simulation tools as well as maintenance and operational data.

Using the Collaborative Virtual Workspace delivered in the Design4Energy project, would enable actors to manipulate different building components, energy solutions, current usage parameters of the tenants, energy related parameters (weather, external light, temperature, airflow, etc.) to explore "what-if" scenarios to understand the impact of their decisions within a broader design context. These exploratory features offer an interactive design space for design teams to make validated and qualified choices as early as possible, offering considerations on the regulations, user comfort, constraints, and future evolution of the building's energy performance over time. In this platform, the University of Salford team implemented an integrated workflow to visualise the various phases within the whole project's life cycle, the activities within each phase and the set of tools required to perform such activities.

The research approach used to develop the Collaborative Virtual Workspace combined mixed methods of Information Delivery Manual (IDM) together with scenario development. IDM was used to capture business processes and identify detailed user information exchange requirements using BPMN (Business Process Modelling Notation), a standard tool for IDM based process modelling to produce flow-oriented representations of business operations. In addition to IDM, the exploitation of scenario development provided a context to produce process maps, which were utilised to identify and clearly present processes, actors and

information flow, supported by BIM tools. The whole process of designing the process maps, identifying use cases, and providing exchange models' descriptions was enhanced by, and verified with, several industry representatives including architects, engineers, energy experts and contractors through several meetings and teleconferences. The prototype of the Collaborative Virtual Workspace was developed and presented to the end-users through an iterative process of design and validation to ensure coherency and consistency with their requirements.

Design and implementation of the Collaborative Virtual Workspace was structured around three visionary scenarios identified in the project, focusing on neighbourhood, new build and retrofit. The first scenario considers neighbourhood energy matching in building design. The second scenario focuses on holistic energy design optimisation during early design phase while the third one focuses on the use of operational and maintenance data in retrofit.

In addition, Service Oriented Architecture (SOA) was used as a technical approach to define the overall system architecture. With this approach, the Collaborative Virtual Workspace is now developed as an open platform with consideration to modularity, expandability and scalability. This means that each module is developed as independent service module and connected together in a distributed web platform through a service orchestrator to provide the collaborative design services required by the design team. The high level of the system architecture comprises three layers: user interface layer, service layer and data layer.

3.3 Technology database

The building industry has high expectations towards building information modelling (BIM). It is supposed to raise the productivity and efficiency of collaboration of the whole building industry. BIM represents a technology as well as a process. The technology part of it addresses helping the relevant stakeholders in visualising the building in simulation and keeping track of all possible issues that could occur during the construction phase. The process part addresses the close cooperation of all involved stakeholders. This means that there is one model of the building in the centre of the project. This model contains all relevant data. In common building projects well known 3D CAD systems are used to model the specific parts of the building. Regarding the different stages and components that have to be considered in a building project this means that every engineer, specialised in a relevant field will use his own tools to do his work and that the models are generated specifically and will only contain the relevant data for the special topic. BIM mandates a new perspective for the management of the building data. The technology database developed in Design4Energy contains information generated throughout the development process and can be accessed by every stakeholder to get a detailed overview over the project as a whole.

The technology wiki developed by Fraunhofer is based on the media wiki technology fulfilling the following three aspects:

- Open platform providing ready-to-use, software neutral technology knowledge relevant for the identification and choice of new technologies.
- Concept for construction companies to collaboratively and effectively adapt innovative technologies.
- Source of knowledge and technical specifications in regard to technology lifecycle in the building and design process context.

The system is an open source content management system with a large development community in the background providing data format-neutral storing capacity, a semantic search engine, extensive possibilities for developing interfaces and visualizations. MediaWiki is open source software which is commonly known from the community platform Wikipedia.

It is designed to collaborate on web and to enable multiple users to edit knowledge and media content. The main purpose of the MediaWiki is to organize and categorize the knowledge. One of the important extensions of MediaWiki is the so called Semantic MediaWiki (SMW) which has firstly been released in 2005. It is characterized by allowing the MediaWiki to annotate semantic data to encode the content with further meaning in MediaWiki pages. Semantic data is used among others to enhance and add more functions to the wiki such as semantic search, organization, evaluation, aggregation of the page, displaying the content in map formatting, and exporting data to several formats.

The options generator is an important part of the decision support tool. It is the interface between the technology database and the multi-KPI-based evaluation and decision-making. It is automated, web-based and built on a RESTful architecture that creates design options based on individual simulation settings and building component options. The process of creating design options and evaluating them as automatically as possible is a complex procedure focussed on the manipulation and evaluation of gbXML-files. However, this approach in its principle is equally adaptable to IFC or other energy simulation tools. It allows creating variations of the same building model with different building components browsed and loaded from the deep integrated technology database. Hence, the model variants can be evaluated by comparison of the performance indicators such as costs (e.g. investment, operation cost, life cycle costs), performance in use (e.g. air quality, energy system performance), environmental performance (e.g. climate change, water use), or impact on neighbourhood performance (e.g. energy balance). The technology database provides context sensitive search functionalities to support the identification of relevant components.

Data sharing and searching is improved for text and multimedia by the MediaWiki in which the content is categorized by adding one or more category tags. Thus, it makes the search and knowledge easier to access and process than without the extension. The content is turned into knowledge that is computable and becomes traceable on the bases of search problems. Many companies and organizations have started documenting their projects by using MediaWiki. The Wiki engine and machine-readable information is enhanced by using semantic data with Semantic MediaWiki. The following list shows some of the main functionalities of using the MediaWiki:

- Data structures: Usage of categories for structuring data or semantic values to improve and ease the classification system.
- Search information: Enhanced queries for information in wikis pages via the extensions Semantic Drilldown and Semantic Forms.
- Visualization of information: The SMW supports displaying of information such as calendars, timelines and maps. Furthermore, the extensions Semantic Result Formats and Semantic Maps provide complex diagrams to access directly the semantic information base.
- Content Management: Consistency of content, access of knowledge, and reuse of knowledge.

The technical architecture being used for the database system is a combination of the MediaWiki which provides the basic content management system, the semantic extension which is relevant for the enhanced search algorithms, additional databases, and the additional interfaces. The interfaces are partly provided by the wiki system itself. However, for external applications like CSV-, XML-, and IFC-files they first have to be developed. Also the file management system has to be implemented additionally. The database of the MediaWiki is basically a structure that is implemented in MySQL technology on the server which is open source, too. However, the tables need to be manipulated to provide the input-output functionalities for the http web services. These services are mainly used by external tools.

3.4 Interoperability suite

The suite is to improve the interoperability between different data models and formats, including energy-simulation results and unit systems.

The key modules of the Interoperability Framework are as follows:

- Component Catalogue
- eeBIM
- Simulation Platform

As proof of concept of the interoperability framework, Revit software was used as the Design Tool. A plugin has been developed, to be used under Revit software, allowing to import elements from the Technology Database.

There is the possibility of using different file formats, according to the kind of element we want to add to the catalogue. Among such variety of files, the most common are the following:

- Industry Foundation Classes (.IFC)
- Revit Project File (.RVT)
- gbXML (.gbXML)
- IDF (.IDF)

This suite will be very useful considering the multitude of formats and software that currently exist. A tool will report all errors found and all entities that have not been able to transform.

3.5 Lighting simulation & gbXML viewer

Nowadays, there is a growing concern about the rapid development of infrastructure and building projects and their likely impacts on the environment. Particular concerns have been raised about building developments and energy consumption issues. Today, environmental negative impacts of fossil fuel usage are obvious and the building sector is responsible for almost 40% of the total final energy consumption in Europe. In recent years, there has been increasing interest in using daylight to save energy in buildings. Lighting control integrated with daylighting is recognised as an important and useful strategy in terms of energy-efficient building design. It is believed that proper daylighting schemes can help reduce the energy (electrical) demand and contribute to achieving environmentally sustainable building developments.

Therefore passive solar heating and lighting are important issues to be taken into consideration towards the reduction of energy consumption in new buildings.

This can be achieved at the very beginning of the conceptual design by simple simulation methods and techniques based on appropriate building design (bioclimatic architecture) and energy efficient systems and technologies, such as passive solar systems. The Design4Energy platform is envisaged to enable architects and engineers to investigate the bioclimatic advantages and resources at the very early stage of the conceptual design of the construction thus allowing appropriate decision making process.

CADCAMation has proposed to develop and integrate a *Lighting simulation module coupled with a gbXML viewer called "BIM Solar"* within the Design 4 Energy project.

Solar illuminance and radiation calculation on a BIM model can produce relevant bioclimatic information such as hourly income over a given room / zone / piece of envelope. It can be

used by architects and engineers to identify spots to place solar panels, areas to protect by sun shades, etc.

In the early stage of design, natural lighting through daylight factor calculation gives quantitative information on the access of spaces to natural light, depending on openings, glazing, and masking environment.

Based on our experience in the field of ray-tracing technologies for wave simulation CADCAMation has developed accurate algorithms to compute solar income and intensity on any point of a 3D scene, including:

- Direct calculation (from sun)
- Diffuse calculation (from the sky dome)
- Indirect calculation (reflection of diffuse and direct lighting over the environment).

Ray-tracing is also used to compute daylight factor at a given point, using Monte-Carlo ray tracing simulation.

In order to make the process attractively relevant within the Design4Energy platform and process flow, the simulation tool needs to be very simple and easy to use, to encourage its quick adoption by users with different professional profiles: architects, HVAC experts, engineers or even building owners. The solar simulation tool used in the Design4Energy project can be characterized by the following features:

- User-friendly GUI interface
- Straight-forward process and BIM compliant based on interoperability and compatibility with existing software and BIM model (gbXML and IFC compliant)
- Last but not least, fast computing algorithms and accurately realistic results for reliable decision

The proposed functionalities will be initially achieved only for solar irradiance intensity computing and interior daylight analysis, but could be further extended to other solar based simulation and energy efficiency analysis.

CADCAMATION has been exploring the solar and lighting analysis in the Design4Energy project and for this, proposes a bioclimatic simulation module which can be accessed through the Design4Energy cloud platform.

Users' benefits

- Qualitative information:
    - Solar income calculation can be displayed on the 3D model using pseudo colors to show which areas receive more energy, over the whole year or over a given period of time.
    - Daylight factor can be displayed as a pseudo color grid map in each space
- Quantitative information:
    - The user could view solar income on an hourly / daily / monthly diagram for a given surface or set of surfaces
    - The user could download csv file of raw data to manage his own outputs
    - The user could view daylight factor values on a grid for a given space, and download it in a csv file.

The solar simulation module will generate the simulated results through JSON format (language-independent data format), describing the results in the form of a class with 4 values:

- WallSolarIrradiance: a list of instances of the class "solar_irradiance", with one instance for each wall of the gbxml file
- OpeningSolarIrradiance: a list of instances of the class "solar_irradiance", with one instance for each opening of the gbxml file
- SolarGain: a list of instances of the class "space_solar_gain", with one instance for each space of the gbxml file
- DaylightFactor: a list of instances of the class "space_daylight_factor", with one instance for each space of the gbxml file

The 3D viewer based on JSON data format (thanks to its web features stateful, real-time server-to-browser communication protocol) instantly allows to:

- Display the building geometry
- Display the qualitative outputs.

Two types of outputs are provided as a result of the solar and lighting analysis. Figure 1 provide examples of qualitative-quantitative outputs to be displayed in the 3D view, while Figure 2 illustrates examples of quantitative analysis outputs on a specific architectural element during a time period.
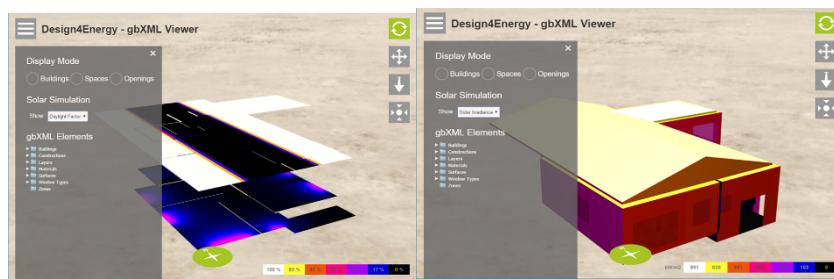
Figure 1 Solar and lighting analysis in 3D view
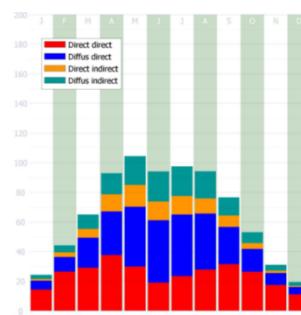
Figure 2 Examples of quantitative analysis outputs

In conclusion, our BIM Solar module allows Design-4-Energy platform to be dedicated to Solar Energy coupled with Architectural design, Engineering and Construction, thus enabling holistic 3D modelling for your residential assets, including:

- Refurbishment from simulation to collaborative decision support: your energy performance + financial targets
- Visualization, personalized follow-up for your logs and forecasts

3.6 eeBIM connected with EnergyPlus

Energy-efficient BIM-based design requires on the one hand creating an extended BIM model that can encompass the data needed for comprehensive whole building simulations and on the other hand, appropriate tools that can be used to accomplish the filtering and transformation of the BIM data to the structure and format required by the input and the respective internal data models of simulation applications such as the widely acknowledged EnergyPlus software suite used in the Design4Energy prototype platform. Typical energy simulation input models are stand-alone, usually in the form of plain text files with poor or non-existent interfaces for data exchange. There is no official modelling standard for the simulation domain. Hence, existing simulation tools like EnergyPlus fail to take advantage of standard data exchange tools that are available for data in the XML or IFC format, except for a few proprietary third-party front ends for gbXML and IFC input with limited functionality.

The physical data models used in energy analysis and simulation tasks require data covering various attributes of a number of architectural and structural building elements as well as elements of the HVAC system together with their interrelationships. Most of them are already considered in the standard BIM schema IFC and in gbXML but external (non-BIM) data has to be considered too, including climate files, occupancy profiles, detailed material characteristics, detailed equipment performance specifications and so on. Consequently, in Design4Energy the model enrichment and model transformation to EnergyPlus is achieved through

- *An energy-extended BIM data structure (eeBIM),* which is based on a Multi-Model approach, and
- *A set of model manipulation tools* (model validator, model combiner, model filtering, eeBIM2SIM converter).

The development of an effective interface between the architectural BIM and the energy analysis and simulation applications required thereby consideration of the following aspects:

- *Assignment of specific attributes and relations in the BIM authoring tool* (Autodesk Revit) as needed for the energy analyses
- *Methods for compiling an analytical data model* that contains an appropriate abstraction of the building geometry derived from the physical BIM model to enable valid and accurate representation of the building for the specified analysis software; such analytical models have to be generated for each type of analysis
- *A data exchange format* that maintains associations between the abstracted analysis model and the physical BIM model, including ID information to support incremental updating on both sides of the exchange.

The developed BIM interface is embedded as essential part of the elaborated highly automated design process as shown schematically on the following Figure 3. It is achieved using a *two-step approach*: (1) Creating the eeBIM model from BIM, and (2) Using eeBIM to create the IDF input for EnergyPlus (see Figure 4).
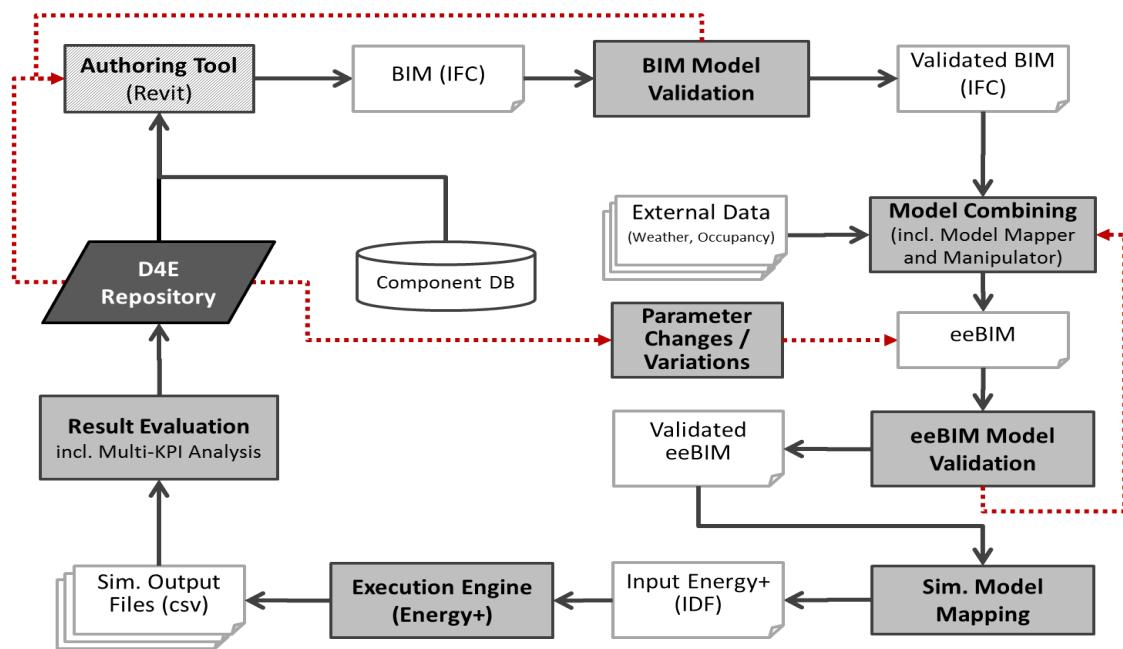
Figure 3 High-level view of the generalized workflow using BIM-IFC

As already mentioned, EnergyPlus is used as the target energy application in the Design4Energy workflow. It provides various functionalities for energy analysis and thermal load simulation. The software takes into consideration the building geometry, user behaviour and energy related systems. The biggest challenge in the realization of the IFC-based BIM interface in that regard was the extraction of geometrical information from the architectural model and its preparation for energy simulations. To achieve that the IFC data had first to be reduced to a model containing only the IFC entities required for the application according to a specifically defined Model View Definition (MVD). The developed filtering operations represent a key aspect in that regard. Appropriate filter rules are implemented to identify problematic properties or arrangements in the used input model. To establish the mapping between the IFC entities and the IDF entities in the corresponding models the relationships between the IFC-based information model and the IDF-based information model are first analysed. Based on the determined relationships, dedicated algorithms for the transformation from IFC data structures to appropriate definitions in the IDF are after that applied. The Space Boundary Tool from the Lawrence Berkeley National Laboratory is used to create a first template of the IDF input file for the simulation with EnergyPlus. The obtained IDF file is then completed so that it contains all relevant information about the building geometry (including definitions of all materials and their thermal properties) and simulation run control parameters, such as convergence tolerances and the simulation time period.
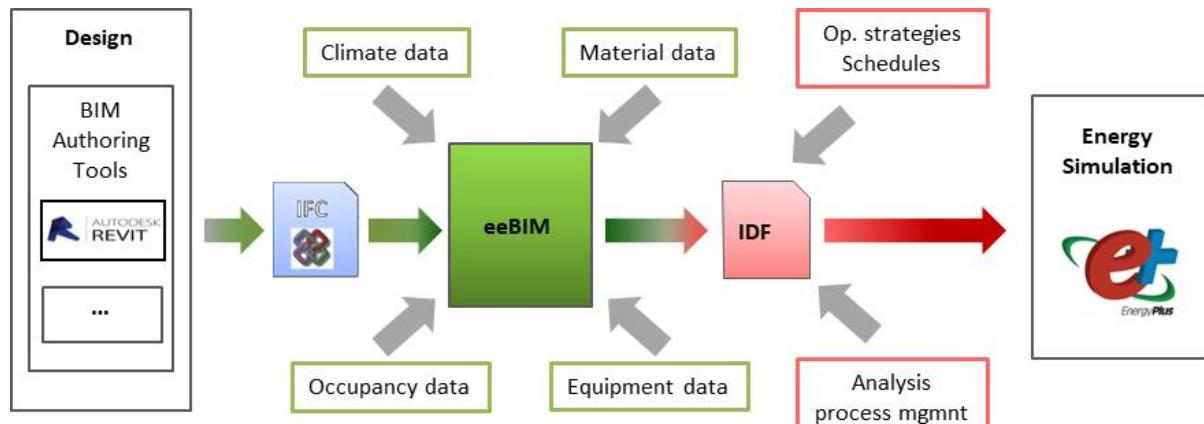
Figure 4 Schematic presentation of the two-step approach of the developed BIM interface

An important feature of the developed overall approach and the implemented support tools and services is the provided capability to easily define, explore and evaluate design and simulation variants as indicated schematically on Figure 3 above. This is an essential prerequisite for truly energy-efficient design. In Design4Energy it is achieved by:

- Enabling the creation of parameter variations at all steps of the described process
- Using standard cloud technology to provide for parallel execution of the generated variant inputs for energy simulation
- Using the developed decision support tool (see Section 3.7) to evaluate the variants and select the most appropriate one.

Generation of the desired design or simulation variants can be done in two ways: (1) by changing the building elements in the eeBIM directly by the user with the help of a developed GUI, and (2) by applying the jEPlus Java Library which enables the user to create complex parameter changes on multiple parameters at once using a text-oriented user interface. The second method is more difficult to use and requires greater user experience but it is also much more powerful as it provides a more sophisticated, more efficient and more time-saving method to achieve the desired result.
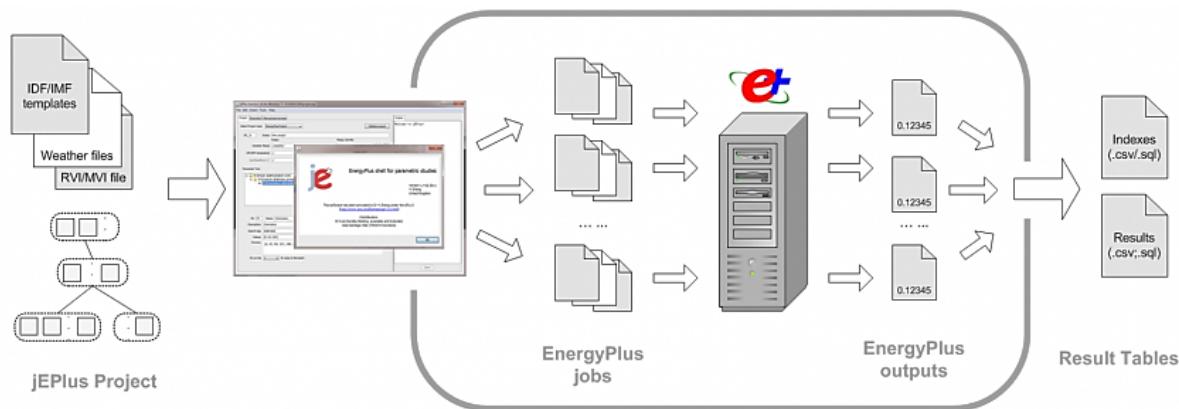
Figure 5 Generation of multiple simulation jobs with varied parameters for EnergyPlus using the jEPlus library

3.7 Decision support tool

To develop the Design4Energy decision support tool LOU team went through a number of development stages as follows:

In Task 5.2 LOU team has conducted an extensive exploration which provided a reference document for decision makers to better control and optimise building operational performances.   The initial achievement was the development of directions for the development of a decision support tool.

In consideration of neighbourhood specifying different KPIs for use in the operation phase. Was the first pre-requisite. Consequently, different analysis methods have been presented for obtaining such metrics. In that context typical factors that play an essential role in energy system performance have been identified and usual weaknesses of energy systems at building and district scale have been mentioned. European directives and Benchmarks were analysed and have been used for identifying most relevant reference performance values at European scale and thus providing an even concreter decision basis.

While in Task 5.3 LOU team has proposed a workflow for the retrofit scenario, extending the use of BIM from the conceptual level and design to the existing buildings, the operation and maintenance stage. The common data modelling method proposed bridged the gap between Building Information Modelling and Building Energy Modelling with a clear orientation to the existing buildings case and the retrofit scenario using an XML based approach.

Guidance was provided on the main information required to be captured when conducting building survey of an existing building and on the good practice when designing in BIM. Specific guidelines, 'The good gbXML guidelines', have been provided for assisting the architect and ensuring compatibility of the exported data with the proposed workflow. The possibility to expand to a neighbourhood level has also been explored using the proposed workflow.   A series of tools was developed to automate the BIM to BEM process for the architect: the 'Enhancer tool'; the 'Conversion tool'; the 'EnergyPlus runner'; and the 'EplusKPI tool'.

A protocol to enable the incorporation of monitoring and basic control in the workflow was established. The workflow was validated through use of a real-life case study building. Each step of the workflow was demonstrated and verified using the case study building. Comparison of the predicted energy performance using the proposed workflow with the measured energy performance as derived from utility bills collected for the building under study presented good agreement of maximum 10% deviation and validated the workflow.

In task 5.4 LOU team has developed a decision support tool which involves: (i) development of prototype tools to automatically generate maintenance/ retrofit advice at different levels of abstraction and for use by different stakeholders, (ii) incorporating ICT visualisation and user-centred design techniques; (iii) creation of strong engagement with the various stakeholders (including industry, consumer and policy) to refine the key features of the retrofit decision support tool and the delivery mechanisms for retrofit or maintenance advice.

A key success factor for further development and application of the solutions being developed was the contribution of maintenance and retrofit stakeholders in the population of both the components database and the benchmarking database.

In the following are the functions and procedures created for the decision support tool:

- Produce retrofit or maintenance brief
- Establish or review and update BIM model
- Analyse LOD 4 models
- Review neighbourhood implications and adaptability
- Improve design material for retrofit/maintenance
- Finalise design alternatives with KPI profiles
- Analyse energy demand at building level
- Review energy option alternatives
- Review design alternatives
- Analyse energy matching at neighbourhood level
- Review design alternatives with energy matching results
- Final selection and approval of a design alternative

3.8 3D Online Gaming

The University of Salford developed a 3D Online Gaming Environment for learning 'how to design Green Buildings' as part of the Design4Energy European project. The idea of the training environment is to enable users to learn individually and/or collectively through a 'team space' to design energy efficient buildings. This training tool is designed to enable

architects and other members of the design team to extend their knowledge on designing better energy efficient buildings taking issues relating to energy, cost and CO_2 emissions into consideration. Furthermore, such a training tool has the potential to be used as an educational tool to teach students attending architectural and other relevant courses about "Green Building" design. The 3D Online Gaming can be accessed through http://thinklab-salford.org/d4e_game/.

An overview of various learning models and theories has been undertaken to understand how people learn. Amongst these, Constructivism and Humanism theories were selected as the most appropriate theories to build the 3D Online Gaming Environment. These theories were used to define a number of learning elements required to foster a learning attitude. This work led to the creation of a learning framework which identified, in addition to the learning elements, a number of skills that learners acquire from using such a training environment as they socially interact with one another through the game.

The development of the training environment is strongly linked to three scenarios, used to outline and structure three learning modules: new build, neighbourhood, and retrofit and maintenance. For each module, a number of learning outcomes was defined with a list of high-level activities, specific tasks and detailed tutorials. In addition, an energy-efficient model was utilised to provide the appropriate content for these learning modules combining energy, environment and social aspects as the following:

- New-build learning module:

This module is designed to investigate environmental aspects such as the impact of orientation and the use of various construction components including materials and glazing on designing energy efficient buildings. In this module, end-users are given a task to design energy efficient residential building. For this, they are provided with a list of construction components with their U-values, structured around sub-sections of walls, floors, roofs, windows and doors. Once the end-users make their selection, the system calculates using SAP the Energy Performance Certificate (EPC), rating, total energy consumption and CO_2 emission for the end-users to visualise. End-users can explore what-if-scenarios by creating various design options and comparing their results.

- Neighbourhood learning module:

This module is designed to explore energy aspects using large data sets to understand energy efficient systems in the neighbourhood and to also diagnose specific problems within that neighbourhood. The module was structured around the concept of an energy efficient system in smart homes to provide end-uses the knowledge about the rapidly increased attention to energy data analysis in recent years amongst researchers, economists, industrialists and policy makers. In this module, end-users can visualise large data sets such as: EPC, air test, building type, construction type/date, occupancy type, building typology, ownership and electricity and gas use. At any time while using this module, end-users can select any of these data sets or a combination of them and visualise them to assist them in analysing the neighbourhood as a group of buildings. End-users can also visualise all data related to each building in the neighbourhood. In addition, the filtering functionalities provided in the module, enable end-users to identify those buildings with high-energy consumption (electricity and gas) within a particular neighbourhood and can also identify the reason(s) behind the inefficiency of building's energy whether it is related to improper use of the building or the actual building design/fabric.

- Retrofit and maintenance learning module:

This module is designed to explore the use of maintenance and operational data to propose retrofit solutions. The module is designed to retrofit an existing residential building with consideration to its neighbourhood. Should the end-users have performed the activities for the neighbourhood module first, then they would have been able to identify and diagnose the buildings in need of retrofit. In using this module, end-users are able to improve current design of a residential building by retrofitting. End-users can do this as they explore the use of construction components as they select various material for roof, floor, windows and doors. For this, they are provided with a list of construction components with their U-values, structured around sub-sections of walls, roofs, windows and doors. Once users make their selection, the system calculates using SAP the EPC rating, total energy consumption and CO_2 emission for the end-users to visualise. End-users can explore what-if-scenarios by creating various design options and comparing their results.

4. POTENTIAL IMPACT, MAIN DISSEMINATION ACTIVITIES AND EXPLOITATION OF RESULTS

4.1 Potential Impact

Architects, engineers and the construction industry in general struggle in different stages in the design and engineering process. The main cases are the realm of technology management, collaboration and data sharing, and the simulation or calculation of energy performance and costs related to design variations. The early design stage is critical part of the novel design process developed and demonstrated in Design4Energy project.

4.1.1 Energy saving and environmental impact

According to the study, commercial and residential buildings consume in fact an amount of 2843 TWh/a and about 70% of the electricity in EU, producing approximately 839 Mt CO_2/a. The Energy Performance of Buildings Directive has determined that the potential for cost-effective energy savings in the EU building stock is about 30% in the period of 2020. Also, about 90% of existing buildings will be still in use by 2050 and the current average energy consumption needs to be reduced by a factor of four or five.

These aspects mean that it is necessary to improve the actual methodologies for a better adaptation to the Future Cities. Design4Energy methodology includes visionary scenarios, road maps, imagining how technology could be applied over the next 10 to 15 years, as well as state-of-the-art research to provide real examples of the application of this methodology for energy efficient building, and in doing so capture new capabilities. Design4Energy expects to increase the energy efficiency of the buildings by providing an easy to use methodology and platform, integrating neighbourhood data and promote the use of new technologies to maximize the environmental and social benefits.

In the evaluation, with the limited options generated for the retrofitting building case study, 18.70 % of consumption reduction can be easily achieved compared to the actual building consumptions. 21.15 % of consumption reduction is simulated for the office building designed with Design4Energy platform in comparison with traditional process, more reduction could be possible by considering more design options or increasing investments.

4.1.2 Social-Economic impact

The EU-28 currently consumes around 1529.6 Megatons of oil equivalent (Mtoe) per year in 2015. About 40% of the total energy consumption corresponds to buildings by covering the needs for heating, cooling and electricity. Based on this data, even consider 20% of reduction, the total energy consumption reduction equivalent to 122.4 Mtoe is expected by using the Design4Energy methodology and tools. According to the German Council for sustainable development more than 2000 full-time jobs could be created for each Mtoe that would be saved, which means, a reduction of 122.4 Mtoe will derive in 244736 full time jobs creation.

In other studies for building retrofitting, energy efficient renovation of buildings supports employment. It is calculated that for every million euros invested, 19 jobs can be generated. Estimations of employment creation differ from source to source, probably due to the different depths of renovation possible and the different targets that are being explored. A 2014 study for Eurima, states that a 'deep renovation' scenario would lead to the creation of an additional 1.4 million jobs by 2050. This implies that the number of jobs created in the

sector is positively correlated to the ambition of the renovation and energy saving targets in building design.

From the point of view of household investment and energy bills reduction, energy unit prices will increase dramatically when actual demand exceed forecasted demand. End-users have no incentive to change consumption during periods of peak demand because real-time prices do not exist at the moment. The energy matching concept integrated in the methodology and tools encourage the incorporate of RES and energy balancing in the neighbourhood, this will favour the deployment of smart grids, putting into practice cost-effective real-time pricing to manage the consumed energy and take advantage of a new framework in which energy price was adapted to energy demands. With the new solution, the existing buildings will need less electricity, gas and fuels to cover the requirements of the building.

Design4Energy methodology developed a KPI framework, the target setting tool enables the end user to consider the energy consumption and the indoor comfort, the simulation and new technology provided as options will enable user to make better decision, improving the building performance without compromising user comfort.

It is clear that such a solution largely contributes to the energy reduction of our economy. Approaches developed in this project, can be used not only for large buildings, but also office or residential environment. The impact of consumption reduction will differ from case to case and highly depend on the investment, but with Design4Energy, building performance can be tackled in early design phase before it is too late to change. The conversation evokes by using Design4Energy during building design will have a large impact in making people more environmentally conscious and will trigger them to adapt their better solution to make the building more energy efficient and lower building lifecycle cost.

4.1.3 Impact on architectural sector

According to the study of the architectural profession, 2016, nearly three quarters of all architectural practices in Europe comprise between one and four persons. An increase of the use of BIM tools has been registered during the last years, especially in the Nordic Countries and United Kingdom. Thanks to national programmes, a significant proportion of the European industry will be using BIM within 2016 and 2020. The change Design4Energy and BIM offers the construction industry has been even bigger than the transformation CAD brought to traditional drawing practices.

Nowadays energy efficiency design and engineering is an important part of intelligent asset management of buildings. Asset management is the optimisation of management, finance, economy, engineering and practices to ensure most effective ways of handling the values connected to properties. It is a systematic process of operating, maintaining and upgrading assets cost-effectively. On strategic level the building owners can help fulfilling political expectations and legislative demands. This includes reaching the EU level energy efficiency targets.

The widespread application of the proposed methodologies and tools, would have a significant impact on reducing the price of architectural projects and O&M labours for energy efficient building design. This new paradigm will provide to new business opportunities for providers, architect firms and consultancy enterprises. Design4Energy methodology enables building owners to set targets and follow the process as well as assess the design proposals that are most capable to fulfil holistic energy efficiency targets. The chief architect is one of the main roles supported by Design4Energy methodology. Architectural offices gain positive socio-economic benefits by being able to offer broader, more holistic energy design services to clients, covering all phases from feasibility study to the cycles of retrofitting the buildings.

The potential impact on the architectural sector can be summarized with the following points:

- Reduce time and people in correcting or changing building design, energy modelling, and energy efficient building design.
- Improve Project Quality by using the Target Setting and Consideration of energy issues in the early stage, Database, benchmarks and Guideline from the project.
- Integrate building performance optimization in early design phase - Energetic Design Timeline Correction.
- Design4Energy could provide the possibility in expanding the service of the architectural studio.
- Design4Energy could contribute the change of expansion strategy of the architectural studios.
- Provide enriched information for building design, facilitate the project management.
- Empower the architects in doing basic energy simulation.
- Initialize the conversation with the clients in energy efficiency issue.
- Provide more information to the clients during decision making phase.
- Optimize the capital investment in new and existing buildings.
- Reduce the risk, improving the accuracy of estimated present and future energy performance, matching with the energy saving targets and the user requirements.
- Design more flexible buildings capable of adapting to local energy infrastructures and conditions, favoring the integration of renewable and the grid connection.

4.1.4 Technological Impact

Although the advance of BIM in the AEC sector provides a sound basis for collaboration, enabling multi-disciplinary design teams to share the same model, further work is still required to enhance the BIM model data with additional energy related information and subsequent mapping to create the appropriate input for energy simulation tools. The Design4Energy project attempted to answer such challenges while developing the methodology, Collaborative Virtual Workspaces and the integrated tools, it enables designer to reach the set of performance targets and create design proposals most capable to fulfil holistic energy efficiency targets, to find the best practical solution during building level design for integration with local electricity and heating neighbourhood net.

The Design4Energy process is supported by set of tools and is automated modelling and simulation. In the process, a comparison is possible of several design alternatives and performance variables during energy analyses. Various technical functionalities are automated through the design driven process to enable architects process their BIM models using an easy and user-friendly approach through an iterative process. This comprises of, model generation and pre-processing to provide the required input for the simulation process (IDF format). The simulation output (csv format) is then post processed using specific tool to generate multi KPI results for the evaluation and decision making processes.

The Collaborative Virtual Workspace offers end-users (architects in particular) two approaches to prepare their models: a proprietary CAD approach and IFC open standard approach. The proprietary CAD approach focuses on supporting tools needed to achieve interoperability where gbXML is used as the data exchange transformation format.

For the gbXML approach, the main concept is component-based: a PlugIn was created for the Revit environment to enable end-users manually generate various design alternatives for a new build design using Option Generator and a simple four step process. Architects can modify the master design by selecting various components with energy parameters from a local library to explore what-if-scenario of their design. In the case of retrofitting existing

buildings, design options are generated automatically with an Option Generator, this option generator is connected to the technology database. However, this database dose not only provide the component library to the option generator, but also knowledge and information to the end user, such as the database of building benchmarks, building components and energy system technologies validated and valued by architects in the early design stage. It enables them to estimate key performance indicators by integrated decision support tools for e.g. costs, environmental impacts or energy performance. The developed database gives manufacturers and technology providers the possibility to present their products which also gives insight of the maturity of the according technology. The database can serve as a platform for sharing technological information which is relevant to the stakeholders for the development of existing or new resources such as software solutions, physical characteristics or distribution of services.

The gbXML approach also facilitate the solar and lighting analysis. Bioclimatic architecture and energy efficient systems and technologies are used to calculate solar irradiance, space solar gain and daylight. Light and solar analysis results are visualised in a solar simulation viewer. Thus this BIM Solar module integrated within the platform, focuses on analyzing the day lighting and measuring the thermal gain / loss of proposed buildings at their conceptual design stage, thus complementing the BIM into an integrated BIM-BEM system (Building Energy Management System), in this way, the platform can provide users with an opportunity to explore different energy saving alternatives early in the design stage, thus avoiding the time-consuming process of re-entering all the building geometry and other supporting information necessary to complete the energy analysis.

For the IFC approach, the eeBIM connected with Energy plus, has several strengths compared to current technology progress, such as the achieved interoperability between BIM and EnergyPlus, which closes a significant gap in today's practical application of BIM in the energy domain, the use of a technological database (library of products) to fill in the modelling gaps with regard to equipment and building element properties and, again, the ability to easily generate and analyse multiple variants. With such solution, the possibility of opening the developed models and tools to many different authoring and analysis tools using the same technology and in establishing interoperability standards in terms of eeBM, tool interoperability in the energy domain and a generalized BIM-IFC design process on medium term. However, the main threats are also associated to the uptake of the IFC standard which is still relatively low and not yet sufficiently supported by today's established CAD systems with regard to the energy domain. Currently, interoperability on the basis of the IFC standard is more difficult to achieve than by other more practice-oriented models such as gbXML, even though the latter lack the generality of the IFC-based approach. Hence, the level of penetration of BIM-IFC on larger scale in industry practice may have decisive influence in the future.

Additionally, the Collaborative Virtual Workspace offers end-users the possibility to visualise large sets of neighbourhood data as multi-layers from both the public sector and the end-user project spaces. Examples of data sets include building layer, social date and energy information can be analysed through a filtering functionalities, thus enabling end-users to better understand the neighbourhood context of their particular building.

Using the proposed integrated BIM methodology at the conceptual stage of the project will help designers determine the products that best meet their needs, evaluate the sustainability of the building based on selected rating systems, and visualize the energy and lighting analysis results in an easy, quick, and convenient way.

Combining sustainable design strategies with BIM technology has the potential to change traditional design practices and to efficiently produce high-performance designs for proposed

buildings and integrated BIM can support the design and analysis of a building system at the early design phase.

4.2 Main Dissemination Activities

4.2.1 Dissemination tools

4.2.1.1   Project presentations

A basic project presentation was created at the beginning of the project and was adapted by partners for project presentation purposes at different events and lectures. The content of the presentations includes:
- NMP EeB Program Review
- Project Overview
- Project Objectives
- Project Scheme
- WPs Overview
- Expected impact
- Project Website
- Contact Info，

In addition to the general project presentation, more presentations were created by project partners focusing on different topics. These presentations are more technology oriented, and have been presented in the training workshop and publicly available, covering different solution, theory and other research outcomes:
- Design4Eenrgy: Project Concept
- KPI framework for designing energy efficient buildings in neighbourhoods
- Novel workflow for considering energy issues in collaboration setting
- Exploration of design options through simulations
- Design4Energy workflow for new designs
- Design4Energy workflow for retrofitting design
- From BIM to BEM

These presentations are also parts of training courses and are available on the online training platform and project website (http://design4energy.eu/Courses.html).

4.2.1.2   Project leaflet

Totally four versions of leaflet have been released, which were issued in M3, M13 and M31 and M48 with different improvements and updates in contents. The third version was issued and used in the WBC16 exhibition. This version integrates summaries of the project outcomes till M31, aiming to present an overall view of the project and more details of the technologies in development. The fourth version with more "product perspective" was released in M48 and used in the final demo workshop in UK. All the leaflets are available in: http://www.design4energy.eu/Brochure.html.

4.2.1.3   Flat poster

Totally 3 versions of flat poster were created. The first poster was created by FHR for the R&D conferences and exhibition in M9, later on, a new design was issued in M18 with the updated project research results integrated. The third version of poster was created with key information of the latest project outcomes.

4.2.1.4 Roll-up poster

A roll-up poster has been created in M30 and is widely used in different conferences and fairs. It is available in http://www.design4energy.eu/Posters.html.

4.2.1.5 Video

A promotional video (https://youtu.be/RyPK0xDb-f0) presenting the core concept and benefit of Design4Energy project was created and spread in different channels.

More videos which are more technical focused were created and publicly accessible in http://design4energy.eu/KitCourse.html.

4.2.1.6 Newsletters

Like electronic bulletin, newsletters are downloadable on the project website and sent to the subscribed users. Totally 7 newsletters were issued.

They are available in http://www.design4energy.eu/Newsletter.html.

4.2.1.7 Branding

A project logo (Figure 6) was created at the beginning of the project in order to define a project identity, thus clearly identifying any kind of internal or public document such as deliverables, reports, internal communications, publications, and any other kind of document within the framework of the project.

Figure 6 Logo of the project

The logo was created as an official icon for the project necessary to give the public an immediate recognition about the project. The project logo was used in the following cases:
-   In all documents developed under the framework of the project, and in particular in documents submitted to the EC such as deliverables, etc.;
-   In PowerPoint presentations used for communication and dissemination activities carried out by each Participant under the framework of the project;
-   On the project website, social networks, and in websites of the Participants with a link to the project website.

The partners' logos were also included according to the dissemination activity and circumstances such as events or presentations but also on publications such as the brochures and posters.

4.2.2 Project Website

The project website (http://www.design4energy.eu/) has been created and accessible since M3 and is continuously updated, aiming to increase the visibility of the Design4Energy project to the public and provide them with a reference for receiving updates during the project activity period. Project report, events, publications, online courses and key information of the tools

developed have been added to the website, even more, the links of some open tools were included in the website.

Statistics on the visitors of the website are also recorded. *Table 1* summarizes the main traffic to the website from M3 to M48. *Table 2* breaks this down by location.

Table 1 Key statistics for website (M3-M48)

Total Visits	Total Users	Page Views	Pages per Visit	Bounce Rate	Avg Visit duration	New Visits
10,423	7810	24,004	2.3	67.4%	1 min 35 sec	74.93%

Table 2 Statistics for top ten countries who visited website (M3-M48)

Country / Territory	Visits	New Visits	Pages / Visit	Avg. Visit Duration	New users	Bounce Rate
United States	1,507	97.94%	1.31	00:00:30	1,476	84.74%
United Kingdom	1,174	71.89%	3.01	00:01:37	844	54.34%
Spain	1,101	38.42%	4.03	00:04:01	423	44.32%
(not set)	997	99.80%	1.13	00:00:18	995	89.17%
Brazil	603	100.00%	1.05	00:00:01	603	97.68%
Germany	551	72.96%	3.20	00:02:00	402	54.26%
China	468	69.23%	1.84	00:01:30	324	71.79%
Poland	360	64.44%	2.71	00:02:24	232	49.17%
Russia	311	21.22%	1.56	00:02:51	66	50.48%
Italy	304	78.62%	2.33	00:01:23	239	62.17%

4.2.3 Social media

Accounts including LinkedIn, Twitter, Facebook have been created to build social communities with the aim to deliver project information to wider publics.

LinkedIn, Facebook and Twitter are the main social networking channels used in the past project periods. Connections with other communities were established by exchanging information, events and news about recent project activities and results, announce project events or events in the scope of the project.

4.2.4 Moodle courses

Public can access the platform in the project website via the e-learning icon, register an account with an email address and carry out the courses online.

The Moodle together with the training material and 3D online gaming environment can be accessed with this link: http://www.design4energy.eu/Courses.html

4.2.5 Publications

4.2.5.1 Scientific Publications

During the project, partners were contributing actively in many international and national conferences and events in the area of energy efficiency in buildings, construction, Building Information Modelling technology, technology cooperation and R&D management related areas. In total, 26 papers, including 5 peer reviewed journals papers, 7 articles in edited book, were published, 14 of them are open access, also there is one chapter of book is accepted and will be published in March 2018.

The list of scientific publications is shown in Template A1 of "Use and dissemination of foreground" part of the final report.

4.2.5.2 Professional Journal

The consortium tried to contact the German professional journal "Allgemeine Bauzeitung" and finally a general article about Design4Energy project was published.

Figure 7 Design4Energy in Allgemeine Bauzeitung

4.2.5.3 Other Appearance

The Design4Energy project was invited to contribute to EeB PPP Project Review 2014, 2015-Issue IV and V of the E2BA annual publication to disseminate project impact, a project summary has been submitted in above editions.

CAD is a member of the Innolab association, where CAD is quite active. Project information of Design4energy is presented in the website (http://www.innolab-swiss.eu/design4energy.html).

Project information and link of the project are included in most project partners' official websites.

4.2.6 Main events

During the project, the consortium has been active in disseminating the project outputs, participating in different fairs, exhibitions, forums, conferences and workshops, including clustering and networking activities. Among these activities, there are 47 oral presentations to a wider public, including the courses and lectures in universities, 9 organization of workshops, 3 participation in exhibitions. Clustering activities such as the ECPPM 2014, ECPPM2016, Sustainable place 2016 and 2017, Impact workshops, EeBers large Stakeholders workshop were successful and beneficial by sharing project outcomes and ideas with other similar

projects. The Design4Energy public exploitation workshop, training workshop and final demo workshop presented the platform and methodology to a wider public, demonstrating the latest technologies and project concept, the possibility in improving the energy efficiency in early design phase by implementing the Design4Energy methodology and tools.

In total, 93 activities were registered during the project, the list of dissemination activities is shown in the Template A2 of "Use and dissemination of foreground" part of the final report.

4.3 Exploitation of Results

The key exploitable results (KERs) were identified, as described in the section 3.

The exploitation of these KERs is classified into two main strands: scientific and potential commercial.

The scientific partners of the Design4Energy consortiums have done numerous presentations of Design4Energy, proceedings throughout the execution a number of publications in different conference and scientific communities that can be found in D1.5.

Further research will make the project outcomes finer and more market demanded. Especially for the backbones of the tools, processes and methodologies, IFC approach could inspire more innovation and integrated in other research programs. At the meantime, these the research results and theories could also be used for educational program which can mean another way to further improve the developed functions and modules.

The following aspects are considered as key activities for the commercial exploitation:

- Sale of Software as a Service (SaaS), including common software delivery paradigms: download-and-install and software-as-a-service, such as Customised support, Premium Users, Support and maintenance service for paid users.
- Validation Service for the 3rd parties that would like to plug their tools into Design4Energy Platform.
- Sale of consultancy services on hourly or project basis, such as a requested design, special energy simulation or other consulting services.
- Training services.

Five potential collaborations methods are defined in D10.7:

1. A Joint Venture (or spin-off company).
2. Responsible partner with access right of the developed tools or licensed granted by the corresponding IPR owner.
3. Collaboration among the members of Design4Energy association.
4. Individual exploitation with high priority support from other partners when needed.
5. Collaboration in new projects and support from other project partners.

Four time frames were considered in the exploitation of the KERs, Figure 8 summarises the key information of the start-up, short-term, mid-term and long-term phase.

2013	2014 - 2016	2017	2018	1st Year	2nd Year

Project Duration				Post Project Periods	
Start-Up Phase	**Short-term: Trial Phase**		**Mid-term: Launch Phase**	**Long-term: Expansion Phase**	
❖ R&D and preparation	❖ Testing of prototype ❖ Implementation in projects ❖ Business preparation and plan design		❖ Collaboration, launching and business development	❖ Improvement of products and expansion of service and market	
• Product and service identification and analysis. • Target group analysis. • Value propositioning. • General project information via website, flyers, publications. • First product related information via flyers and presentations. • Identification of potential future collaborators and market opportunities. • Analysis and forming of exploitation strategy. • Direct contact with potential participants	• Exposure of Design4Energy products and services in different events and channels. • Platform testing and evaluation in three buildings design. • Target group analysis and positioning. • Product analysis and Business model creation. • Approaching target groups: product flyers, mailings, direct contacts. • Product-specific information campaigns. • Further materials like brochures and videos. • Business creation workshop. • Establishment of Community of Practice (Design4Energy Community). • Identification of collaborators and agreements.		• Legal issues and definition of governmental structure. • Preparation of necessary structure, agreement, financial schema. • IPR management. • Creating spin-off or joint-venture. • Definition of tool for first launch. • Agreement in pre-launching activities. • Adaptation of the market oriented guidelines for business development. • Simplification of products. • Infrastructure and software deployment. • Product testing and evaluation. • Commercial video. • Continuous optimisation (adaptation) of the product.	• Adjustment of Business Plan. • Revision of product positioning. • Enrichment of Database and interoperability suite, conversion tool templates and library. • Launch of more stable tools and plug-ins • Market development and expansion (in service and geographically). • Incentives for Community of Practice (testing and innovation). • Continuous marketing and advertising. • Search potential cooperation with other EU projects. • Integration of latest research results from other H2020 projects.	

Figure 8. Overall planning for Design4Energy exploitation

During the project, a Design4Energy Community of Practice (CoP) was established, aiming to gain more feedback and professional opinions to further evaluate and improve the platform as well as to contribute in business development. The members of the CoP are recruited both through the network of Design4Energy SME partners as well as in the mutual collaboration with the stakeholders of the case study projects. Thus, besides the consortium partners, external stakeholders are also invited. Currently, the consortium is supporting the CoP for further testing.

On the other hand, the consortium partners show great intent to establish such long-term collaborative relationship, and to promote the Design4Energy outcomes and professional service to potential stakeholders together even after the project end. For this common objective, a Design4Energy Association has been established.

As an extension of the collaboration beyond the completion of the Design4Energy project, the Design4Energy Association is a not-for-profit voluntary group limited by guarantee and not having share capital.

The mission is:

- To contribute to a sustainably built environment through an efficient usage of the Design4Energy platform, methodology and other outcomes.

The objectives in pursuit of its Mission are:

- To disseminate and exploit the Design4Energy methodology and tools.
- To extend the collaborative relationship of the project partners, in the area of ICT and EeB sector.
- To explore future business potentials and possibilities in commercializing Design4Energy products.
- To accelerate market assimilation of the project results through appropriate successful actions like workshops, demonstrations or implementation support.

- To provide networking opportunities, specifications and written guidance.
- To manage, maintain, promote and exploit the Design4Energy Collaborative Workspace and the associated tools.
- To ensure that the Design4Energy intellectual property is properly protected.

Currently, 13 partners signed the membership letter and wish to have more collaboration in the future. And under the objectives defined, detailed action plan was extended beyond the project duration and is defined in D10.7.

5. PUBLIC WEBSITE AND RELEVANT CONTACT DETAILS

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6. ACRONYMS AND TERMS

Acronym	Explanation.
AEC	Architecture, Engineering and Construction
BIM	Building Information Modelling
BPMN	Business Process Modelling Notation
CoP	Community of Practice
E2BA	Energy Efficient Buildings Association
ECTP	The European Construction, built environment and energy efficient building Technology Platform
EeB	Energy Efficient Building
eeBIM	energy enhanced BIM
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
GHG	Green-House Gas
GUI	Graphical User Interface
HVAC	Heating, Ventilating, and Air Conditioning
ICT	Information and Communications Technology
IDM	Information Delivery Manual
IFC	Industry Foundation Classes
KER	Key Exploitable Result
KPI	Key Performance Indicators
LOD	Level of Detail
MVD	Model View Definition
SaaS	Software as a Service
SOA	Service Oriented Architecture