OptEEmAL

OPTIMISED ENERGY EFFICIENT DESIGN PLATFORM FOR REFURBISHMENT AT DISTRICT LEVEL

Optimised Energy Efficient Design Platform for Refurbishment at District Level
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D2.1: Requirements and Specification for the District Data Model

WP2, Task 2.1

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Abbreviations and Acronyms

Acronym	Description
OptEEmAL	Optimised Energy Efficient Design Platform for Refurbishment at District Level.
DDM	District Data Model
DPI	District Performance Indicator
BIM	Building Information Model
GIS	Geographic Information System
ECM	Energy Conservation Measure
IPD	Integrated Project Delivery
IFC	Industry Foundation Classes
AEC	Architecture, Engineering and Construction
AEC/FM	Architecture/Engineering/Construction and Facilities Management
PSD	Property Set Definition
ADE	Application Domain Extensions
NEST	Neighbourhood Evaluation for Sustainable Territories
XML	eXtensible Mark-up Language
HVAC	Heating, Ventilation, and Air Conditioning
DHW	Domestic Hot Water

Executive Summary

The objective of OptEEmAL is to develop an Optimised Energy Efficient Design Platform for refurbishment at district level. The platform will deliver an optimised, integrated and systematic design based on an Integrated Project Delivery (IPD) approach for building and district retrofitting projects. This will be achieved through development of holistic and effective services platform that involves stakeholders at various stages of the design while assuring interoperability through an integrated ontology-based District Data Model.

This deliverable is the outcome of Task 2.1 "District Data Model requirements definition and specification". The aim of this task is to define the requirements that the District Data Model (DDM) needs to meet to facilitate the OptEEmAL platform functionalities. The DDM integrates all of the data required to perform a refurbishment analysis of buildings within a district, including: Building data, District data, Contextual data, DPIs, Intermediate results, targets, barriers and boundaries. Building data will be collected and stored using BIM-based tools; district data will be managed with GIS systems; contextual data will be collected from the municipality or from open data repositories (climate agencies, national statistics agencies…); targets, barriers and boundaries will be set by the users; and intermediate results and DPIs will be generated by the platform tools or using external tools.

The DDM plays a key role to ensure the interoperability between different standard data models. The proposed DDM is a comprehensive semantic framework which facilitates the intertwining of standard data models with domain specific ontologies. The DDM will be implemented as a set of interoperable data repositories. At this stage of the project five repositories have been envisaged: BIM repository, City repository, Contextual repository, ECM catalogue, and Platform database.

The data to be stored in each of the five repositories has been identified by analysing the processes to be carried out in the OptEEmAL platform. These processes have been synthesized in processes or groups of use cases described by means of a common template. As a result, the specific data to be stored in each repository will be the following:

- BIM repository: BIM models of the case studies and the Enhanced BIM generated by the platform
- City repository: District data in GIS/CityGML formats
- Contextual repository: weather data, economic indicators, social data and environmental data, among others
- ECM catalogue: energy conservation measures for the refurbishment scenarios to be optimized by the platform
- Platform database: District Performance Indicators, platform users, scenarios, user's inputs (e.g., barriers, targets, and boundaries) and simulation models (energy, economical, and environmental) automatically generated.

Besides identifying the data of each repository, the specific requirements for each data type are included. For the building related information, the IFC standard is able to represent the necessary information required by the DDM. Different alternatives to implement the BIM repository have been considered. For the district data, CityGML is the most widely adopted data model to represent a city in 3D including the geometric and semantic information. The district data will be stored in XML-like files or geospatial databases. For the contextual data, each domain of data will require a specific ontology. The contextual data will be stored in a relational database or in a triple-store server. Simulation models represent an intermediate step between the DDM repositories and the simulation tools. Simulation models that are suitable to represent the thermal characteristics of a building have been studied. The ECM catalogue will comply with the common schema of the DDM to ensure interoperability. It will be implemented as a database-agnostic solution operating with SQL. Specific requirements have been identified for DPIs, the project and user related data and the output data.

An initial version of the "Data Dictionary" is included in the annex. The Data Dictionary will be completed with all required data within the following task (T2.3) in WP2.

In the course of carrying out Task 2.1, inputs and results from other tasks have been incorporated to the work. Especially, the results of Task 1.2 "Definition of required input data to evaluate users objectives and current conditions", Task 3.1 "ECMs catalogue requirements definition and specification" and Task 4.3 "Simulation model input generator module: requirements, specifications and design", have been integrated in this task.

1 Introduction

1.1 Purpose and target group

This report constitutes the Deliverable “D2.1 – Requirements and specification for the District Data Model”, the main outcome of the task “T2.1 – District Data Model requirements definition and specification”.

The main objective of this document is to define the requirements that have to be met by the District Data Model (DDM) to facilitate the OptEEmAL platform functionalities. All data required to perform an effective refurbishment analysis of buildings and districts need to be captured by the DDM. DDM will include several different types of information: District data, Building data, Contextual data, DPIs, Intermediate results, targets, barriers, boundaries, etc. Information at building level will be collected and stored using BIM-based tools, information at district level will be managed with GIS systems, contextual data will be collected from the municipality or from open data repositories (Climate agencies, national statistics agencies…), barriers, boundaries, targets and priorities will be set by the user as an input, intermediate results and DPIs will be generated by the OptEEmAL tool or using external tools.

The approach followed in Task 2.1 to collect the data requirements is based on three main processes developed in parallel and merging into the identification of the requirements of the DDM.

- Identification of the data needed for calculation of the District Performance Indicators (DPIs).
- Identification of the data requirements to optimize the refurbishment scenarios. That means the analysis of the data needed by the simulation tools to be used in the OptEEmAL platform.
- Identification of the data available at buildings and district level that the user of each case study can provide for the usage of OptEEmAL platform.

The approach followed in this task is aligned with the General Project Methodology used to define the OptEEmAL requirements, which is presented in the following figure and described below.

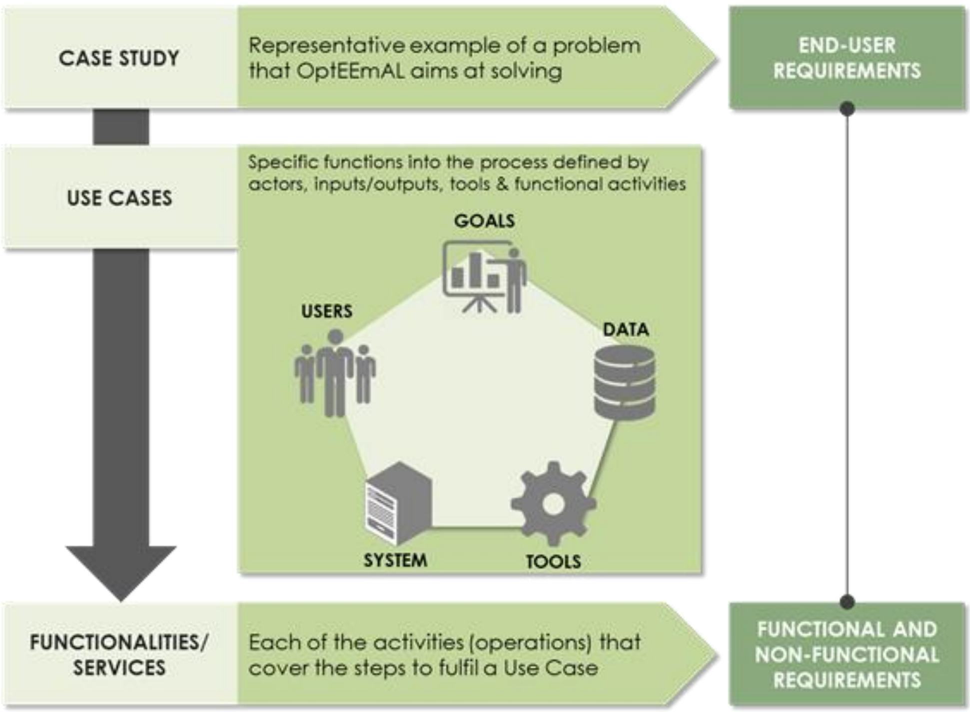

Figure 1 OptEEmAL project methodology

The methodology for OptEEmAL requirements identification is based on the following steps (See OptEEmAL D1.2 [01]):

- **Step 1** – Definition of the case studies by the identification of the real problems that the OptEEmAL Platform aims at solving (based on the 6 case studies and 3 demo cases in the project).
- **Step 2** – Identification of the use cases by means of specific functions that the tool will have to cover and defined in terms of actors, inputs/outputs, tools, goals, etc. for each of the case studies.
- **Step 3** – Aggregation and normalisation of the use cases once defined the complete list to identify those use cases that are included in various case studies.
- **Step 4** – Identification of functionalities that the OptEEmAL platform will have to cover in order to address each of the use cases identified.
- **Step 5** – Identification and definition of requirements for each of the functionalities of the OptEEmAL Platform.

1.2 Contributions of partners

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

Table 1: Contribution of partners

Participant short name	Contributions
TEC	Task Leader. Responsible of the content of the deliverable. Main contributor of Section 1 (Introduction), contributor of Section 5 (District Data Model and Data Repository: Information, Implementation and Interoperability), and Section 6 (Conclusions). Has provide relevant contributions to all the sections
FUNITEC	Main contributor of Section 2.2 (Overall approach of the DDM) and Section 3 (Review of approaches for interoperability), contributor to Section 5 (District data model: information, implementation, and interoperability).
CAR	Main contributor of Section 2.1 (DDM in the OptEEmAL Platform) and Section 4.5 (Optimize Scenarios)
TUC	Main contributor of Section 4.3 (Simulate Current State and Scenarios) and Annex 1: Data Dictionary.
ACC	Main contributor of Section 2.3 (DDM within the IPD based approach), Section 4.1 (Set up a New Project) and Section 4.7 (Export scenario data) that are related to the IPD approach
UTRC-I	Main contributor of Section 4.2 (District Data Modelling)
ES	Main contributor of Section 4.4 (Generate Scenarios) and Section 4.6 (Select and Complete Scenario)
ARG	Main contributor of Section 4.8 (Show Information)

1.3 Relation to other activities in the project

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

Table 2: Relation to other activities in the project

Deliverable Number	Contributions
D1.2	Requirements and specification of input data process to evaluate users objectives and current conditions
D1.3	Requirements and specification of geo-clustering data sets access module
D2.2	Report on District Sustainability Indicators to formulate and optimise scenarios
D3.1	Requirements and specification of the ECMs catalogue
D5.1	Platform High-level architecture
D4.4	Requirements and design of the simulation model input generator module

1.4 Structure of the document

After the introductory section above, in Section 2 the main features of the District Data Model (DDM) and its role in the OptEEmAL platform are introduced. This includes the data requirements to be fulfilled by the DDM. These requirements have been collected through the Use Cases proposed in Deliverable D5.1 "Platform High-level architecture". Also, the requirements of actors participating in Integrated Project Delivery processes have been considered. The characteristics of the data repository which will store and manage the data processed by the platform are outlined. This repository is composed of five different data repositories (BIM repository, City repository, Contextual repository, ECM catalogue and Platform database) whose specifications are also described.

Section 3 focuses on the state of the art regarding interoperability in refurbishment projects at the district level. It includes an overview of the existing standards used by GIS and BIM models and their limitations.

Section 4 is dedicated to identify the requirements for the processes to be conducted in the OptEEmAL platform. These requirements have been specified by creating a set of processes based on the Use Cases proposed in D5.1 and the different types of interaction between the end-users and the platform. Input and output data requirements are provided for each process using a common template. According to this template, data requirements are classified in different categories (e.g. exchange information, availability of the information, information type, and scale).

In Section 5 the work to compile and link the different repositories to be developed in OptEEmAL is presented. A list of issues to be addressed in the subsequent development of the DDM is specified. Different alternatives to implement the various repositories of the DDM are proposed.

Finally, in Section 6 the conclusions about the work done in this task are presented.

In Annex 1, a data dictionary is provided which included parameters needed to carry out simulations with Energy Plus and CitySim; district performance indicators and project data,

2 Role of DDM in OptEEmAL

2.1 DDM in the OptEEmAL Platform

The main objective of OptEEmAL is the development of an Optimised Energy Efficient Design Platform for refurbishment at building and district level. For this purpose, the platform will integrate several interoperable modules and tools (some internal and some external) in order to provide services for diagnosis, scenarios generation, evaluation and optimisation and data export. Those specific modules will work with a large amount of heterogeneous data and will be both included in the platform/connected to the platform.

In this context, it is necessary to ensure the **interoperability** between each step of the design and also with external tools. The development of a Data Model is thus needed to fulfil these interoperability requirements, allowing a framework in which all the actors are using the same language. Also, to ensure this interoperability, it will be necessary to develop an exchange protocol compliant with the different data sources used in OptEEmAL.

The name “District Data Model” makes direct reference to the district scale. However, it should not be forgotten that the DDM will also contain information at the building level, as well as information about the refurbishment project (e.g. project DPIs). As already indicated, this information will be used either inside the platform or outside the platform with external tools.

The information exchanged between the different modules of the platform would be:

- User’s input:
  - District Data: CityGML model
  - Building Data: IFC model
  - Contextual Data: user’s input data and geo-clustered input data
  - Other input information: targets, barriers, boundaries and prioritization criteria
- Data for the operation of the tool:
  - List of DPIs to visualize or calculate
  - Information about generated scenarios
  - Intermediate results
- Final Results - Information to export:
  - enhanced BIM,
  - documentation with advanced information for covering the design purposes and standards and further steps

Other information that will be necessary in the platform:

- Data about the IPD users: name, contact information…
- Data about the platform users/administrator

Considering the heterogeneity (in terms of sources, formats…) of the above information, it appears necessary to establish a common framework and common rules to ensure the right operation of the platform.

In the design process made in the platform, the different modules will communicate with the diverse Data Repositories defined by the DDM in order to ask information or to store processed information. The platform will store the information obtained as result of each one of the steps if this data are used in posterior steps.

The list of Use Cases identified through the definition of the Case Studies in OptEEmAL is listed below and described in detail in Deliverable D5.1:

- UC1: CREATE NEW PROJECT
- UC2: CREATE NEW IPD GROUP SET
- UC3: INSERT DATA

- UC4: CALCULATE DPIs FOR DIAGNOSIS
- UC5: QUERY THE CATALOG
- UC6: OBTAIN SIMULATION MODELS
- UC7: CHECK STRATEGIES
- UC8: GENERATE SCENARIOS – (PREPARE INFORMATION FOR THE OPTIMIZER)
- UC9: OPTIMISE SCENARIOS
- UC10: SELECT OPTIMAL SCENARIO
- UC11: GENERATE THE ENHANCED BIM
- UC12: EXPORT CHOSEN SCENARIO

The definitive list of Use Cases will be detailed in the task T5.1 Platform architecture definition, and collected in the deliverable D5.1 Platform High-level architecture.

Also, the platform should communicate with external tools for advanced calculations and for other services. All the modules of the platform and the external tools will need a common language for exchange the information. The DDM will provide this common language, offering the interoperable scheme to enable the communication and interaction between all the modules and tools involved in the process.

Figure 2 shows the structure of the DDM and the interactions with the OptEEmAL platform.

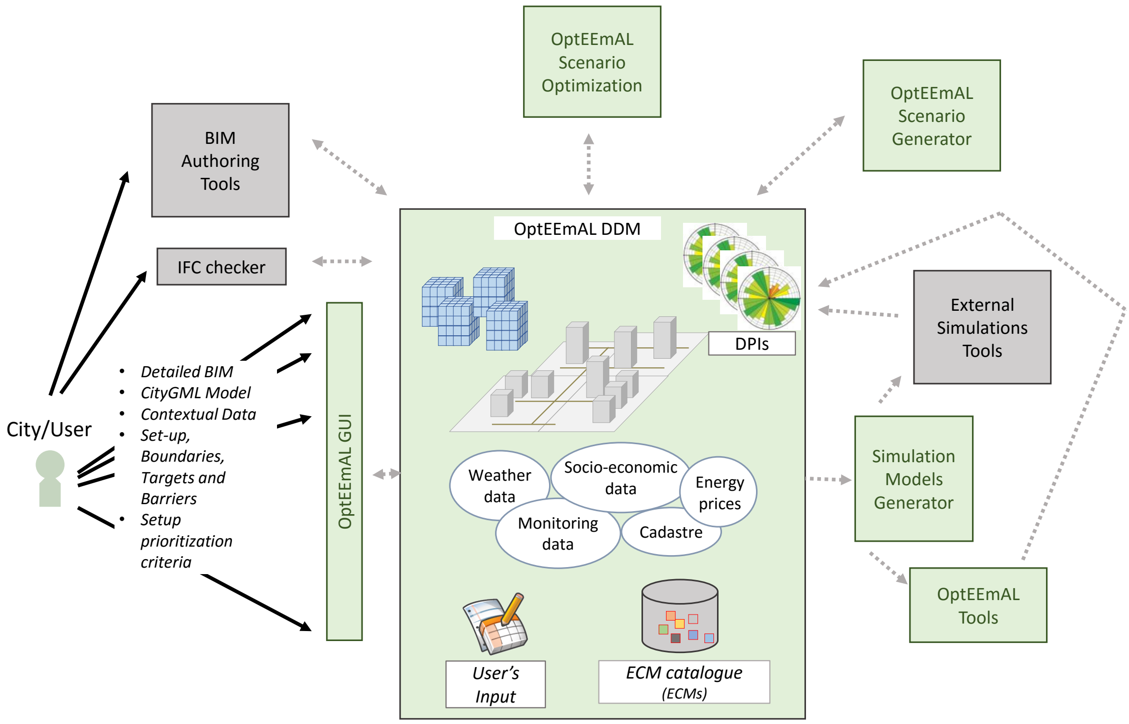

Figure 2 DDM within the OptEEmAL Platform

2.2 Overall Approach of the DDM

The **District Data Model (DDM)** is a comprehensive ontologies-based framework for district information representation based on the intertwining of standard data models (e.g., CityGML, IFC) with ontologies in domains related with sustainable regeneration (energy, social, environment, comfort, urban morphology and economic). The DDM provides a semantically integrated data model (including information about the geometry, materials, equipment, and indicators, at the building and urban scales) that the OptEEmAL platform needs to perform the different functionalities. A **data repository** is a DDM component whose goal is to manage the information required to carry out the platform's processes. Furthermore, the outputs of these processes as well as the users' inputs are stored in the data repository.

The following figure shows the role of the DDM in the OptEEmAL platform along the main functionalities provided by the platform.

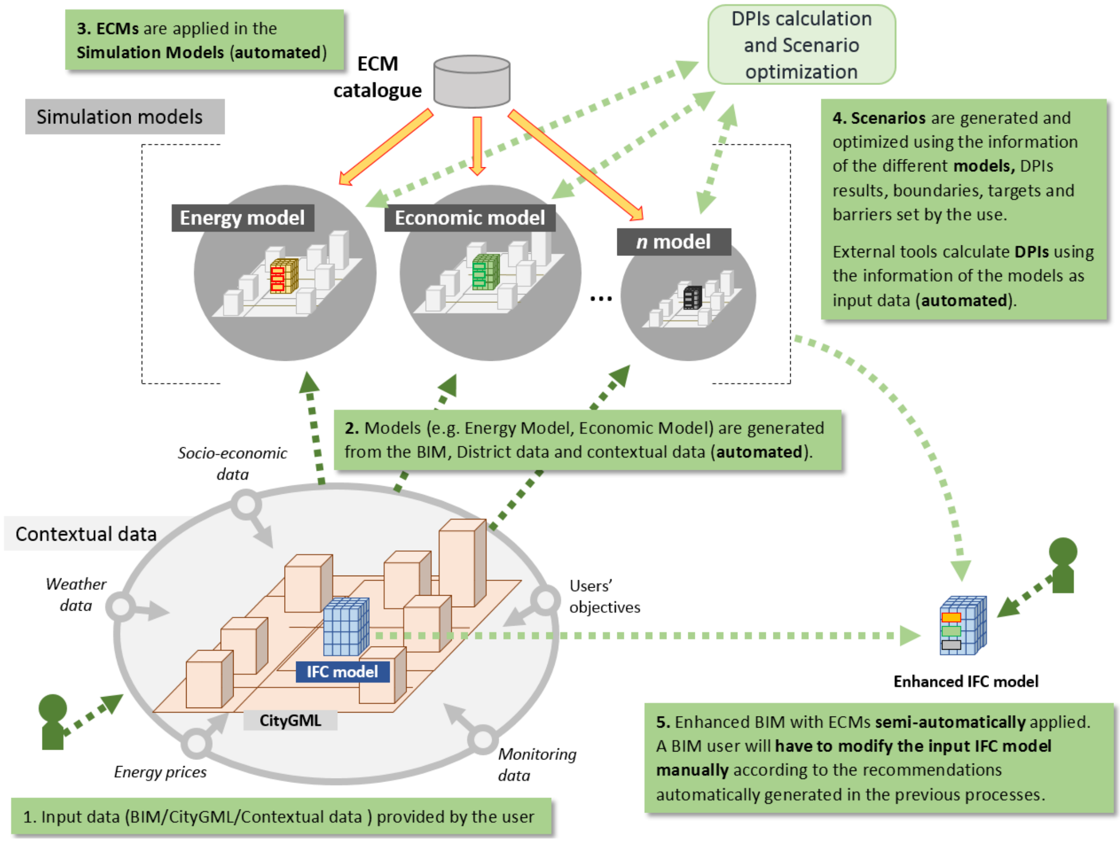

Figure 3 Role of the DDM in the OptEEmAL platform

The DDM represents the data provided by the actors involved in the IPD processes (IPD Principal actors in D1.2), such as IFC/CityGML files and contextual data (weather data, economic indicators, social data, environmental data,...) From this data, different models -such as the Energy Model, Economic Model, and Environmental Model among others- can be generated to calculate specific district Performance Indicators (DPIs). For example, the Energy Model will be used to calculate the energy indicators while the Economic Model will be used to determine the economic indicators. These models are automatically generated. The measures selected from the ECM catalogue are applied to these models to generate scenarios for optimization. External tools will calculate the DPIs using as inputs the data provided by the models. Some of the outputs of the calculations will be automatically introduced in the IFC model provided at the start of the process thus giving rise to an enhanced BIM model. Other changes will have to be introduced manually by the BIM-manager such as the proper replacement of HVAC equipment and pipes to avoid spatial collisions.

The data repository is composed of several repositories to store and manage the data used in the OptEEmAL platform. The repositories store the data provided by the user, the data already existing in the platform (e.g. ECM catalogue, barriers, targets), and the data generated within the platform (e.g. scenarios, simulation models). Five repositories are being considered (Figure 3):

- BIM repository to store the models of the buildings of the case studies. The enhanced BIM models generated by the platform will also be stored in this repository. The number of BIM models to be included in the repository will depend much on the availability of those models. An optimum scenario will include one BIM model for each building, however currently it is not very common to have such models, even less probable for existing buildings. In such case the minimum number of BIM models will be one and will be desirable to have at least a BIM model for each building typology.

- City repository to store a district model. The buildings represented in this model will be linked to the BIM models stored in BIM repository.
- Contextual repository to store the contextual data of the case studies such as weather data, economic indicators, social data, environmental data, among others. These data should be linked to the data stored in BIM and City repositories.
- ECM catalogue to store the energy conservation measures used to generate the refurbishment scenarios to be optimized by the OptEEmAL platform.
- Platform database to store the data generated within the platform such as District Performance Indicators, platform users, scenarios, user's inputs (e.g., barriers, targets, boundaries, priorities) and simulation models (Energy, Economical, Environmental...) automatically generated.

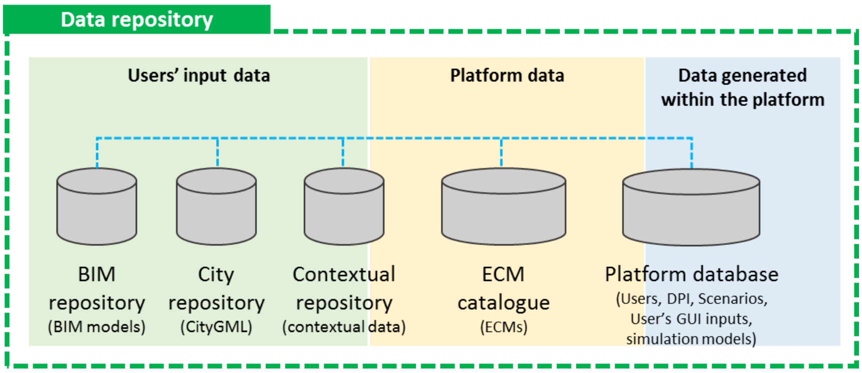

Figure 4 Components of the data repository

2.3 DDM within the IPD-based approach

The main aspect of the DDM in which this is going to be affected by the Integrated Project Delivery approach is that it has to contain all the information of the district that are useful for the user spectrum that is going to be present.

The DDM has to take into account the different needs of the different users that are going to use the platform. Users will manage interactions between them and with the platform using the IPD paradigm. The IPD paradigm is based on "Essential Principles" (See Figure 5) as depicted in the "Optimized Summary" of the official documentation "Integrated Project Delivery: An Updated Working Definition". These principles are:

- Optimize the Whole, Not the Parts
- Early and Clear Goal Definition
- Collaboration
- Integration (people and systems)
- Joint Ownership
- Respect
- Trust
- Transparency
- Safe Environment
- Shared Risk and Reward
- Good Technology

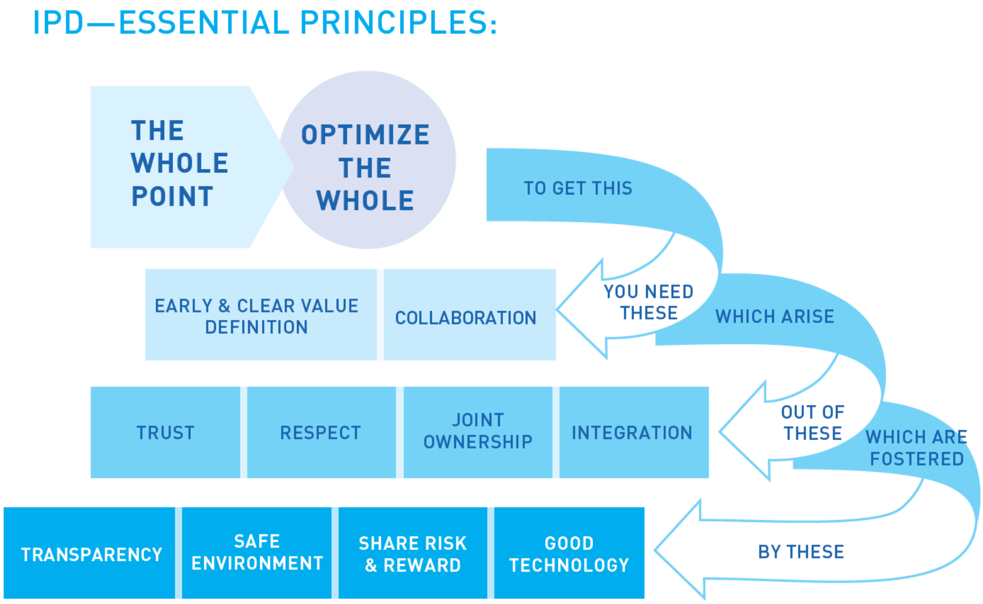

Figure 5 IPD Essential Principles (source: "Integrated Project Delivery: An Updated Working Definition")

Between the items of the above list there are some that are going to have implications in the common District Data Model that is going to be used in the OptEEmAL platform.

2.3.1 Optimize the Whole, Not the Parts

In particular, the official documentation says: "*The point of integrating the project team is to deliver the whole project in a way that gives owners what they value. Whether that is optimized design solutions, increased efficiency over the building's lifetime, or a fast track schedule, higher performance requires that all parties make decisions that are best for the project, rather than their own slices of the pie.*"[02]

The implication that the previous statement has in the platform is:

- The model has to be such that it will be capable of integrating all the interest of the users not separately but in an integrated manner. This means that the platform has to take into account the scenario that describe the district as a whole, not dealing with a separate part without having into account the whole. This can be resumed as "**The model of the district has to be fully integrated having into account the interactions between the different elements and aspects reflected in the model, when it is being modified in one of its parts**".
- The model has to reflect the different associations between the users and the aspects reflected in the model. If one change is proposed by a user, it has to be notified to every user that has a responsibility associated to that aspect or to other that is going to be affected by it. This can be summarized as "**the model has to include the association between the elements described and the users that have their focus on them**".

The previous requirements are for assuring not to make possible to take decisions that can affect to other without their knowledge.

2.3.2 Early and Clear Goal Definition

In the official documentation t is said that "*In order to optimize the whole, the team must agree on what the "whole" is. Project goals are developed early and agreed upon by all participants. Project budget is set early and the team designs to the price, rather than pricing a design.*" [03]

If we focus on the impact that this fact is going to have, we can find that:

- **The model has to reflect all changes from an economic perspective.**
- **The model has to represent to the users the district as a whole (after agreement on what "the whole" is).**

The intention of the previous statements is to ease the establishment of clear and feasible goals.

2.3.3 Collaboration

The specific text for this principle is: "*In order to optimize the whole, the project team must collaborate closely, deeply, and continuously*".

The identified implication it has are:

- **The model has to be such that it allows the access to the information at any time with all the modifications reflected**. This is mandatory if we want a team working "continuously".
- **The model has to be such that it will allow the users to know what changes are being done and by who.** This will help to work "closely".

2.3.4 Integration (people and systems)

"*People cannot collaborate unless they can easily share information, find appropriate times and spaces to communicate, understand how their different design processes interact, get their billing departments to work in harmony, and get many other systems (big and small) integrated together across company lines*".

The implication of this statement has been described in the previously described requirement:

- **The model has to be such that it will allow the users to know what changes are being done and by who.**

Anyway, all the previous requirements are aligned with the collaboration need that is expressed by the above statement.

2.3.5 Joint Ownership

Related to this, it is stated in the official documentation that: "*Meaningful collaboration requires participants to have a sense of ownership over the project and end goals".*

- **The model has to be able to represent (to be aware) of the project goals.** This requirement will ease the identification with the goals and their implications.

2.3.6 Transparency

"*Trust requires transparency. Communication among the team is not limited to traditional silos or top-down distribution. Information of all types, from design rationale to Building Information Modelling (BIM) lives in a central location so all team members have access to accurate and current information. Often an investment in technology compatibility will be necessary to ensure that all team members have access to the information they need to coordinate.* "

- **The model has to be able to work with BIM instances.**
- **The model has to grant access to the information each type of user has to coordinate.**

2.3.7 Safe Environment

For explaining this topic, the document [03] states that "*Trust also requires a project environment in which team members are safe to experiment and suggest innovations without fear of being wrong*".

- For being capable of tackling this problem, **the model should support a Change Log System that allows the system to going to previous stages**.

2.3.8 Standard requirements

The previous sections were focused on the IPD approach, but the data model has to tackle with the common requirements for any platform regarding the users.

- **The model has to be able to process the registration of users.**
- **The model has to store information about the role that a specific user is going to have in the platform.**

2.3.9 Summary for requirements related to the relations between the Integrated Project Delivery paradigm and the District Data Model

- **The model has to be fully integrated having into account the interactions between the different parts and aspects reflected in the model, when it is being modified in one of its parts.**
- **The model has to include the association between the elements described and the users that have their focus on them.**
- **The model has to be aware of the price that every change would imply.**
- **The model has to be such that allows the users to be aware of the district as a whole (for being able to agree what the whole is).**
- **The model has to be such that it allows the access to the information at any time with all the modifications reflected.**
- **The model has to be such that it will allow the users to know what changes are being done and by who.**
- **The model has to be able to represent (to be aware) of the goals.**
- **The model has to be able to work with BIM instances.**
- **The model has to grant access to the information each kind of user need to coordinate.**
- **The model should support a Change Log System that allows the system to go to previous stages easily.**
- **The model has to be able to process the registration of users.**
- **The model has to store information about the role that a specific user is going to have in the platform.**

3 Review of Approaches for Interoperability

3.1 Extension of standard data models

One of the most common limitations associated with the use of standards for interoperability is that they are unable to represent information that is not defined in their data schemes. To try to overcome this limitation, some standards turn to extension mechanisms that facilitate the integration of new domains of information. Such mechanisms are described below for both IFC and CityGML standards. Alternatively to these extension mechanisms, ad hoc interoperable solutions can be created to facilitate the extensibility at the schema level. In these solutions, the information required from the different models is defined under a common understanding encompassed as an ontology.

3.1.1 IFC

The IFC (Industry Foundation Classes) standard is the most extended ISO open and standardized data schema in the AEC sector It started to be developed in 1994 by the BuildingSMART consortium (formerly, the International Alliance for Interoperability, IAI) to support data exchange in the AEC/FM industry. It is also considered as the first standard for exchanging Building Information Models. The IFC standard has been adopted by different government agencies from different countries in the world requiring the information of the building model in this delivery format. They chose it because of its great popularity and acceptance by industry and also because it is supported by the large software vendors, which have been promoting its use and have implemented the necessary interfaces to export and import information in this format.

The main mechanism for dynamic definition extension of IFC models is through the IFC properties set (Pset) which are additional properties assigned to an IFC Entity and include different parameters depending on the case. These property sets can be divided in two groups: 1. properties standardized by BuildingSMART and (2) non-standardized properties (custom properties) that can be created when the model is exported from BIM authoring applications. The properties of the first group are defined into the Property Set Definition (PSD) schema which purpose is to provide an additional specification for properties and property sets outside of the IFC specification, including information such as applicable IFC entities or types (BuildingSMART, 2015). The names of these properties start with the prefix “Pset_” (e.g. Pset_BeamCommon).

3.1.2 CityGML

CityGML is an open and highly scalable standard for data representation, storage, and exchange of urban models based on XML mark-up language. It provides basic entities, attributes, and relations to build a 3D model of an urban area. Objects in this model are split into parts in a logical fashion. An object representation includes its geometry, topology, semantics and appearance for five levels of detail (LOD). A CityGML model can include entities such as buildings, sites, districts, cities, regions, and countries. These models can be used in different application domains such as environmental and training simulations, energy demand estimations, city lifecycle management, urban planning, and urban facility management among others.

Like IFC, the interoperability between tools and services is solved by exchanging data through importing and exporting CityGML files. However, for those domains that are not covered by CityGML data schema can be modelled by means of Application Domain Extensions (ADE). There are several ADEs to extend the CityGML. One of them is the ‘CityGML Energy ADE’ which has been created to store the results of energy simulations and to improve data exchange among tools used to generate them [04].

3.2 Semantic-based interoperability

The purpose of semantic interoperability is to ensure that the meaning of the data can be understood unambiguously by humans and systems. Broadly speaking, semantic interoperability is grounded on a shared understanding of the meanings associated to the data handled by the intercommunicating systems by means of ontologies which make explicit the semantics in a formal language based on a shared understanding of the meaning of the data. Semantic interoperability models, with explicit semantics, can ensure that the meaning of data can be unambiguously understood by both humans and systems [05]. By means of ontologies it is possible to integrate multiple data models, including models created with standards like IFC and CityGML, along with information provided by other data sources (cadastre, GIS, statistics, consumption and climate, for example). Semantic-based interoperability using Semantic Web technologies is a reasonable technological solution to integrate data from multiple heterogeneous sources and to ensure the communication between the integrated data and an open set of tools.

The use of semantic technologies to enhance IFC and CityGML has already been explored in some research works. For example, Katranuschkov et al. [06] created an ontological framework as part of an extensible and open architecture to access data in IFC format. More recently, and as a result of some research projects [07], [08], [09], IFC is now available as an ontology (ifcOWL) with the support of the BuildingSMART. The ifcOWL ontology enables extensions towards other structured data sets using semantic web technologies [10]. Regarding CityGML, [11] presented various approaches based on the use of ontologies to improve the interoperability between 3D urban models. This helped to demonstrate that ontologies can overcome the semantic limitations in CityGML data models.

4 Data Model Requirements for OptEEmAL Processes

From the complete list of Use Cases identified in OptEEmAL the main processes have been selected. Processes are those Use Cases or group of Use Cases with a common interaction between different components of the OptEEmAL platform. The complete list of processes is:

- **Set-up a New Project**: It covers UC1 and UC2
- **District Data Modelling**: It corresponds with UC3
- **Simulate Current State and Scenarios:** It covers UC4 and UC6
- **Generate Scenarios**: It corresponds with UC5, UC6, UC7 and UC8
- **Optimize Scenarios**: It corresponds with UC9
- **Select and Complete Scenario**: It covers UC10 and U11
- **Export Scenario Data**: It corresponds with UC12
- **Show Information**: It is represented in all the UCs

Data model requirements are identified based on OptEEmAL processes because from the point of view of the DDM some of the Use Cases must be grouped into one and also because the visualization of the information is quite relevance from the DDM point of view but it is embedded into all the Use Cases.

For each of the processes the following questions must be answered in order to complete the Data Model requirements.

- **What is going to be provided to the DDM** for each of the processes identified for the OptEEmAL platform? It will define the **Input Data** required from the DDM for each process.
- **What is going to be asked to the DDM** for each of the processes identified for the OptEEmAL platform? It will define the **Output Data** to be used by the platform for each process.

In this section, the DDM is placed in the center and the data requirements are identified with the viewpoint focused on the DDM. In each of the processes identified, the DDM interacts with one or more components of the OptEEmAL platform. The exercise described in this section is to place the view point in the DDM and for each process to identify what information will need the DDM of the other components (Input Data) and what information will provide the DDM to the other components (Output Data).

The requirements for Input and Output data are collected in a table like the following one (See **¡Error! No se encuentra el origen de la referencia.**) for each of the processes identified (some options for values are included as reference).

Table 3 Data Model Requirements Collection

Requirement Name:	Process Name – Input/Output
Exchange Information	Name of the Information
Availability of the Information	User manual input Generated by External tools (specify if known) Generated by OptEEmAL tools Open Data Geo-clustering Data harvesting …
Information Type	Geometric

	Climatic data Socio-economic information Performance Indicator Energy related …
Scale	Europe Country Region City District Building Building Element (specify: Façade, Window, Door, Roof, etc.) Building Installation …
Variability of the information	Static Very low (specify) Yearly Monthly Daily Very high (specify) …
Data Formats	IFC CityGML SHP (GIS file) XLS XML TEXT CSV …
Tools	Energy+ CitySim NEST GIS Tools (ArcGIS, QGIS, gvsig, etc.) CityGML generation Tool (FME, TECNALIA, etc.) BIM Authoring tools (Revit, AllPlan, etc.) IFC chequer (IfcObjectCounter, Solibri, etc.) OptEEmAL Tools (specify) …
Required Precision	High (specify if possible) Medium (specify if possible) Low (specify if possible) …
Unit	If applicable

4.1 Set-up a New Project

The objective in this process of the workflow, also stablished as the first process of the platform, is to create a new project in the platform. To achieve the creation of the new project some data has to be exchanged between the users and the platform. In the next table these data is studied and described with its characteristics to fulfil the objective of quality information in the right form and time.

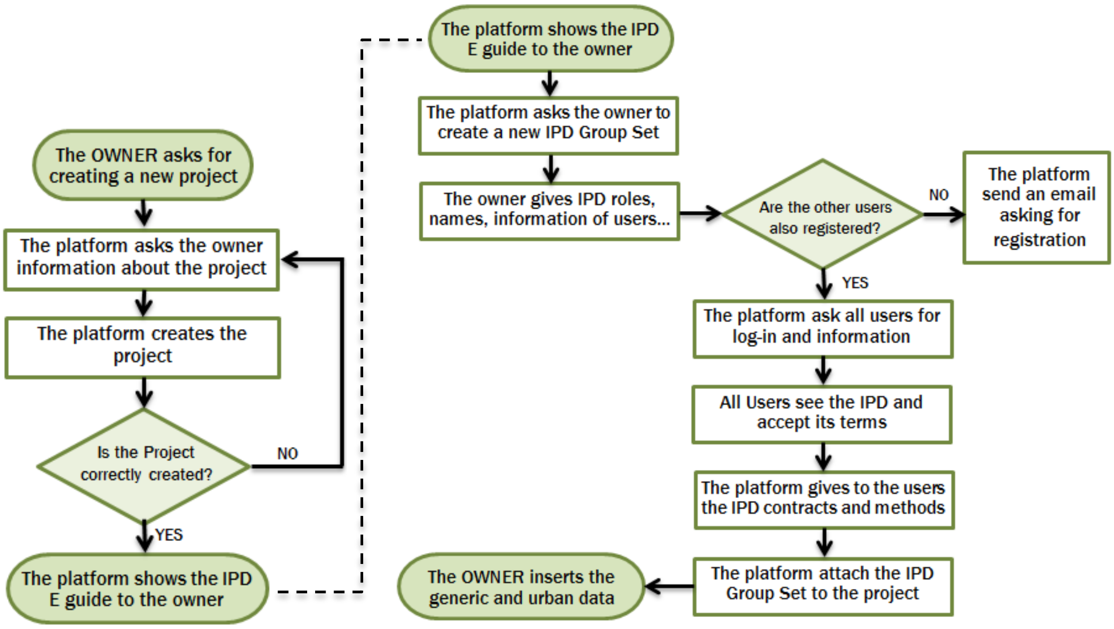

Figure 6 Workflow Create New Project - Create New IPD Group Set

4.1.1 Input Data

Requirement Name:	Set-up a New Project - Input	
Exchange Information	Project Data	Users Data
Availability of the Information	User's Input	User's Input
Information Type	Project Name Description Location Contact Person User's List	IPD group related to the project: Name e-mail Address User Name Password Project List Role in a Project
Scale	District	NA
Variability of the information	Very Low (project data can be edited by the contact person, but it is very unlikely)	Very Low (User data can be edited, but not very often)
Data Formats	TEXT	TEXT

	Location Coordinates	
Tools	Web Form	Web Form
Required Precision	NA	NA
Unit	NA	NA

4.1.2 Output Data

Requirement Name:	Set-up a New Project - Output
Exchange Information	IPD E –guide
Availability of the Information	Information included in the platform
Information Type	Text guide
Scale	World wide
Variability of the information	Static (The information will be fixed, only modify if its needed in future)
Data Formats	PDF
Tools	PDF Viewer (Acrobat Reader, Foxit Reader, etc.)
Required Precision	As specific as needed to understand the guide
Unit	NA

4.2 District Data Modelling

Urban or district model is a virtual representation of the reality of a city or district. Urban Models are used for testing the consequences of physical changes in the built environment of the cities. Urban modelling is a necessary tool for planning and development of policies [12] as they can support from the design of policies to the implementation of specific strategies. Georeferenced 3D models represent an increasingly accepted solution for storing and displaying information at urban scale for energy performance analysis, due to that many of the essential variables influencing the energy demand have to be analysed in a 3D environment. The information contained in the DDM should allow the development of analysis and simulations both at building and district scale. This approach requires the integration of Geographic Information Systems (GIS) and Building Information Models (BIM) into the DDM. At the same time all the contextual information (weather, socio-economic, energy, cadaster, etc.) that represents the current situation of the district should be collected into the DDM.

District Data Modelling process has only Input Data.

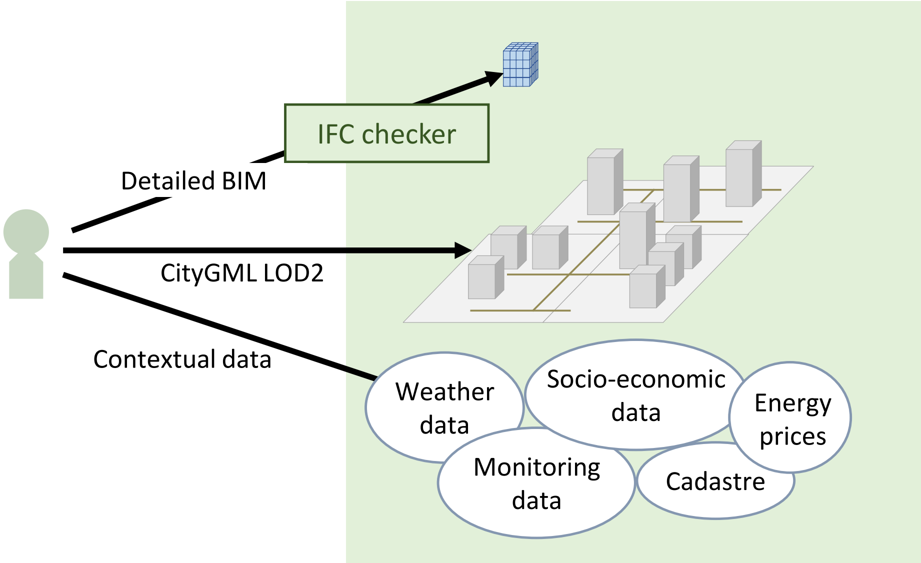

Figure 7 District Data Modelling applied to OptEEmAL

4.2.1 Input Data

Requirement Name:	District Data Modelling - Input					
Exchange Information	District Data	Building Data	Contextual Data	Targets, boundaries and barriers	Prioritization criteria	List of DPIs
Availability of the Information	Generated by External tools	Generated by External tools Estimates based on reference buildings	User manual input Data harvesting Geo-clustering techniques Metered Data	User manual input The information may be collected through a questionnaire	User manual input The information may be collected through a questionnaire	User manual input The information may be collected through a questionnaire
Information Type	Geometric Basic Semantic	Geometric Utility estimates, schedules, energy mix information Building Management / Automation Systems for monitored and weather data Owner or occupier supplied data based on historical consumption Engineering and architectural design data from architects and 3D	District Coordinates: User manual input Urban Data Climatic Data: from weather stations Energy and environmental data: from utility providers or metered data Social data: from city councils and municipality Economic data: from city councils and municipality Etc.	Targets are the goals of the refurbishment project. They are anything that the user considers important, but they do not have a determined limit. Boundaries are the frontiers of the refurbishment project in term of economic limits, comfort limits, impacts, etc. Boundaries could also be the targets with determined limit. Barriers are facts that have to be taken into account for the design project, and that restrict the application of some energy conservation	The prioritization criteria define the importance of each DPI in the optimization algorithm.	Performance Indicators

		models		measures.		
Scale	District Building	Building: Renewables, local generation and storage. Building use and schedules. Building Element (Façade, Window, Door, Roof, etc.) Building Installation: HVAC equipment / controls / set-points	District	District	District	District
Variability of the information	Static	Very low (Related to scenarios)	Depends on the context (e.g. Climatic data variability will be very high, however variability of social data will be very low)	Very Low (They could be modified after the diagnosis of the current situation)	Very Low (It could be modified after the diagnosis of the current situation)	Very Low (They could be modified after the diagnosis of the current situation)
Data Formats	CityGML (File or Geospatial Data Base)	IFC ANSI/ISO BACnet for monitored data XML for HVAC design data	Depending on the context	TEXT	TEXT	TEXT
Tools	GIS Tools (ArcGIS, QGIS, gvsig, etc.) CityGML generation Tools	BIM Authoring tools (Revit, AllPlan, etc.) IFC chequer	Geo-clustering services Data harvesting tools	Web forms	Web forms	Web forms

	(FME, TECNALIA, etc.)	(IfcObjectCounter, Solibri, etc.) BIM - BAS/BMS interfaces (BACnet, WebCtrl, KNX) BIM – BEMS interface (PlantCtrl, I3CON BSG)				
Required Precision	Low (LoD 2 from CityGML)	High (IFC4)	High for monitored and metered data, location and weather data Medium for socio-economic data	Medium-High	Medium-High	NA
Unit	NA	ISO units for mechanical measurements EU/industry standard practices	ISO units for mechanical measurements EU/industry standard practices	NA	NA	NA

4.3 Simulate Current State and Scenarios

The user of the OptEEmAL platform inserts data to describe the current scenario. In the platform, the current scenario is represented by the District Data (CityGML model), the Building Data (BIM model) and the contextual data (urban data, climatic data, energy and environment data, social data, etc.). To complete the description of the current situation, according to the targets, boundaries, barriers and the prioritization criteria, for the refurbishment of the case study provided by the user, the platform calculates the set of DPIs (District Performance Indicator) applicable to the current situation of the district. For this purpose it is necessary to generate different simulation models for each Simulation Tool (Energy+, CitySim, NEST and OptEEmAL Tools).

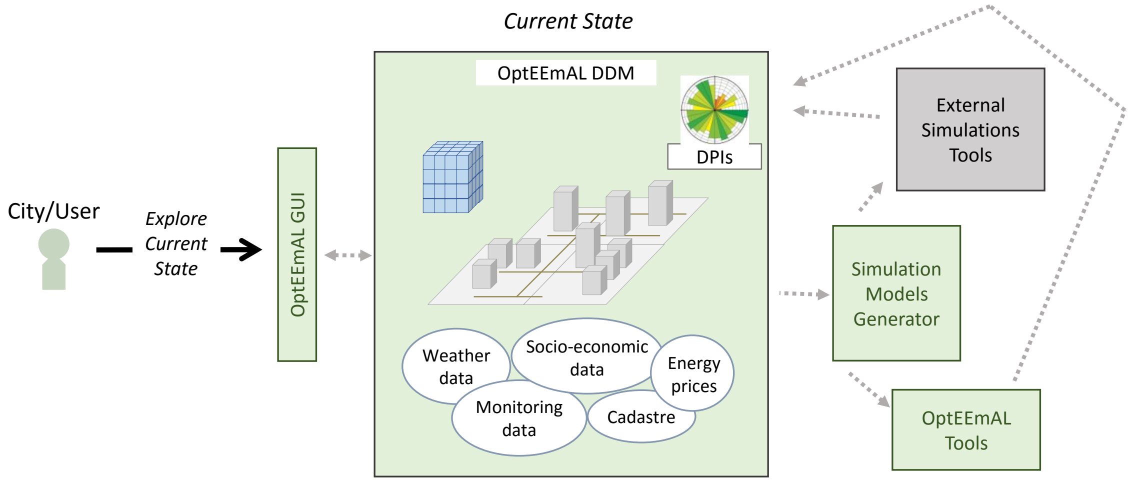

Figure 8 Diagnosis of the Current State

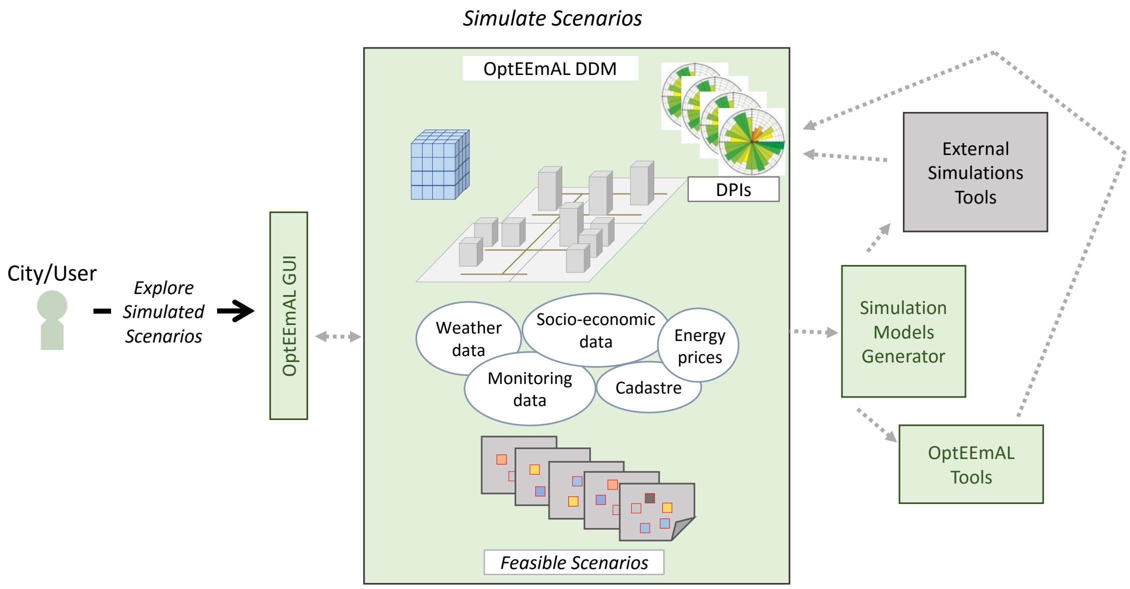

Figure 9 Simulate Scenarios

4.3.1 Input Data

Details on data requirements for each type of information are included as annex in the document (See Annex 1: Data Dictionary).

Requirement Name:	Simulate Current State and Scenarios - Input
Exchange Information	List of DPIs
Availability of the Information	Generated by External tools Generated by OptEEmAL tools
Information Type	Performance Indicator
Scale	District Building
Variability of the information	Static (Only if the information about current state changes it must be updated)
Data Formats	XLS / XML / TEXT / CSV
Tools	Energy+ CitySim NEST OptEEmAL Tools: Implementation of mathematical formulas
Required Precision	High - Medium (The precision depends on the level of detail of the models)
Unit	See Annex for the whole list of DPIs and detail on each Calculation Method

4.3.2 Output Data

Details on data requirements for each type of information are included as annex in the document (See Annex 1: Data Dictionary).

4.3.2.1 EnergyPlus Requirements

Requirement Name:	Simulate Current State and Scenarios – Output - EnergyPlus								
Exchange Information	Simulation Parameters	Building Geometry Description	Building Materials	Weather Data	Schedules	Internal Gains	Energy Systems	Exterior Energy Use Equipment	Renewable Energy Systems
Availability of the Information	Platform Repository (Predefined Dataset)	BIM or CityGML models	Platform Repository (Predefined Dataset), ECM Catalogue, BIM model	Weather Stations, Weather Services	Platform Repository (Predefined Dataset)	Platform Repository (Predefined Dataset)	Platform Repository (Predefined Dataset), ECM Catalogue, BIM model	Platform Repository (Predefined Dataset)	ECM Catalogue, BIM model
Information Type	Simulation parameters	Zone List Zone Description and Geometry	Material data, Properties of materials	Climate data	Simulation data	Simulation data of Electric equipment, People, Lights etc.	Heating, Cooling, HVAC, DHW	Simulation data of Exterior lights, fuel and water equipment, etc.	Photovoltaic Systems Wind Turbine Combined Heat and Power Geothermal Heat Pump
Scale	District	Building Thermal	Building	City	Thermal zone	Thermal zone	Thermal zone	Building	District Building

		zone							
Variability of the information	Static	Static	Static	Hourly	Static	Static	Static	Static	Static
Data Formats	XML, RDF	XML, RDF	XML, RDF	CSV, EPW, XML, RDF	XML, RDF	XML, RDF	XML, RDF	XML, RDF	XML, RDF
Tools	Platform API	Platform API	Platform API	Meteonorm, Wunderground	Platform API	Platform API	Platform API	Platform API	Platform API
Required Precision	High	High	High	High	High	High	High	High	High
Unit	See Annex	See Annex	See Annex	See Annex	See Annex	See Annex	See Annex	See Annex	N/A

4.3.2.2 CitySim Requirements

Requirement Name:	Simulate Current State and Scenarios – Output - CitySim							
Exchange Information	Simulation Parameters	Building Geometry Description	Building Materials	Weather Data	Schedules	Internal Gains	Energy Systems	Renewable Energy Systems
Availability of the Information	Platform Repository (Predefined Dataset)	CityGML model	Platform Repository (Predefined Dataset), ECM Catalogue, BIM model	Weather Stations, Weather Services	Platform Repository (Predefined Dataset)	Platform Repository (Predefined Dataset)	Platform Repository (Predefined Dataset), ECM Catalogue, BIM model	Platform Repository, ECM Catalogue, BIM or CityGML model
Information Type	Simulation parameters	Building Thermal Zone	Layer Group Type	Location and Climate data	Occupants Occupancy	Simulation data of Electric	Heat Tank Cool Tank	PV Solar Heater

		Wall Roof Floor ZoneSurface Ground Surface Ground	Wall Type		Yearly Profile Occupancy Daily Profile Activity Type Activity	equipment, People.	DHW Tank Heat Source Boiler Heat Pump	Micro Wind Turbine
Scale	District	Building Thermal zone	District	City	Building	Building	Building	Wall Roof
Variability of the information	Static	Static	Static	Hourly	Static	Static	Static	Static
Data Formats	XM, CSV	RDF, XML	RDF, XML	CSV, CLI, XML	RDF, XML	RDF, XML	RDF, XML	RDF, XML
Tools	Platform API	Platform API	Platform API	Platform API	Platform API	Platform API	Platform API	Platform API
Required Precision	High	High	High	High	High	High	High	High
Unit	See Annex	See Annex	See Annex	See Annex	See Annex	See Annex	See Annex	See Annex

4.3.2.3 NEST Requirements

Requirement Name:	Simulate Current State and Scenarios – Output - NEST			
Exchange Information	Building Description	ECM Catalogue	List of DPI	Conversion Factors
Availability of the Information	BIM or CityGML model	ECM Catalogue,	Generated by External tools (Energy+ or CitySim)	Included in NEST

Information Type	Building usage Building energy generation systems Building lifetime Building number of user Building area and unit of materials	List of ECM and associated quantities	Energy Demand Energy Consumption per type of fuel	GWP/type of fuel GWP/type of materials (for maintenance) GWP per ECM Primary Energy/type of fuel Primary Energy /type of materials (for maintenance) Primary Energy per ECM €/type of fuel LCC cost/type of materials (for maintenance) LCC cost per ECM
Scale	Building	District Building	Building	City
Variability of the information	Static	Static	Hourly	Static
Data Formats	RDF, XML	XML	CSV	TEXT, XML
Tools	OptEEmAL tools	OptEEmAL Tools	Energy+	Provided by user Geo-clustering services
Required Precision	High	High	High	Medium
Unit	NA	NA	kWh/m²	NA

4.3.2.4 OptEEmAL Tools for DPI calculation Requirements

Requirement Name:	Diagnosis of the Current State - Output - OptEEmAL Tools		
Exchange Information	List of DPIs	Conversion Factors	Contextual Data (energy production costs, number of Inhabitants, mean income level, city population, etc.)
Availability of the Information	Platform Database	Platform Database	Platform Database
Information Type	Performance Indicator	Factors	Costs
Scale	Building	Global	City District
Variability of the information	Dynamic	Static	Static
Data Formats	XML	XML	XML
Tools	Platform API	Platform API	Platform API
Required Precision	High	High	High
Unit	N/A	N/A	N/A

4.4 Generate Scenarios

To generate a new scenario, the platform starts from the current situation as well as from targets, boundaries and barriers provided by the user. In order to identify applicable scenarios, the system retrieves, using the ECM catalogue, the set of measures applicable to the current situation. These sets of measures are the strategies that the platform can use to modify the current scenario. The set of strategies retrieved are proposed to the users, to allow him to select a subset of them that satisfy his needs. Comments are provided by the users about the proposed strategies and the final list of applicable strategies is selected. With the selected list of applicable strategies the platform will generate Feasible Scenarios taken into account the district, buildings and ECM characteristics. The set of feasible scenarios (measurements from ECM catalogue) will be combined with the information about the current state in order to generate the simulation models that should be evaluated and optimized by the platform (See previous process 4.3).

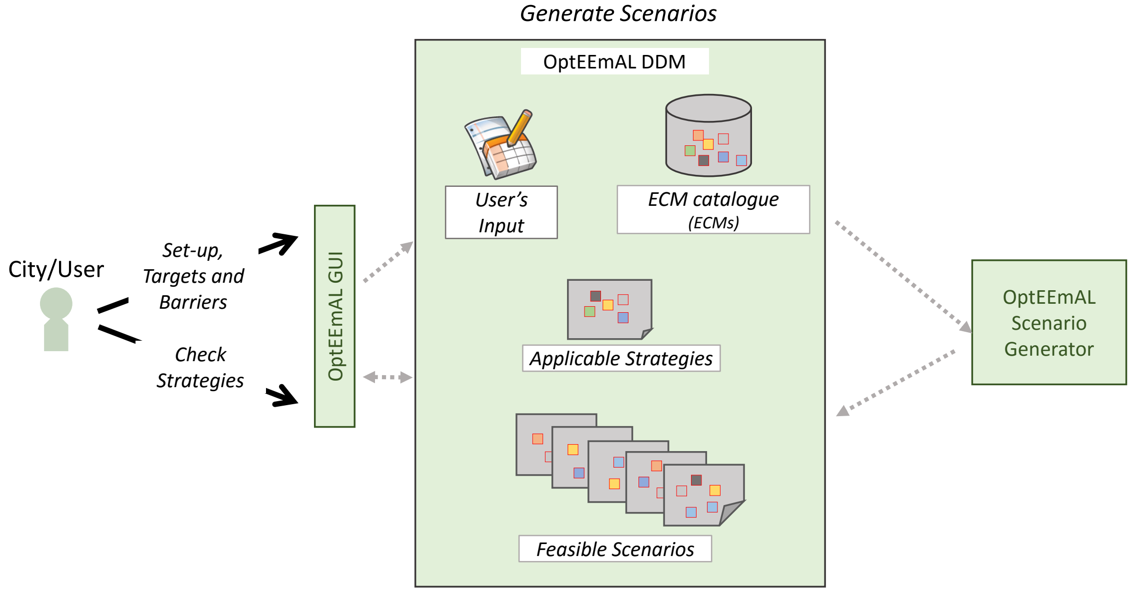

Figure 10 Generation of Feasible Scenarios

4.4.1 Input Data

The user has to interact with the platform in the phase of scenarios generation:

- Providing targets and barriers, to identify among the ECM measurements which are the compliant ones with the user needs. Targets, barriers and boundaries are provided by the user during the district data modelling process. The user can modify the values at this step.
- Selecting which are the strategies (ECM measures) provided by the platform that can be used in the evaluation and optimization phase.

Requirement Name:	Generate Scenarios – Input – OptEEmAL GUI		
Exchange Information	User comments and selection of the applicable strategies	Target, boundaries and barriers	Prioritization criteria
Availability of the Information	User manual input	User manual input	User manual input
Information Type	Comments and	Goals / Targets	Prioritization

	Feedback	Boundaries Barriers	Criteria
Scale	ECM Strategy	District	District
Variability of the information	Static (A user can provide more than one but they all must be stored)	Very Low (They Could be modified after the diagnosis of the current situation)	Very Low (It Could be modified after the diagnosis of the current situation)
Data Formats	TEXT	TEXT	TEXT
Tools	NA	NA	NA
Required Precision	NA	Medium-High	Medium-High
Unit	NA	NA	NA

Requirement Name:	**Generate Scenarios – Input – Scenario Generator**	
Exchange Information	Applicable Strategies	Feasible Scenarios
Availability of the Information	Generated by OptEEmAL tools (Scenario Generator)	Generated by OptEEmAL tools (Scenario Generator)
Information Type	List of ECMs	List of ECMs applied to a building, a set of building or to the district as a whole.
Scale	District	Building(s) District
Variability of the information	Very Low (Some of the ECMs in the initial list identified by the platform can be removed by the user)	Low (For each iteration in the Optimization process a new set of feasible scenarios can be generated)
Data Formats	XML	XML
Tools	OptEEmAL Tools	OptEEmAL Tools
Required Precision	NA	NA
Unit	NA	NA

4.4.2 Output Data

Requirement Name:	**Generate Scenarios – Output – Scenario Generator**
Exchange Information	ECM Catalogue

Availability of the Information	ECM Catalogue
Information Type	Energy related
Scale	District Building
Variability of the information	Static
Data Formats	XML
Tools	OptEEmAL Tools
Required Precision	High
Unit	NA

4.5 Optimize Scenarios

The optimization module will use as input the baseline that consists in diverse simulation models (energy, cost…) and the results of the DPIs calculated in the diagnosis. Other input is a set of different energy conservation measures preselected by the user that can be potentially applied in the district. Last but not least, the prioritisation criteria are used as input for this process, as well as the targets, boundaries and barriers.

With this information the optimization module will use the simulation scenarios module for the evaluation of the behaviour of the district or building using a determined combination of parameters of some of the preselected ECMs. The results of each simulation will be used for recalculating the DPIs that were calculated for the diagnosis, in order to compare the new situation with the initial one. Apart from these DPIs, the optimization module must calculate other indicators for the evaluation, which illustrate the degree of improvement that the scenario offers. It is important to highlight that the boundaries, targets, barriers and prioritisation criteria defined by the user will be used for the ponderation of the calculated DPIs.

Optimization process is an iterative process so once the simulation results are obtained, the Generate Scenarios process (See 4.4) will generate a new set of "Optimised" feasible scenarios. This process will be repeated until all possible combinations of ECM parameters have been considered. Finally the output of this module will be a set of the best scenarios ranked attending to the DPIs and the other evaluation indicators.

Therefore the optimizer module will demand the following information to the DDM:

- User's input:
    - Targets
    - Barriers
    - Boundaries
    - Prioritization Criteria
- List of DPIs
- ECMs preselected initially by the platform and then by the user

And, on the other hand, the optimizer module will store into the DDM the following information:

- Ranking of applicable Scenarios. The information for each applicable scenario is:
    - Combination of ECMs (with their parameters)
    - Result of the DPIs

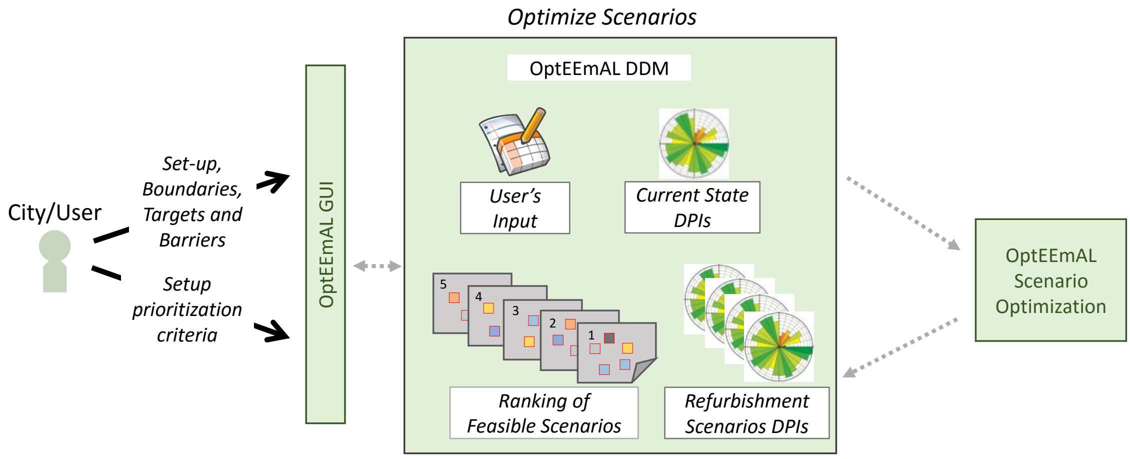

Figure 11 Optimize Scenarios

4.5.1 Input Data

Requirement Name:	Optimize Scenarios – Input – Scenario Optimization	
Exchange Information	Ranking list of Feasible Scenarios	Result of the DPIs
Availability of the Information	Generated by OptEEmAL tools (Scenario Optimization)	Generated by External tools Generated by OptEEmAL tools
Information Type	Ranked list of ECMs applied to a building, a set of building or to the district as a whole.	Performance Indicator and degree of improvement Indicator
Scale	District/Building	District/Building
Variability of the information	A combination of ECM parameters (belonging to a unique or multiple ECMs) for each scenario (from those analysed as the best scenarios)	One set of DPIs for each scenario (from those analysed as the best scenarios)
Data Formats	XLS / XML / TEXT / CSV	XLS / XML / TEXT / CSV
Tools	OptEEmAL Tools: OptEEmAL engine (simulate scenarios)	External tools (defined in Simulate Current State and Scenarios process 4.3)
Required Precision	High	High
Unit	NA	See Annex for detail on each DPI

4.5.2 Output Data

Requirement Name:	Optimize Scenarios – Output – DPIs
Exchange Information	Diagnosis DPIs

Availability of the Information	Calculated in the diagnosis step
Information Type	Performance Indicator
Scale	District/Building
Variability of the information	Static
Data Formats	XLS / XML / TEXT / CSV
Tools	Energy+ CitySim NEST OptEEmAL Tools
Required Precision	High
Unit	See Annex for detail on each DPI
Comment	DPIs calculated in the diagnosis step are needed by the optimizer module, in order to compare with the initial situation

Requirement Name:	Optimize Scenarios – Output – User's Input	
Exchange Information	Targets/Boundaries/Barriers	Prioritization Criteria
Availability of the Information	Defined by the user in the data input step	Defined by the user in the data input step
Information Type	Goals / Targets Boundaries Barriers	Prioritization Criteria
Scale	District/Building	District
Variability of the information	Very Low (They are defined in the first step and could be modified after the diagnosis of the current situation)	Very Low (They are defined in the first step and could be modified after the diagnosis of the current situation)
Data Formats	XML / TEXT / CSV	XML / TEXT / CSV
Tools	Web forms	Web forms
Required Precision	High	High
Unit	NA	NA

4.6 Select and Complete Scenario

The output of the optimization phase is an ordered list of scenarios by DPIs. Every scenario analyzed by the optimization module has a set of DPIs associated that the user can compare with the set of DPIs of the starting situation. User can select the scenario optimized that is the best for his needs that can be different from the best scenario for the platform.

When the user decides which the best scenario is, OptEEmAL platform supports the user in generating the new scenario, applying the ECM measures to the BIM model in order to obtain an Enhanced BIM model. The BIM model will probable be enhanced using a BIM Authoring tool.

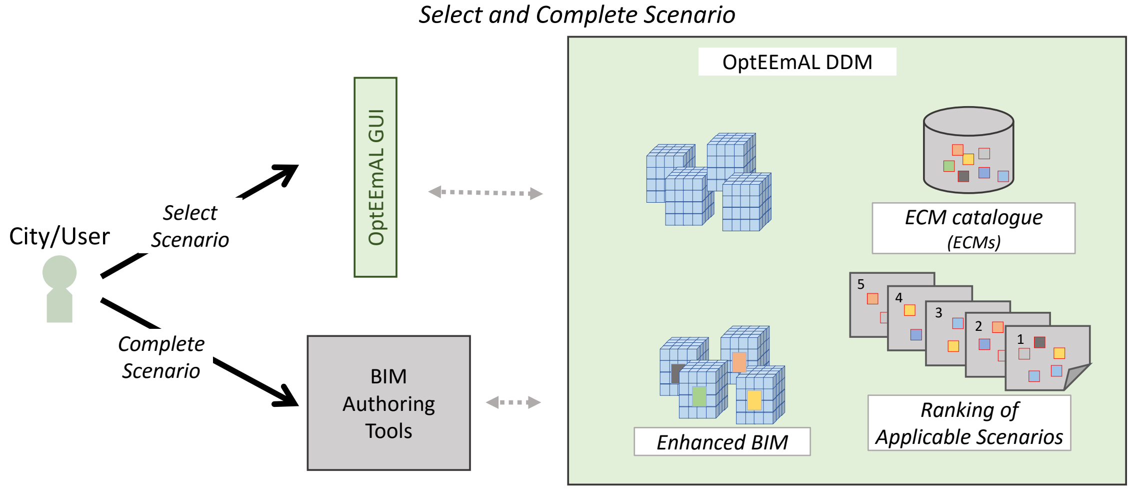

Figure 12 Select and Complete Scenario

4.6.1 Input Data

Requirement Name:	Select and Complete Scenario – Output – BIM Authoring Tools
Exchange Information	Enhanced BIM
Availability of the Information	Generated by External tools (BIM Authoring Tools)
Information Type	Geometric Basic semantic
Scale	Building Building Element Building Installation
Variability of the information	Static
Data Formats	IFC
Tools	BIM Authoring tools (Revit, AllPlan, etc.) IFC chequer (IfcObjectCounter, Solibri, etc.)
Required Precision	High (IFC4)

Unit	NA

4.6.2 Output Data

Requirement Name:	Select and Complete Scenario – Input – BIM Authoring Tools	
Exchange Information	ECM Catalogue	BIM Model
Availability of the Information	ECM Catalogue	Generated by External tools
Information Type	Energy related	Geometric Basic semantic
Scale	District Building	Building Building Element Building Installation
Variability of the information	Static	Static
Data Formats	XML	IFC
Tools	OptEEmAL Tools	BIM Authoring tools (Revit, AllPlan, etc.) IFC chequer (IfcObjectCounter, Solibri, etc.)
Required Precision	High	High (IFC4)
Unit	NA	NA

4.7 Export Scenario Data

Users can obtain data from the platform for the selected scenario. Export scenario data has only exchange Output Data.

- Enhanced BIM (IFC)
- Report (DPIs, figures…) as a tables, chart, pdf, csv….

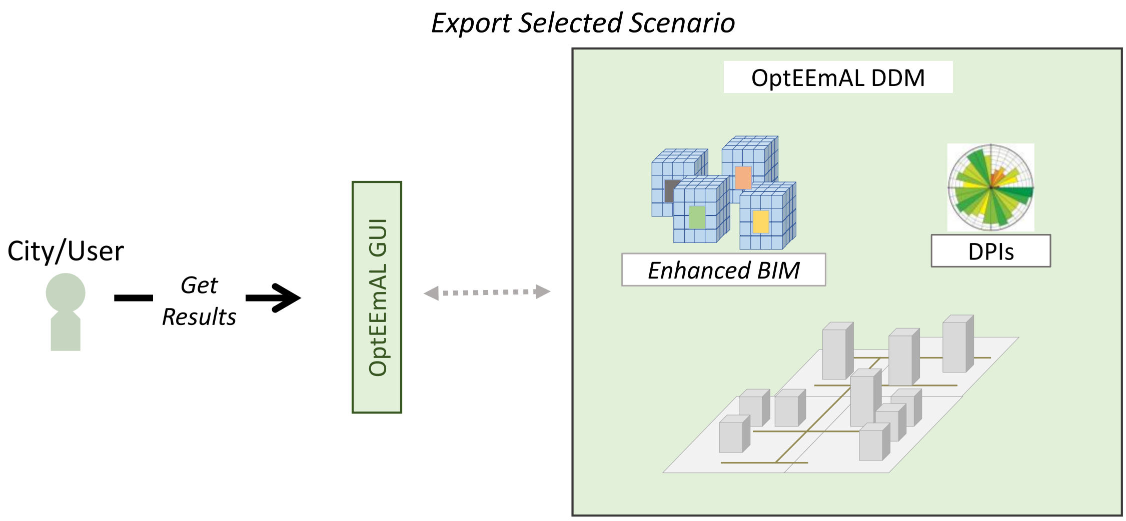

Figure 13 Export Scenario Data

4.7.1 Output Data

Requirement Name:	Export Data – Output – OptEEmAL GUI		
Exchange Information	Building Representation (Enhanced BIM)	District Representation	Reports
Availability of the Information	Generated by OptEEmAL tools		Generated by OptEEmAL tools or External Tools
Information Type	Geometric data	Geometric data	DPIs
Scale	Building Building Element Building Installation	District Building	District Building
Variability of the information	Static (The enhanced BIM represents the buildings in the district with the retrofitting measures applied)	Static	Static (One report for the district and one for each of the buildings in the district)
Data Formats	IFC (file format)	CityGML (file format)	PDF file format for DPI reports CSV format for tables with numbers
Tools	BIM server or similar	The 3D City Database Importer/Exporter	Tools to generate PDF files Tools to generate

			CSV files
Required Precision	High	Low	High
Unit	NA	NA	NA

4.8 Show Information

This process represents the visualization of information for each of the previously defined processes. For each process an initial idea of the GUI mock-up is included. These mock-ups represents an early approach of the final GUI and will allow the identification of requirements concerning the type of information to be displayed to the user.

4.8.1 Input Data

Not Applicable

4.8.2 Output Data

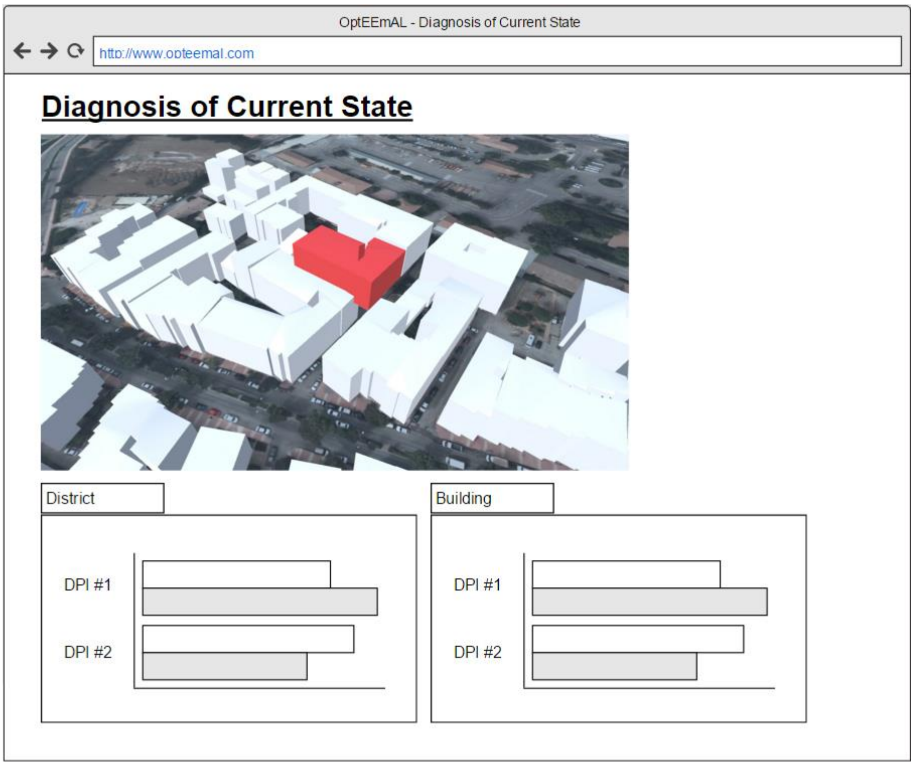

Figure 14 GUI Mock-up Diagnosis of the Current State

Requirement Name:	**Diagnosis of the Current State – Output – OptEEmAL GUI**	
Exchange Information	List of DPIs	District CityGML Data, Building CityGML Data

Availability of the Information	Generated by External tools Generated by OptEEmAL tools	User input
Information Type	Performance Indicator	Geometric and possibly semantic regarding building elements
Scale	District Building	District Building
Variability of the information	Very High (Changes per selected building/s)	Static per project (assuming that user uploads one set of data per project)
Data Formats	Text	CityGML
Tools	Html/Javascript	CityGML reader and 3D visualization tools (webgl or Unity web player)
Required Precision	Sensible numerical precision considering orders of magnitude of the DPI's	High (CityGML models should be accurate to cm/mm precision)
Unit	See Annex for detail on each DPI	NA

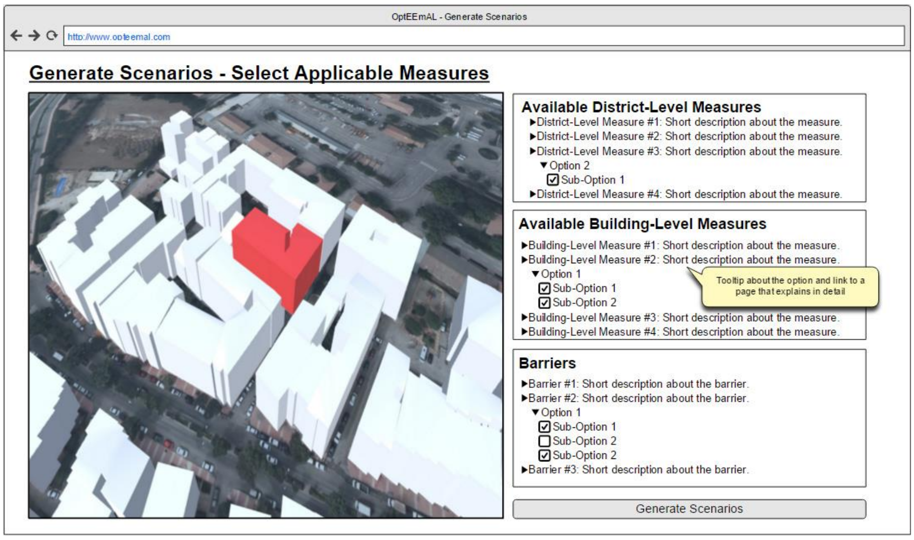

Figure 15 GUI Mock-up Generate Scenarios

Requirement Name:	**Generate Scenarios – Output – OptEEmAL GUI**		
Exchange Information	List of applicable strategies (i.e. ECM measures)	User preferences and barriers	District CityGML Data, Building CityGML Data
Availability of the Information	Platform Users (Project Owner, Prime Designer, Prime Constructor)	Platform Users (Project Owner, Prime Designer, Prime Constructor)	User input

Information Type	Geometric, energy related, material-related, visual	Geometric, energy related, material related, visual	Geometric and possibly semantic regarding building elements
Scale	District, Building, Building Element, Building Installation	District, Building, Building Element, Building Installation	District Building
Variability of the information	Very High (depends on user input up to this process)	Very High (depends on user input up to this process)	Static per project (assuming that user uploads one set of data per project)
Data Formats	Text	Text	CityGML
Tools	Html/Javascript	Html/Javascript	CityGML reader and 3D visualization tools (webgl or Unity web player)
Required Precision	N/A	N/A	High (CityGML models should be accurate to cm/mm precision)
Unit	N/A	N/A	N/A

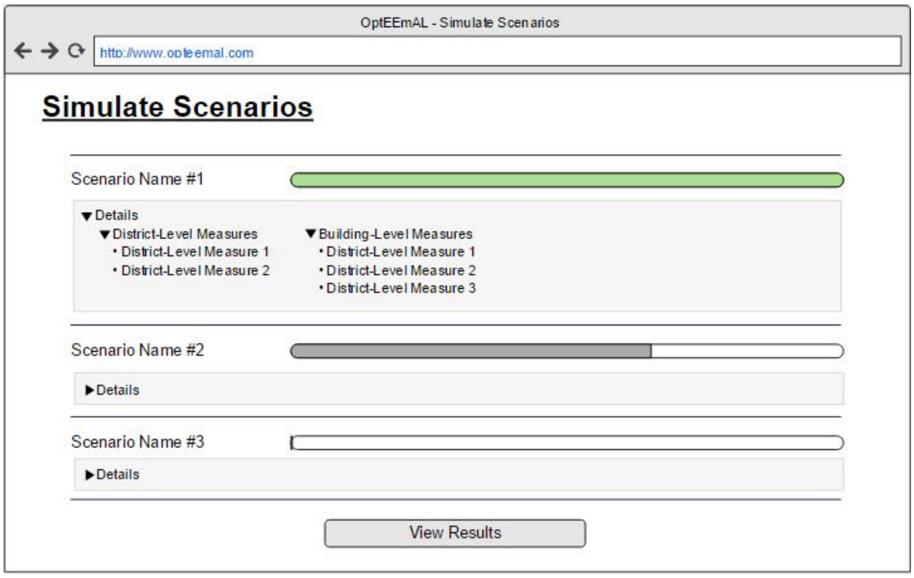

Figure 16 GUI Mock-up Simulate Scenarios

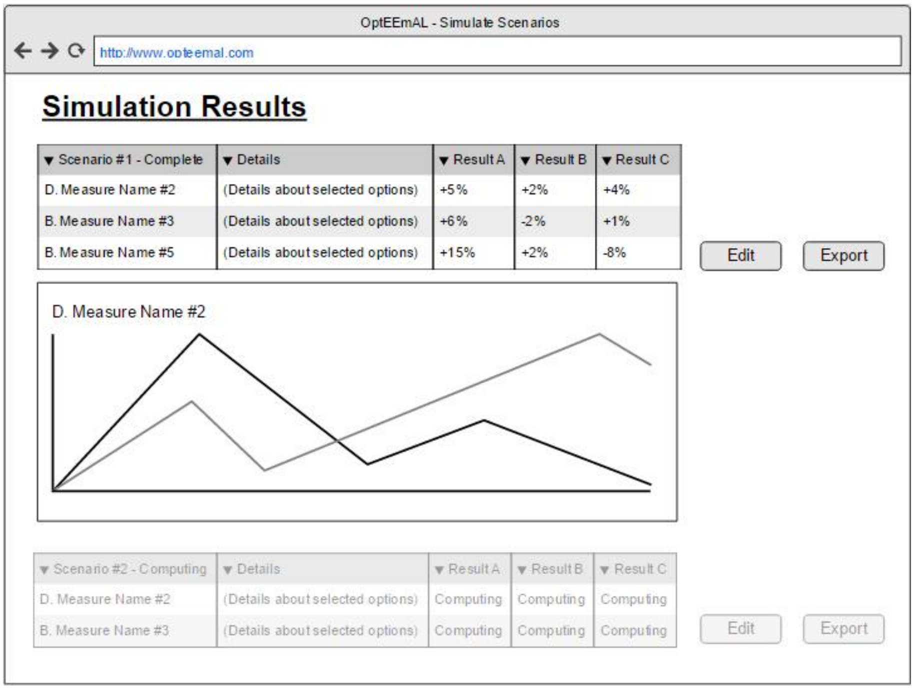

Figure 17 GUI Mock-up Simulation Results

Requirement Name:	Simulate Scenarios – Output – OptEEmAL GUI	
Exchange Information	List of DPIs	List of applied strategies corresponding to each scenario (i.e. ECM measures)
Availability of the Information	Generated by External tools Generated by OptEEmAL tools	Platform Users (Project Owner, Prime Designer, Prime Constructor)
Information Type	Performance Indicator	Geometric, energy related, material-related, visual
Scale	District, Building	District, Building, Building Element, Building Installation
Variability of the information	Very High (Depends on the selected buildings and strategies)	Very High (depends on user input up to this process)
Data Formats	Text	Text
Tools	Energy+ CitySim NEST OptEEmAL Tools	None
Required Precision	Sensible numerical precision considering orders of magnitude of the DPI's	N/A
Unit	See Annex for detail on each	N/A

	DPI	

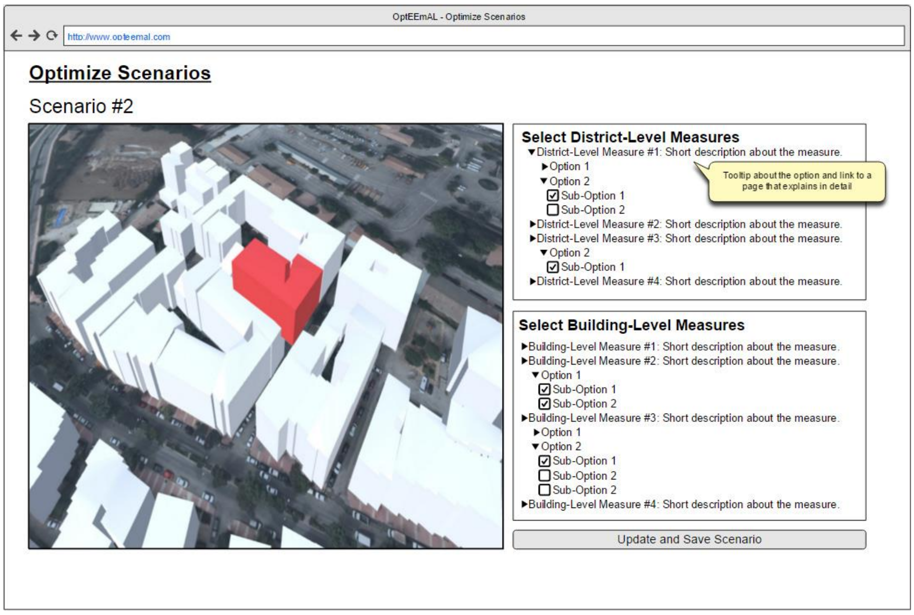

Figure 18 GUI Mock-up Optimize Scenarios

Requirement Name:	Optimize Scenarios – Output – OptEEmAL GUI
Exchange Information	List of applicable strategies (i.e. ECM measures)
Availability of the Information	Platform Users (Project Owner, Prime Designer, Prime Constructor)
Information Type	Geometric, energy related, material-related, visual
Scale	District, Building, Building Element, Building Installation
Variability of the information	Very High (depends on user input up to this process)
Data Formats	Text
Tools	Html/Javascript
Required Precision	N/A
Unit	N/A

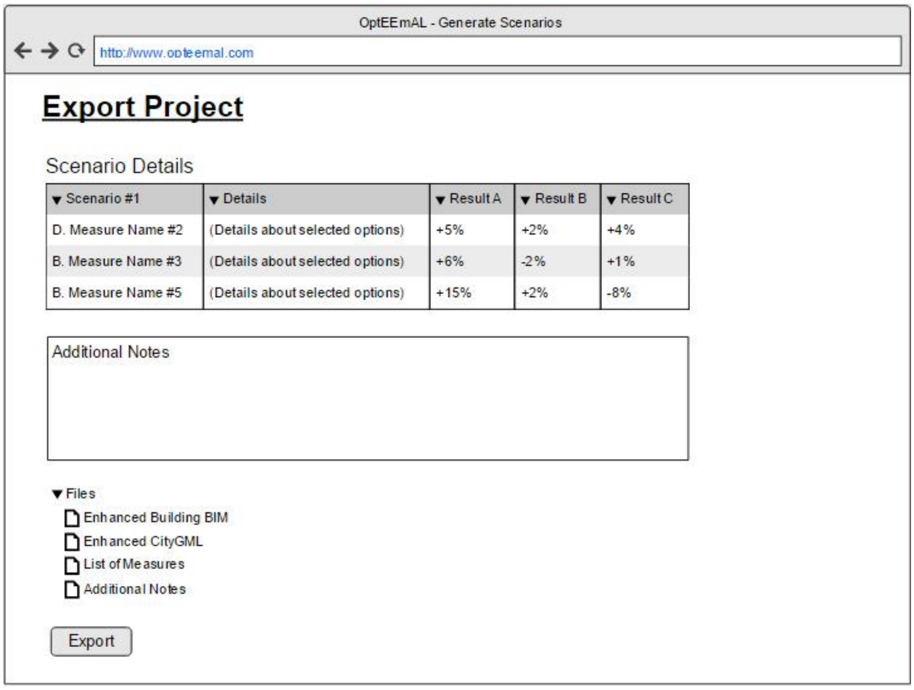

Figure 19 GUI Mock-up Export Project

Requirement Name:	Export Data – Output – OptEEmAL GUI	
Exchange Information	Enhanced BIM model	List of DPIs
Availability of the Information	Project Owner	Generated by External tools Generated by OptEEmAL tools
Information Type	Enhanced BIM model, List of files to be generated	Performance Indicator
Scale	District, Building, Building Element, Building Installation	District, Building
Variability of the information	High (Exported data changes with user selections)	Very High (Depends on the selected buildings and strategies)
Data Formats	IFC / XLS / CSV / TEXT	Text
Tools	OptEEmAL tools (to generate enhanced BIM model and other data)	Energy+ CitySim NEST OptEEmAL Tools
Required Precision	High	Sensible numerical precision considering orders of magnitude of the DPI's
Unit	N/A	See Annex for detail on each DPI

5 District Data Model and Data Repository: Information, Implementation and Interoperability

In this section the requirements collected in the previous section (Section 4) are compiled and linked to the different repositories to be developed in OptEEmAL. An interoperability solution to handle different data models and their interrelation will be implemented according to the DDM requirements. The following table contains a list of questions to be addressed by the DDM. The issues are grouped in different categories according to the type of information to be requested (users' input data, project data, contextual data, etc.). For each issue, the corresponding process and use case is identified.

Table 4 Issues to be addressed by the District Data Model

Issue	Related process	Related Use case
Platform users		
Who created the project?	Set-up a New Project	UC1
Who are the users of the project?	Set-up a New Project	UC2
Who uploaded the XXX model? (e.g., BIM, CityGML…)	District Data Modelling	UC3
Who set/modified a barrier, target, boundary or goal?	Simulate Current State and Scenarios	UC3/UC4/UC5
Who selected the "optimal" scenario?	Select and Complete Scenario	UC10
Who checked an ECM?	Generate Scenarios	UC7/UC8
Who accepted/rejected an ECM?	Generate Scenarios	UC7
Project related		
Which are the barriers, targets, boundaries and goals of a project?	Generate Scenarios	UC5
Which are the prioritization criteria of a project?	Optimize Scenarios	UC9
District/City		
Which are the weather conditions of a region?	Simulate Current State and Scenarios	UC4
Which are the energy prices of the region?	Simulate Current State and Scenarios	UC4/UC6
Building related		
Which are the buildings of a district?	Generate Scenarios	UC6
Which are the XXX elements of a building? (e.g,	Generate Scenarios	UC6

window, wall, HVAC system...)		
Which value has the XXX property of an element? (e.g., U-value of a window/wall...)	Generate Scenarios	UC6
Which is the XXX property of a building (e.g., Conditioned surface, address, id**...)**	Generate Scenarios	UC6
Which are the surrounded buildings of a given building?	Generate Scenarios	UC4/UC6
Does a building model have a detailed BIM?	Generate Scenarios	UC6
Does a building model have a XXX model? (e.g., energy, economic...)	Generate Scenarios	UC6
Which is the wealth of the building occupants?	Generate Scenarios	UC6
Which is the schedule of the building occupants?	Generate Scenarios	UC6
Scenarios/Optimization		
Which are the scenarios for a given district?	Select and Complete Scenario	UC10
Which are the XXX models for a given scenario? (e.g., energy, economic...)	Generate Scenarios	UC8
Which are the DPI of a district for the Baseline/Scenario?	Select and Complete Scenario	UC9/UC10
Which are the DPI of a given building for the Baseline/Scenario?	Select and Complete Scenario	UC9/UC10
Which are the user comments of a scenario?	Select and Complete Scenario	UC10
Which is the "optimal" scenario selected?	Select and Complete Scenario	UC10/UC11
DDM functionalities		
Generate a XXX model (e.g., energy, economic,...) from input data	Simulate Current State and Scenarios	UC6
Store an XXX model (e.g., energy, economic...)	District Data Modelling	UC3
Store a scenario	Generate Scenarios	UC8

Based on the data model requirements for the OptEEmAL processes identified in the previous section (Section 4) and the issues and questions listed in the previous table (**¡Error! No se encuentra el origen de la referencia.**) to be addressed by the DDM, in the following sections requirements for each of the components of the DDM are identified. DDM implementation in OptEEmAL will follow the overall approach presented in section 2.2. For each of the repositories identified in that section (2.2) implementation alternatives are listed and analysed below.

5.1 Building Information Model

The use of BIM for the design of building projects in the construction industry is growing all over the world. This fact cannot be ignored by the OptEEmAL platform because open standards best enable data exchange between a wide variety of software used by participants of a building project (Integrated Project Delivery: A Guide 2007 AIA), and their adoption is necessary as a common basis on which to build any solution based on interoperability. BIM represents a new approach for building construction processes and communication and collaboration between different stakeholders involved in the processes. BIM is based on a shared digital virtual representation of the building which allows better understanding and planning of the building construction processes. It makes the exchange of information easier and also makes changes more manageable and traceable.

The most widespread format for data exchange in this industry is the IFC standard (BuildingSMART, 2015) because of:

- It is a standard and neutral format which can be used in different AEC software.
- It provides a rich set of construction entities and attributes to be compatible with different domains and scenarios.
- Since it is an open file format, the specification is available for everyone.
- It facilitates interoperability. It can be used for many kind of task, in fact it was not only developed for architecture but also for engineering and construction.
- It is a particular type of xml file so that the software to manipulate it is well known and thus it has standardized solutions for manipulating it.
- It is supported by a large number of software applications.

From the point of view of requirements for the OptEEmAL platform described in section 4, the IFC standard is able to represent the necessary information required by the DDM regarding to the building. These requirements can be checked according to table 4.

The following list includes the requirements identified for IFC models in OptEEmAL:

- **IFC models in OptEEmAL must contain information of a building.**
- **Elements in the IFC models must be represented with sufficient level of detail required to perform the simulations. For example, second level space boundaries can be required to represent building elements that bound the space.**
- **Building geometry entities like building elements, openings and volumes are also necessary to perform the simulations.**
- **The connection between geometry and space boundaries need to be defined in IFC models.**
- **Default units need to be specified.**
- **Properties to enable the interpretation of building elements (e.g. exterior vs. interior walls) need to be provided in the expressivity of the IFC schema.**

5.1.1.1 Implementation

Different alternatives can be considered to store IFC models of buildings and enhanced BIM models generated by OptEEmAL platform in the BIM repository introduced in section 2.2.

The BIM repository can be implemented as:

- **BIM Server**. It is an open source building information model server where IFC data is interpreted by a smart core and stored in an underlying database (following the structure of

IFC data). Since this is based on a Model-Driven Architecture approach is possible to query, merge and filter the BIM-model and generate IFC files on the fly. It tries to supply a project model repository and exposes an API which allows the integration into existing environments.

- **3drepo.** is an open source 3D BIM version control system and platform highly extensible and scalable which supports over 40 different 3D file formats (including the IFC). This enables metadata queries across 3D models.
- **bim+** is a centralized, open BIM platform for building projects. Delivered by AllPlan, a Nemetschek company. bim+ is Open BIM compliant and provides universal access, sharing and connection of relevant building information; enabling seamless collaboration among all people in the project. The bim+ API provides RESTful services for accessing, creating, modifying and deleting different levels of information in a building model on the bim+ platform.
- **Custom solution.** A custom server for BIM models can also be implemented based on previous developments of any of the partners in the OptEEmAL project. TECNALIA has previously implemented a data base structure for the storage and management of the versioning of BIM models connecting these models with projects, users, resources and comments or suggestions.

5.2 City Model

Current approaches to building retrofitting manage buildings as isolated objects, ignoring the interaction between them and the district scale. However this approach has been proven as not optimal for cost-effective and holistic improvements. To carry out a refurbishment project of a building or a set of buildings, it is necessary to consider them as part of a district. This approach allows, on the one hand considering interactions between buildings and between the buildings and other city objects (green areas, city furniture, etc.). On the other hand it makes easier to consider energy management strategies at district level, such as the installation of district heating or renewable energy sources or exploit the synergies between buildings with different profiles.

The city model should point to the representation of the buildings that are included in the project. The format for representing the district might have the same characteristics than the BIM one identified in the previous section:

- It has to be platform neutral (it should work fine in more than one platform, e.g. Windows, IOS, Linux.
- It has to have an open file format for containing it.
- It has to be ready for interoperability.
- It should be defined into an xml file.

The following is a list of identified requirements for the City Model in OptEEmAL:

- **City Model in OptEEmAL must contain information of a district.**
- **City Model must include different urban elements, apart from buildings it must support other urban objects such as roads, green areas, transportation networks or city furniture.**
- **All the city objects within district must be represented in 3D and correctly geo referenced on a coordinate reference system in longitude, latitude and elevation.**
- **The information included in the entity that will represent the district has to include references to the specific buildings that are being under the scope of the retrofitting work.**
- **Generation of the City Model should be easy and low cost. Data models already adopted by European cities are preferable. On the same it must be feasible to generate the City Model from existing data sources.**
- **Coherence must be maintained between geometric and semantic information.**

From the point of view of requirements for the OptEEmAL platform and the questions to be addressed by the DDM, **CityGML** [13] is the most adopted standard data model to represent a city in 3D including geometry and semantic information. The aim of the development of CityGML was to reach a common definition and understanding of the basic entities, attributes, and relations within a 3D city model. CityGML is an open data model based on XML format for storage and exchange of virtual models of 3D city defined by the OGC (Open Geospatial Consortium). A city in CityGML is defined as an aggregation of elements of different types. CityGML data model represents most of the elements of the city. Some of these elements are buildings, tunnels, bridges, roads, green areas, rivers, urban furniture, elevation models, etc.

5.2.1.1 Implementation

One of the repositories identified in section 2.2 is the City Repository. It will store the information about the district following the requirements listed above. Different alternatives are envisioned for the implementation of the City Repository, addressing both, the generation of the City Model and the storage of the resulting data model.

5.2.1.1.1 Generation of CityGML

For the generation of the City Model using the CityGML data model there are many tools that can be used. The following figure (Figure 20) shows already identified workflows for the generation of CityGML- based data models.

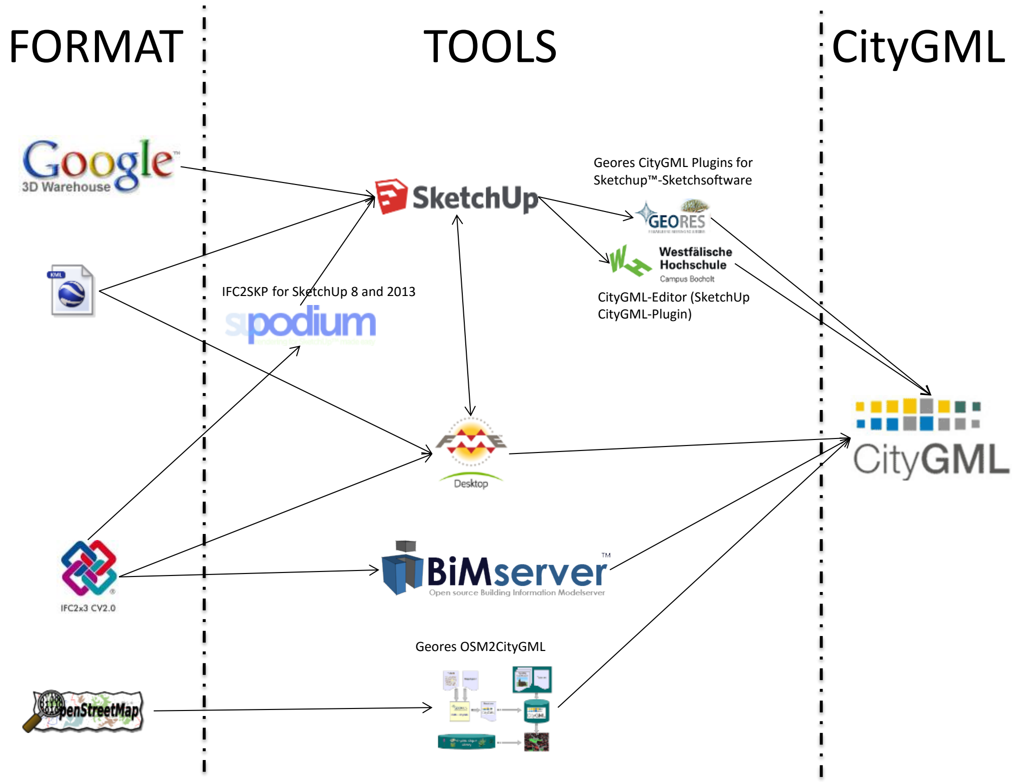

Figure 20 Workflows for CityGML generation

There are different data exportations and transformations that can be performed in order to obtain a resultant CityGML file. In the above figure a variety of formats have been identified (Collada, KML, IFC and OSM) as inputs. Then different tools and plugins that allow geospatial data exchange can be used, such as SketchUp (with plugin like IFC2SKP, Geores CityGML Plugins for Sketchup™-Sketchsoftware or CityGML-Editor (SketchUp CityGML-Plugin)), FME Desktop, BIMServer or Geores OSM2CityGML. In each tool user manual interaction is needed in order to obtain better final results. As an example, in FME Desktop, a basic exportation process can be run; however, the resultant file is not CityGML semantically well completed. A better solution can be obtained by creating a workspace with custom data transformation workflows. Even if it implies mayor user interaction, that have to be done just once and then it is reused, the resultant CityGML quality is greater. As output from the different tools and plugins a CityGML file is obtained.

5.2.1.1.2 Storage of CityGML

CityGML is intended to represent the semantic and geometric information of city objects. XML is the recommended format to exchange this information but it is not suitable for storing and retrieving complex city models where hundreds or thousands of objects can be involved. These files can take up to several gigabytes. Some other drawbacks of using XML are that redundant information is stored unnecessarily, data is more difficult to access and manage, there is no atomicity and integrity and the security level is lower. The alternative is to store the same information in a relational database system extended with spatial capabilities.

3DCityDB is a database scheme to represent and store the information modelled by CityGML [14]. An importer / exporter tool is also available as open source to process, store and retrieve efficiently and quickly CityGML datasets. Currently there are implementations of the database scheme as well as the importer and exporter for Oracle Spatial and PostGIS. The export functionality includes Collada and KML as output formats. The access to the stored city objects is made through Web Services that additionally allows retrieving particular pieces of the whole city model and different stakeholders or applications share the same information. Thus, city models taking up to various gigabytes can be accessed and shared in real time. Since one of objectives in the project is the interoperability between data models and information, standard web services defined by the OGC will be used for accessing the City Model information. WFS (Web Feature Service) is the most used web service for accessing retrieving and editing geographical information. Numerous commercial and open-source implementations of the WFS interface standard exist, including some open-source reference implementations such as GeoServer and deegree.

5.3 Contextual Data

The contextual data will be provided by the end user of the platform and also by the geo-clustered techniques to be developed within the project. A comprehensive description of the requirements of the geo-clustered methods can be found in D1.3 *Requirements and specification of geo-clustering data sets access module*.

The main difficulty to take into account is that the contextual data comes from different domains and is available in different formats. A mandatory requirement of the DDM is to provide an interoperability solution to solve this diversity. Semantic Web technologies have been proven as a valid solution to implement integration process of heterogeneous data sources. A semantic data integration process requires of using a formalised ontology to represent the domains of the data sources. It is important to use already existing ontologies or to extend them in case it is needed. For each domain of data is required to use an ontology. In the following table are listed some ontologies that can be used in the DDM to represent the domains of data:

Domain	Ontology
Land registry	Cadastre and Land Administration Thesaurus

	http://www.cadastralvocabulary.org/
Construction and building materials	FreeClassOWL Ontology http://www.freeclass.eu, http://www.freeclass.eu/freeclass_v1.owl
City Indicators	Global City Indicators http://ontology.eil.utoronto.ca/GCI-v1.owl
Sensors and observations	Semantic sensor network ontology https://www.w3.org/2005/Incubator/ssn/ssnx/ssn
Units of measurements	MUO - Measurement Units Ontology http://purl.oclc.org/NET/muo/muo#
Time	The W3C Time Ontology https://www.w3.org/TR/owl-time

5.3.1.1 Implementation

The contextual data is stored in the contextual repository (See section 2.2 of this document). The contextual data provided by the end user of the platform and by the geo-clustered techniques is modelled in Resource Description Framework (RDF) according to a particular ontology that represents the domain of the contextual data. There are two alternatives to store the RDF data:

- Using a relational database such as PostgreSQL or MySQL where the RDF is stored as a triples. There are several programming libraries (e.g. Jena) that help to manage the RDF data. This alternative only requires a relational database which is not a big deal. However, since the relational database does not support natively RDF the performance of this alternative is not the best.
- Using triple-store such as OpenLink Virtuoso server to store RDF data. The data can be accessed with SPARQL language. Triple-stores have native support to manage RDF and it outperforms the previous alternative. The drawback is the triple-stores that usually have higher system requirements than relational databases

5.4 Simulation Models

As previously stated (See Section 5.1) IFC data model is defined for being used in a broad range of applications and domains. Due to the vast extent of IFC specialized domain application, models should be defined as an intermediate step between the BIM and the Simulation Engine. This intermediate step is represented in OptEEmAL by the Simulation Models. The approach in OptEEmAL will be to use IFC and CityGML as common data models for input and output of the district and building information, which will be further transformed into simulation models tailored for each domain and simulation engine, keeping the traceability and mapping between elements and concepts with the original models. According to the list of DPIs and the way they are grouped into categories, 6 domain models are identified:

- Energy Model

- Environmental Model
- Comfort Model
- Economic Model
- Social Model
- Urban Model

The following are the requirements for the domains models identified in OptEEmAL.

5.4.1 Energy, Environmental and Comfort Model

The tree categories included in this section are very much with the energy performance of the buildings and the district. They will be represented by an Energy Model. The list of main requirements is:

- **The energy model must include simulation parameters to be applied for the whole district.**
- **The energy model must be linked with the climate data sources representative of the weather in the district.**
- **The level of detail required for the Energy Model is the "Zone", which is described with geometry and parameters.**

5.4.1.1 Implementation

The current way of working in the field of Building Energy Performance Simulation (BEPS) involves an architect who designs the building, and an energy expert who has to manually re-create a thermal model using analysis software [15]. The concept of Energy model is an intermediate data format between the architectural model and the energy simulation software. Several data models have been defined for the representation of the thermal characteristics of a building, some of them associated to software tools and others trying to be neutral and compatible with different tools.

- IDF is the input data file format for energy simulation in Energy+. IDF is an ASCII file containing the data describing the building and HVAC system to be simulated.
- gbXML[16] data model was conceived to ease the information exchange between CAD systems and the engineering and simulation tools, mainly energetic ones. It is broadly supported by several leading companies within the sector (Autodesk, Graphisoft and Bentley), which facilitates the interoperability. Moreover, it is based on XML, which facilitates its adoption by software developers. Compared to IFC, this model is more specific in the field of energy efficiency, therefore is more suitable for modelling certain related aspects. As a result, the quantity of data to exchange is less.
- SIMMODEL is an interoperable, structured and easily extensible XML-based data model designed to enable an improved inter-disciplinary data exchange within the simulation domain. The idea behind this model is to reduce the overhead associated with the definition of the input data necessary in whole building energy simulation. The reuse of geometric and other data from different models, for example described in different formats such as IFC, gbXML, and others, enable to reduce the overhead associated with the definition of input data, as well as to reduce error-prone manual processes [17].

5.4.2 Economic, Social and Urban Model

The three categories included in this section are very much related with non-energy related components of the sustainability of the district. They all share a common list of requirements due to the nature of information and data sources. The list of main requirements is:

- **Values for information need to be aggregated at district scale in order to avoid privacy problems and to obtain average values.**
- **Estimations or benchmarking will be used when real data will not be available.**
- **Data will remain very static or the variability will be very low.**

It has not been identified any specific implementation for these simulation models.

5.5 ECM Catalogue

Requirements for ECM Catalogue are included in this deliverable as a summary of the requirements identified in D3.1 "Requirements and specification of the ECMs catalogue" and its implementation according as one of the repositories identified in section 2.2.

The list of main requirements of the ECM Catalogue related with the DDM have been obtained from D3.1 and listed below.

- The catalogue has to include strategies to reduce the district energy demand and consumption through passive, active, local RES integration and control strategies measures.
- The ECMs catalogue must be compliant with the user's goals in the terms the user will define, taking into account the targets, barriers and boundaries.
- The concreteness and level of detail of the information consulted to the ECM will depend on the phase of the project design.
- Constraints of each ECM have to be included into the catalogue developing logics and algorithms when needed.
- ECM catalogue must contain the parameters needed to feed the building and district simulation models.
- For the data completion and the creation of the enhanced BIM a BIM ECM is required.

5.5.1.1 Implementation

The ECM Catalogue is stored in the ECM Catalogue repository (See section 2.2 of this document). The DDM will be used as the common scheme to ensure the interoperability at syntactic and semantic levels. Therefore, the ECM catalogue should comply with the common DDM defined in the project

As stated in the D3.1, the way the BIM of the ECM is provided need to be defined in the following tasks of the project. There are two main alternatives: using external existing databases or implement a new one into the catalogue (from commercial or non-commercial products). Several alternatives have been identified and analyzed in D3.1, some of them allow the possibility to create a link to them from an external catalogue and are classified as of potential interest for OptEEmAL. They must be analyzed in more detail further in the project.

As a conclusion of the D3.1 is stated that the implementation of the ECM Catalogue will be a database agnostic solution. The only constraint will be to using one with the capability of using SQL (simple query language and thus, relational).

5.6 District Performance Indicators Data

The following is the list of requirements for district performance indicators data:

- Each building needs to have a list of indicators which have been calculated by the simulation tools.
- Each district needs to have a list of indicators which have been calculated by the simulation tools.
- The indicators should be able to be aggregated by different options such as: use of the building, year of construction...

- The baseline situation (current state) needs to have a list of indicators which have been calculated by the simulation tools.
- Each scenario needs to have a list of indicators which have been calculated by the simulation tools.

5.6.1.1 Implementation

The performance district indicators will be stored in the platform database (See section 2.2 of this document).

5.7 Project and User Related Data

Project data contains all the information about the district retrofitting to be designed using OptEEmAL. Based on the IPD approach, several actors can collaborate in the project. Information about the users and roles of each of them in the project is described here. Users' input such as targets, boundaries and barriers will be also managed within this dataset.

The following is the list of requirements for project and user related data:

- Each project needs to have a Contact Person of the project, who creates a new project and can edit an existing project.
- More than one user can play the same IPD role in a project
- A user can belong to more than one project and can play different IPD role in each project
- Each user needs to play at least one IPD role in a project
- Each user registered in the platform needs to provide at least an e-mail address
- Each project needs to have a list of goals or targets from a predefined set.
- Each project needs to have a list of boundaries from a predefined set
- Each project needs to have a list of barriers from a predefined set.
- Each project needs to have a list of DPIs of interest for the project
- Each DPI will have a weighting value representing the prioritization criteria of such DPI in a specific project.
- Goals / Targets, boundaries, barriers and prioritization criteria will be set by the user during the district data modelling.
- Goals / Targets, boundaries, barriers and prioritization criteria can be modified after the diagnosis of the current state.

5.7.1.1 Implementation

One of the repositories identified in section 2.2 is the **Platform Repository**. It will store the information about the project and user related data following the requirements listed above.

5.8 Output Data

Output data are those data that will be accessible from the OptEEmAL platform after the design of the refurbishment project based on OptEEmAL.

Enhanced BIMs are the main output data. They will follow the same data requirements and implementation described in section 5.1.

Apart from the BIM models, it is envisioned several kinds of reports. The main one will be the **DPIs report**, which is the report that will include the effects that the proposed retrofitting will have in the district. For being useful and to comply with what it is said in the IPD specification. For choosing the file format, the main concern is to use an open format that is available. The usual PDF file complies with the requirement.

- **The format for all the reports that the platform will include has to be in Portable Document Format (PDF) except for the tables with numbers.**

For representing **large amounts of numbers** it is more useful to use a format that can be read by usual Spreadsheets. The usual XLS is not an open format, so that it is better to use one that it is. Among the possibilities, the most versatile is the CSV one, which is a plain text that separates the fields using a specific character. We can say that:

- **The tables with numbers will be delivered using the CSV format.**

5.8.1.1 Implementation

One of the repositories identified in section 2.2 is the **Platform Repository**. It will store the information about the output data following the requirements listed above.

5.9 Interoperability Requirements

One of the main requirements in OptEEmAL is the fact that heterogeneous information included in the DDM should be exchanged in an easy way between different users and different software tools. Interoperability is a key issue in the project and especially in the definition of the DDM. Interoperability can be achieved mainly by two different means:

- Using open standards for exchanging information.
- Using open services which filter proprietary data formats of different software tools.

The approach to be followed in OptEEmAL is to define the DDM as much as possible based on standards. In that way, the interoperability between data models at different levels (Building – BIM and District – CityGML) and also within different domains (simulation models) will be eased.

The integration of BIM and CityGML is currently a research area and a challenge to be partially faced in OptEEmAL. Efforts of aligning CityGML and IFC have been made in the form of extensions. For IFC the IFC for GIS (IFG) extensions was created, for CityGML the GeoBIM extension. There are also several converters available which do convert IFC into CityGML (e.g. IFCExplorer or FME), however none of them fully addresses the CityGML standard, the accuracy of the results decreases for higher LoDs[18]. There are also ongoing initiatives led by BuildingSMART and OGC to develop an effective integration of both scales. Currently, the OGC is working on the InfraGML standard definition (not yet released). InfraGML searches to link the Geospatial and BIM worlds and influence the conditions and requirements for the infrastructure projects and the contractors. At the same time, BuildingSMART announced the IFC Alignment project [19], which prepares the specification to enhance the current IFC4 data standard for Infrastructure. OGC and buildingSMART are now working closely to arrive at a common conceptual model.

The Semantic Web technologies can be a solution to the interoperability issue of dealing with different standard data models and contextual data from diverse domains. The Semantic Web technologies can be applied at different levels. The minimum requirements are to connect the different data models through links that enable the navigation between the different models. A complete use of the Semantic Web technologies would have stronger requirements such as to have an ontology coded in a formal language (e.g., OWL) for each data model and the data modelled in RDF according to the ontologies. In this case, the links between the different models are set by means of object properties. Those links can be generated manually or using automated ontology matching methods.

In addition to the standards to be used for the definition of the different components of the DDM in OptEEmAL, the definition of links between different data models is required in order to achieve the implementation of the processes defined in OptEEmAL. As a result, the DDM will be implemented as a linked data model in OptEEmAL. Links to be defined in OptEEmAL will address three different levels:

- Model Level Link: It means link between different data models in different repositories describing the same district. All the information which describes a district should be collected and linked. It will include building and district information, contextual data such as energy related, climate and social data, project and user related data and DPIs. Data models can be in the same server or distributed through the web. The same ECM Catalogue could be shared by different districts.
- Object Level Link: It means link between object into different data models (e.g. a building into the IFC and CityGML). This link level is clearly addressed when the simulation model is generated. For the generation of the simulation models, information from different data models must be extracted. In order to get the appropriate information for each data model the proper link between objects must be clearly implemented into the DDM.
- Scenario Level Link: It means link between different alternative retrofitting scenarios describing the same building or district. Alternative retrofitting scenarios will represent variants of the model of a specific district. Several ECMs can be applied to the same district for each alternative. The connection between the ECM and the corresponding object(s) in building(s) should be ensured. Retrofitting scenarios will not address the district level, so the district information will remain static for a specific district in the different scenarios.

6 Conclusions

The work presented in this document furnishes a vision of the District Data Model (DDM) and the associated data repository proposed by the OptEEmAL project to solve the interoperability between various standard data models, namely, IFC and CityGML. According with this concept, the data modelled with these standards will be linked using ontologies. This way, models to carry out specific analysis (energy simulation, economic assessment, etc.) which include data at the building, city and contextual levels, will be derived automatically from de DDM. This vision of the DDM will be later validated with the implementation of a prototype with the available data in the case studies.

A comprehensive review of the data required for each process to be conducted in the OptEEmAL platform has been carried out. This review has helped to define the requirements of the District Data Model and the data repository. Moreover, different alternatives to implement the data repository have been considered.

OptEEmAL is a complex project which requires the development and integration of different modules such as the DDM, ECM catalogue, geo-clustering techniques, and scenario optimizer, among others. This makes it difficult to come up with a complete list of requirements and specifications until all the modules are more precisely defined. At the current stage of the project development, it is only possible to have a first specification of the DDM requirements.

One of the main conclusions of the work carried out is that it is necessary the support of an expert BIM user to generate the final enhanced IFC models. There are energy conservation measures that cannot be automatically applied to a model IFC, since they can lead to structural changes in the building. The proposed solution is to automate as much as possible the processes undertaken by the platform, but letting to the final user the task to complete and verify the proposed changes in the BIM model.

Assuring the interoperability between heterogeneous information is a major requirement of the OptEEmAL platform. In addition to the use of standards like IFC and CityGML, it will be necessary to create links between different data models to perform the functionalities foreseen in the platform. Three different types of link can be identified at this stage: (1) links between different data models in different repositories describing the same district; (2) links between objects into different data models (e.g. a building into the IFC and CityGML); and (3) links between alternative retrofitting scenarios describing the same building or district.

The work described in this document is part of the OptEEmAL platform's requirements identification process, which will continue in Task 5.1 "Platform architecture definition". In the subsequent development of the platform, the specifications of the DDM presented in this document will need to be reviewed and further enhanced. Also, the work done in this task will set the basis for other tasks in WP2, in particular those concerned with the design, implementation and deployment of the DDM repositories.

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8 Annex 1: Data Dictionary

8.1 Simulation Parameters needed by Energy Plus

Table 4 Location data needed by Energy Plus

Energy Plus Requirement:	Simulation Data	Units	Object Type
Exchange Information	Time step		Integer
	Starting month		Integer
	Starting day of month		Integer
	End month		Integer
	End day of month		Integer
	Outside surface heat balance algorithm		Enumeration (Simple Combined, TARP, MoWiTT, DOE-2, Adaptive Convection Algorithm)
	Inside surface heat balance algorithm		Enumeration (Simple, TARP, Ceiling Diffuser, Adaptive Convection Algorithm)
	Zone air heat balance algorithm		Enumeration (Third Order Backward Difference, Analytical Solution, Euler Method)
	Shadow calculation algorithm		Enumeration (Sutherland Hodgman, Convex Weiler Atherton)
	Solar calculation algorithm		Enumeration (Simple Sky Diffuse Modelling, Detailed Sky Diffuse Modelling)
Availability of the Information	Platform Repository (Predefined Dataset)		
Information Type	Simulation parameters		

Scale	District
Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Table 5 Location data needed by Energy Plus

Energy Plus Requirement:	Location Data	Units	Object Type
Exchange Information	Latitude	°	Double
	Longitude	°	Double
	Time zone Offset	hrs	Integer
	Elevation	m	Integer
Availability of the Information	User manual input		
Information Type	Location data		
Scale	District		
Variability of the information	Static		
Data Formats	GML, EPW, CLI, XML, RDF		
Tools	METEONORM		
Required Precision	Medium		

Table 6 Climate data needed by Energy Plus

Energy Plus Requirement:	Climate Data	Units	Object Type
Exchange Information	Date	ISO	List<Date>
	Dry-bulb temperature	°C	List<Double>
	Relative humidity	%	List<Double>
	Atmospheric pressure	Pa	List<Double>
	Global horizontal radiation	Wh/m²	List<Double>

	Direct normal radiation	Wh/m^2	List<Double>
	Diffuse horizontal radiation	Wh/m^2	List<Double>
	Global horizontal illuminance	lux	List<Double>
	Direct normal illuminance	lux	List<Double>
	Diffuse horizontal illuminance	lux	List<Double>
	Zenith illuminance	lux	List<Double>
	Wind speed	m/s	List<Double>
	Wind direction	°	List<Integer>
	Total sky cover		List<Integer>
	Rain indicator		List<Boolean>
	Snow indicator		List<Boolean>
Availability of the Information	Weather Stations, Weather Services		
Information Type	Climate data		
Scale	City		
Variability of the information	Hourly		
Data Formats	CSV, EPW, XML, RDF		
Tools	METEONORM, WUNDERGROUND		
Required Precision	High		

Table 7 Building data needed by Energy Plus

Energy Plus Requirement:	Zone List	Units / Cardinality	Object Type
Exchange Information	Name		String
	Zone	1…*	**Zone**
Availability of the Information	BIM models or CityGML models after processing by internal tool		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		

Data Formats	XML, RDF
Tools	Platform tool
Required Precision	High

Energy Plus Requirement:	Zone	Units / Cardinality	Object Type
Exchange Information	Name		String
	People	0…*	**People**
	Lights	0…*	**Lights**
	Electric equipment	0…*	**Equipment**
	Gas equipment	0…*	**Equipment**
	Steam equipment	0…*	**Equipment**
	Other equipment	0…*	**Equipment**
	Hot water equipment	0…*	**Equipment**
	Infiltration zone	1…1	**Infiltration Design Flow Rate**
	Ventilation zone	1…1	**Ventilation Design Flow Rate**
	Building surface	1…*	**Building Surface Detailed**
	Fenestration surface	1…*	**Fenestration Surface Detailed**
	Internal mass	0…*	**Internal Mass**
	Inside convection algorithm		Enumeration (Simple, Detailed, Ceiling Diffuser, Adaptive Convection Algorithm, Trombe Wall)
	Outside convection algorithm		Enumeration (Simple Combined, TARP, DOE-2, MoWiTT, Adaptive Convection Algorithm)
	Part of total floor area		Boolean
Availability of the Information	BIM models or CityGML models after processing by internal tool		
Information Type	Simulation data		
Scale	Building		

Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform tool
Required Precision	High

Energy Plus Requirement:	Building Surface Detailed	Cardinality (Units)	Object Type
Exchange Information	Name		String
	Surface type		Enumeration (Wall, Floor, Ceiling, Roof)
	Construction name		String
	Outside boundary condition		Enumeration (Surface, Adiabatic, Zone, Outdoors, Ground)
	Outside boundary condition object	0…1	**Building Surface Detailed**
	Sun exposure		Enumeration (SunExposed, NoSun)
	Wind exposure		Enumeration (WindExposed, NoWind)
	View factor to ground		Double
	Vertex (x, y, z)	3…120(m)	List<Double>
Availability of the Information	BIM models or CityGML models after processing by internal tool		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform tool		
Required Precision	High		

Energy Plus Requirement:	Fenestration Surface Detailed	Units / Cardinality	Object Type

Exchange Information	Name		String
	Surface type		Enumeration (Window, Door, Glass Door, Tubular Daylight Dome, Tubular Daylight Diffuser)
	Construction name		String
	Building surface name		String
	Outside boundary condition object	0...1	**Fenestration Surface Detailed**
	Shading Control Name		String
	Frame and Divider Name		String
	View factor to ground		Double
	Vertex (x, y, z)	3...4 (m)	List<Double>
Availability of the Information	BIM models or CityGML models after processing by internal tool		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform tool		
Required Precision	High		

Energy Plus Requirement:	Internal Mass	Units / Cardinality	Object Type
Exchange Information	Name		String
	Zone	1...1	**Zone**
	Construction	1...1	**Construction**
	Surface	m^2	Double
Availability of the Information	BIM models or CityGML models after processing by internal tool		
Information Type	Simulation data		
Scale	Thermal zone		

Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform tool
Required Precision	High

Energy Plus Requirement:	**Schedule**	**Cardinality**	**Object Type**
Exchange Information	Simulation Timestamp	1…1	List<Long>
	Schedule value	1…1	List<Double, Boolean, Integer>
Availability of the Information	Platform Repository		
Information Type	Simulation data		
Scale	Building / District		
Variability of the information	Variable (daily, hourly, sub-hourly)		
Data Formats	XML, RDF		
Tools	Platform tool		
Required Precision	High		

Energy Plus Requirement:	**People**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Maximum number of people		Integer
	Zone	1…1	**Zone, Zone List**
	Occupancy schedule	1…1	**Schedule**
	Fraction radiant	[0,1]	Double
	Sensible heat fraction	[0,1]	Double
	Carbon dioxide gen rate	$m^3/s \cdot W$	Double
Availability of the Information	Platform Repository (Predefined Dataset)		

Information Type	Simulation data
Scale	Thermal zone
Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	Lights	Units / Cardinality	Object Type
Exchange Information	Name		String
	Design level	W	Double
	Design level calculation method		Enumeration (Lighting Level, Watts/Area, Watts/Person)
	Zone	1…1	**Zone, Zone List**
	On off indicator	1…1	**Schedule**
	Watts per zone floor area	W/m²	Double
	Watts per person	W/p	Double
	Return air fraction	[0,1]	Double
	Fraction radiant	[0,1]	Double
	Fraction visible	[0,1]	Double
	Fraction replaceable	[0,1]	Double
Availability of the Information	Platform Repository (Predefined Dataset)		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Equipment	Units	Object Type
Exchange Information	Name		String
	Design level	W	Double
	Design level calculation method		Enumeration (Equipment Level, Watts/Area, Watts/Person)
	Zone	1...1	**Zone, Zone List**
	Schedule name	1...1	**Schedule**
	Watts per zone floor area	W/m²	Double
	Watts per person	W/p	Double
	Fraction latent	[0,1]	Double
	Fraction radiant	[0,1]	Double
	Fraction lost	[0,1]	Double
Availability of the Information	Platform Repository (Predefined Dataset)		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Infiltration Design Flow Rate	Units / Cardinality	Object Type
Exchange Information	Name		String
	Schedule	1...1	**Schedule**
	Design flow rate calculation method		Enumeration (Flow/Zone, Flow/Area, Flow/Exterior Area,

			Flow/Exterior Wall Area, Air Changes/Hour)
	Design flow rate	m³/s	Double
	Flow per floor area zone		Double
	Flow rate per exterior surface area		Double
	Air changes per hour	1/hr	Double
	Constant term coefficient		Double
	Temperature term coefficient		Double
	Velocity term coefficient		Double
	Velocity squared term coefficient		Double
Availability of the Information	Platform Repository (Predefined Dataset)		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Ventilation Design Flow Rate	Units / Cardinality	Object Type
Exchange Information	Name		String
	On off indicator	1...1	**Schedule**
	Design flow rate calculation method		Enumeration (Flow/Zone, Flow/Area, Flow/Person, Air Changes/Hour)
	Design flow rate	m³/s	Double
	Flow per zone floor area		Double
	Flow rate per person		Double

	Air changes per hour		Double
	Ventilation type		Enumeration (Natural, Exhaust, Intake, Balanced)
	Fan pressure rise		Double
	Fan total efficiency		Double
	Constant term coefficient		Double
	Temperature term coefficient		Double
	Velocity term coefficient		Double
	Velocity squared term coefficient		Double
Availability of the Information	Platform Repository (Predefined Dataset)		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Exterior Energy Use Equipment		Units	Object Type
Exchange Information	Lights	Design level	W	Double
		On off indicator	1..1	**Schedule**
	Fuel Equipment	Design level	W	Double
		Fuel type		Enumeration (Electricity, Natural Gas, Propane Gas, Fuel Oil, Diesel, Gasoline, Coal, Steam, District Heating, District

				Cooling)
		On off indicator	1…1	**Schedule**
	Water Equipment	Design level	m^3/s	Double
		On off indicator	1…1	**Schedule**
Availability of the Information	Platform Repository (Predefined Dataset)			
Information Type	Simulation data			
Scale	Building			
Variability of the information	Static			
Data Formats	XML, RDF			
Tools	Platform API			
Required Precision	High			

Table 8 Building materials needed by Energy Plus

Energy Plus Requirement:	Construction	Units / Cardinality	Object Type
Exchange Information	Name		String
	Outside layer	1…1	**Material, Phase Change Material, Green Roof Material**
	Material	1…*	**Material, Phase Change Material**
Availability of the Information	Platform Repository, ECM Catalogue, BIM		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus	Material	Units	Object Type

Requirement:			
Exchange Information	Name		String
	Roughness		Enumeration (Very Rough, Rough, Medium Rough, Medium Smooth, Smooth, Very Smooth)
	Thickness	m	Double
	Conductivity	W/m · K	Double
	Density	Kg/m^3	Double
	Specific heat	J/kg · K	Double
	Thermal absorptance		Double
	Solar absorptance		Double
	Visible absorptance		Double
	Medium envelopment transmittances	$W/m^2 \cdot K$	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Phase Change Material	Units	Object Type
Exchange Information	Name		String
	Roughness		Enumeration (Very Rough, Rough, Medium Rough, Medium Smooth,

			Smooth, Very Smooth)
	Thickness	m	Double
	Conductivity	W/m · K	Double
	Density	Kg/m³	Double
	Specific heat	J/kg · K	Double
	Thermal absorptance		Double
	Solar absorptance		Double
	Visible absorptance		Double
	Medium envelopment transmittances		Double
	Temperature coefficient for thermal conductivity		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Green Roof Material	Units	Object Type
Exchange Information	Name		String
	Height of plants	m	Double
	Leaf area	m²	Double
	Leaf Reflectivity		Double
	Leaf Emissivity		Double
	Minimum stomatal resistance	s/m	Double
	Roughness		Enumeration (Very Rough, Rough, Medium

			Rough, Medium Smooth, Smooth, Very Smooth)
	Thickness	m	Double
	Conductivity	W/m · K	Double
	Density	kg/m³	Double
	Specific heat	J/kg · K	Double
	Thermal absorptance		Double
	Solar absorptance		Double
	Visible absorptance		Double
	Saturation Volumetric Moisture Content of the Soil		Double
	Residual Volumetric Moisture Content of the Soil		Double
	Initial Volumetric Moisture Content of the Soil		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Window Material Simple Glazing System	Units	Object Type
Exchange Information	Name		String
	U factor		Double
	Solar heat gain coefficient		Double
Availability of the	Platform Repository, ECM Catalogue, BIM models, City models with		

Information	domain extensions
Information Type	Simulation data
Scale	Building element
Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions
Required Precision	High

Energy Plus Requirement:	Window Material Glazing	Units	Object Type
Exchange Information	Name		String
	Thickness	m	Double
	Optical data type		Enumeration (Spectral Average, Spectral, BSDF)
	Solar transmittance		Double
	Front side solar reflectance at normal incidence		Double
	Back side solar reflectance at normal incidence		Double
	Visible transmittance at normal incidence		Double
	Front side visible reflectance at normal incidence		Double
	Back side visible reflectance at normal incidence		Double
	Infrared transmittance at normal incidence		Double
	Front side infrared hemispherical emissivity		Double
	Back side infrared hemispherical emissivity		Double
	Conductivity	W/m · K	Double

Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions
Information Type	Simulation data
Scale	Building
Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	Window Material Gas	Units	Object Type
Exchange Information	Name		String
	Type		Enumeration (Air, Argon, Krypton, Xenon)
	Thickness	m	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Window Material Shade	Units	Object Type
Exchange Information	Name		String
	Solar transmittance		Double
	Solar Reflectance		Double
	Visible transmittance		Double

	Visible reflectance		Double
	Thermal Hemispherical Emissivity		Double
	Thermal Transmittance		Double
	Thickness	m	Double
	Conductivity	W/m · K	Double
	Shade to glass distance	m	Double
	Top opening multiplier		Integer
	Bottom opening multiplier		Integer
	Left side opening multiplier		Integer
	Right side opening multiplier		Integer
	Air flow permeability		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Table 9 HVAC System

Energy Plus Requirement:	Zone HVAC Equipment List	Units / Cardinality	Object Type
Exchange Information	Name		String
	Cooling sequence		Double
	Heating or no load sequence		Double
	Equipment list	1…*	**Set <Enum, Zone HVAC>**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		

Scale	Thermal zone
Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	**Zone HVAC Equipment Connections**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Equipment list	1…1	**Zone HVAC Equipment List**
	Zone air inlet node		String
	Return air stream inlet		String
	Zone air node		String
	Return node		String
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	**Zone Control Thermostat**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Zone	1…1	**Zone, Zone List**
	Thermostat schedule	1…1	**Schedule**
	Thermostat set-point type		Enumeration (Single Heating, Single Cooling, Single Heating or Cooling,

			Dual Setpoint)
	Thermostat set-point object	1...1	**Thermostat Set-point Dual Set-point**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Thermostat Setpoint Dual Setpoint	Cardinality (Units)	Object Type
Exchange Information	Name		String
	Heating schedule	1...1 (°C)	**Schedule**
	Cooling schedule	1...1 (°C)	**Schedule**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Table 10 Zone HVAC Forced Air Units

Energy Plus Requirement:	Zone HVAC Four Pipe Fan Coil	Units / Cardinality	Object Type
Exchange Information	Name		String
	Capacity control method		Enumeration

	Supply air maximum flow rate	m³/s	Double
	Availability	1...1	**Schedule**
	Outdoor air mixer object	1...1	**Outdoor Air Mixer**
	Supply air fan	1...1	**Fan On Off, Fan Constant Volume, Fan Variable Volume**
	Cooling coil	1...1	**Coil Cooling Water**
	Heating Coil	1...1	**Coil Heating Water, Coil Heating Electric**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Zone HVAC Packaged Terminal Air Conditioner	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1...1	**Schedule**
	Outdoor air mixer object	1...1	**Outdoor Air Mixer**
	Supply air fan	1...1	**Fan On Off, Fan Constant Volume, Fan Variable Volume**
	Cooling coil	1...1	**Coil Cooling DX Single Speed, Coil Cooling DX Variable Speed**
	Heating Coil	1...1	**Coil Heating Water, Coil Heating Electric, Coil Heating Steam, Coil Heating Gas**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		

Information Type	Simulation data
Scale	Building
Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	Zone HVAC Packaged Terminal Heat Pump	Units	Object Type
Exchange Information	Name		String
	Availability	1...1	**Schedule**
	Outdoor air mixer object	1...1	**Outdoor Air Mixer**
	Supply air fan	1...1	**Fan On Off, Fan Constant Volume, Fan Variable Volume**
	Cooling coil	1...1	**Coil Cooling DX Single Speed, Coil Cooling DX Variable Speed**
	Heating Coil	1...1	**Coil Heating Water, Coil Heating Electric, Coil Heating Steam, Coil Heating Gas**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Zone HVAC Water to Air Heat Pump	Units	Object Type
Exchange Information	Name		String

	Availability	1...1	**Schedule**
	Outdoor air mixer object	1...1	**Outdoor Air Mixer**
	Supply air fan	1...1	**Fan On Off, Fan Constant Volume, Fan Variable Volume**
	Cooling coil	1...1	**Coil Cooling Water to Air Heat Pump Equation Fit, Coil Cooling Water to Air Heat Pump Variable Speed Equation Fit**
	Heating coil	1...1	**Coil Heating Water to Air Heat Pump Equation Fit, Coil Heating Water to Air Heat Pump Variable Speed Equation Fit**
	Supplemental heating coil	1...1	**Coil Heating Water, Coil Heating Electric, Coil Heating Steam, Coil Heating Gas**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Zone HVAC Dehumidifier DX	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1...1	**Schedule**
	Rated water removal		Double
	Rated energy factor		Double
	Rated air flow rate	m^3/s	Double
	Water removal curve	1...1	List<Double>
	Energy factor curve	1...1	List<Double>

Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions
Information Type	Simulation data
Scale	Building
Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	Zone HVAC Energy Recover Ventilator	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1...1	Schedule
	Heat exchanger	1...1	**Heat Exchanger Air to Air Sensible and Latent**
	Supply air flow rate	m^3/s	Double
	Exhaust air flow rate	m^3/s	Double
	Supply air fan	1...1	**Fan On Off**
	Exhaust air fan	1...1	**Fan On Off**
	Ventilation rate	m^3/s	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building element		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Table 11 HVAC Radiance Convective Units

Energy Plus Requirement:	Zone HVAC Baseboard Radiant Convective Water	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1…1	**Schedule**
	Rated average water temperature	°C	Double
	Rated water mass flow rate	kg/s	Double
	Rated capacity	W	Double
	Fraction radiant	m^3/s	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Zone HVAC Baseboard Radiant Convective Steam	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1..1	**Schedule**
	Degree of sub cooling	°C	Double
	Maximum steam flow rate	m^3/s	Double
	Fraction radiant		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		

Tools	Platform API
Required Precision	High

Energy Plus Requirement:	**Zone HVAC Baseboard Radiant Convective Electric**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Availability		Schedule
	Normal capacity	W	Double
	Efficiency		Double
	Fraction radiant		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	**Zone HVAC Low Temperature Radiant**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Availability	1...1	**Schedule**
	Hydronic tubing inside diameter	m	Double
	Hydronic tubing length	m	Double
	Temperature control type		Enumeration (Mean Air Temperature, Mean Radiant Temperature, Operative Temperature, Mean Air Temperature Setpoint, Mean Radiant

			Temperature Setpoint, Operative Temperature Setpoint)
	Maximum hot water flow	m³/s	Double
	Heating control throttling range	°C	Double
	Maximum cold water flow	m³/s	Double
	Condensation control type		Enumeration
	Condensation control dew point offset	°C	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building element		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Zone HVAC Ventilated Slab	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1...1	**Schedule**
	Maximum air flow rate	m³/s	Double
	Outdoor air control type		Enumeration
	Minimum outdoor air flow rate	m³/s	Double
	Maximum outdoor air flow rate	m³/s	Double
	Hollow core inside diameter		Double
	Hollow core length		Double
	Number of cores		Double
	Temperature control type		Enumeration
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		

Information Type	Simulation data
Scale	Building
Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Table 12 HVAC Air Loop Terminal Units

Energy Plus Requirement:	Air Terminal Single Duct Constant Volume Reheat	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1...1	**Schedule**
	Maximum air flow rate	m^3/s	Double
	Reheat Coil	1...1	**Coil Heating Water, Coil Heating Electric, Coil Heating Gas, Coil Heating Steam**
	Maximum reheat air temperature	°C	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Single Duct VAV Reheat	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1...1	**Schedule**

	Maximum air flow rate	m³/s	double
	Reheat coil	1…1	**Coil Heating Water, Coil Heating Electric, Coil Heating Gas, Coil Heating Steam**
	Damper heating action		
	Maximum reheat air temperature	°C	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Single Duct VAV Variable Speed Fan	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1…1	**Schedule**
	Maximum cooling air volume flow rate	m³/s	Double
	Maximum heating air volume flow rate	m³/s	Double
	Zone minimum air flow fraction	[0,1]	Double
	Fan	1…1	**Fan On Off**
	Heating coil	1…1	**Coil Heating Water, Coil Heating Electric, Coil Heating Gas, Coil Heating Steam**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		

Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	Single Duct VAV Heat and Cool Reheat	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1…1	**Schedule**
	Maximum air flow rate	m^3/s	Double
	Reheat coil	1…1	**Coil Heating Water, Coil Heating Electric, Coil Heating Gas, Coil Heating Steam**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Single Duct VAV no Reheat	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1…1	**Schedule**
	Maximum air flow rate	m^3/s	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		

Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	Single Duct Series PIU Reheat	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1...1	**Schedule**
	Total volume flow rate through ATU	m^3/s	Double
	Mixer	1...1	**Air Loop HVAC Zone Mixer**
	Fan	1...1	**Fan On Off**
	Reheat coil	1...1	**Coil Heating Water, Coil Heating Electric, Coil Heating Gas, Coil Heating Steam**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Single Duct Parallel PIU Reheat	Units / Cardinality	Object Type
Exchange Information	Name		String
	Availability	1...1	**Schedule**
	Maximum primary air flow rate	m^3/s	Double

	Maximum secondary air flow rate	m³/s	Double
	Mixer	1..1	**Air Loop HVAC Zone Mixer**
	Fan	1...1	**Fan On Off**
	Reheat coil	1...1	**Coil Heating Water, Coil Heating Electric, Coil Heating Gas, Coil Heating Steam**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	**Single Duct Constant Volume Four Pipe Induction**	**Units / Cardinality**	**Type**
Exchange Information	Name		String
	Availability	1..1	**Schedule**
	Maximum total air flow rate	m³/s	Double
	Induction ratio	%	Double
	Mixer	1...1	**Air Loop HVAC Zone Mixer**
	Heating coil	1...1	**Coil Cooling Water**
	Cooling coil	1...1	**Coil Heating Water**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		

Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	**Single Duct Constant Volume Cooled Beam**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Availability	1...1	**Schedule**
	Cooling beam type	m³/s	Double
	Induction ratio	%	Double
	Cooling coil air inlet node	1...1	**Coil Cooling Water**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	**Dual Duct VAV**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Availability	1...1	**Schedule**
	Maximum air flow rate	m³/s	Double
	Induction ratio	%	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		

Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	**Dual Duct VAV Outdoor Air**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Availability	1..1	**Schedule**
	Maximum air flow rate	m^3/s	Double
	Induction ratio	%	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Table 13 HVAC Equipment

Energy Plus Requirement:	**Fan On Off**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Fan efficiency	%	Double
	Pressure rise	Pa	Double
	Maximum flow rate	m^3/s	Double
	Motor efficiency	%	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		

Information Type	Simulation data
Scale	Building
Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	**Coil**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Design water flow rate	m³/s	Double
	Design air flow rate	m³/s	Double
	Design inlet water temperature	°C	Double
	Design inlet air temperature	°C	Double
	Design outlet air temperature	°C	Double
	Design outlet air humidity ratio		Double
	Rated total cooling capacity	W	Double
	Rated COP		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	**Humidifiers**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String

	Rated capacity	m³/s	Double
	Rated power	W	Double
	Rated fan power	W	Double
	Standby power	W	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Heat Recovery Units	Units / Cardinality	Object Type
Exchange Information	Name		String
	Heat exchanger type		Enumeration
	Nominal supply air flow rate	m³/s	Double
	Nominal supply air inlet temperature	°C	Double
	Nominal supply air outlet temperature	°C	Double
	Nominal secondary air flow rate	m³/s	Double
	Nominal secondary air inlet temperature	m³/s	Double
	Nominal electric power	W	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		

Tools	Platform API
Required Precision	High

Energy Plus Requirement:	**Distribution Systems**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Water distribution piping schema		Double
	Air distribution ducts schema		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	**Pumps**	**Units / Cardinality**	**Object Type**
Exchange Information	Name		String
	Rated flow rate	m^3/s	Double
	Rated pump head	Pa	Double
	Rated power consumption	W	Double
	Motor efficiency		Double
	Control type		Enumeration (Continuous, Intermitted)
	Pump curve		List<Double>
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		

Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	Solar Collectors	Units / Cardinality	Object Type
Exchange Information	Name		String
	Gross area	m^2	Double
	Test flow rate		Double
	Test correlation type		Enumeration (Inlet, Average, Outlet)
	Maximum flow rate	m^3/s	Double
	Coefficient of efficiency	W/m^2K	Double
	Incident angle	°	Double
	Orientation	°	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Boilers	Units / Cardinality	Object Type
Exchange Information	Name		String
	Normal capacity	W	Double
	Normal thermal efficiency		Double

	Design water outlet temperature	°C	Double
	Design water flow rate	m^3/s	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Chillers	Units / Cardinality	Object Type
Exchange Information	Name		String
	Nominal capacity	W	Double
	Nominal COP		Double
	Design chilled water outlet temperature	°C	Double
	Design water flow rate	m^3/s	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Chiller Heat Absorption	Units / Cardinality	Object Type
Exchange Information	Name		String

	Nominal cooling capacity	W	Double
	Heating to cooling capacity ratio		Double
	Design entering condensed water temperature	°C	Double
	Design leaving chilled water temperature	°C	Double
	Design water flow rate	m^3/s	Double
	Design condenser water flow rate	m^3/s	Double
	Design hot water flow rate	m^3/s	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

Energy Plus Requirement:	Heat Pump	Units / Cardinality	Object Type
Exchange Information	Name		String
	Nominal capacity	W	Double
	Nominal COP		
	Load side flow rate	m^3/s	Double
	Source side flow rate	m^3/s	Double
	Load side heat transfer coefficient	W/K	Double
	Source side heat transfer coefficient	W/K	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		

Variability of the information	Static
Data Formats	XML, RDF
Tools	Platform API
Required Precision	High

Energy Plus Requirement:	District Heating Cooling	Units / Cardinality	Object Type
Exchange Information	Name		String
	Nominal Heating Capacity	W	Double
	Nominal Cooling Capacity	W	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform API		
Required Precision	High		

8.2 Simulation Parameters needed by CitySim

Table 14 Simulation data needed by CitySim

CitySim Requirement:	Simulation Data	Units	Object Type
Exchange Information	Starting month		Integer
	End month		Integer
	Begin day		Integer
	End day		Integer
Availability of the Information	User manual input, Platform predefined options		
Information Type	Simulation parameters		
Scale	District		
Variability of the information	Static		
Data Formats	XML, CSV		
Tools	Platform GUI		
Required Precision	High		

CitySim Requirement:	Location Data	Units / Cardinality	Object Type
Exchange Information	Latitude	°	Double
	Longitude	°	Double
	Elevation	m	Double
	Far field obstruction profile	1…1	**Far Field Obstruction Profile**
Availability of the Information	METEONORM, User manual input		
Information Type	Location data		
Scale	District		
Variability of the information	Static		
Data Formats	XML, RDF		
Tools	Platform APIs Client Libraries, Platform GUI		
Required Precision	Medium		

CitySim Requirement:	Far Field Obstruction Profile	Cardinality (Units)	Object Type
Exchange Information	Degree of elevation per degree of azimuths	360 (°)	List<Double>
Availability of the Information	METEONORM, User manual input		
Information Type	Location data		
Scale	District		
Variability of the information	Static		
Data Formats	XML		
Tools	Platform APIs Client Libraries, Platform GUI		
Required Precision	Medium		

CitySim Requirement:	Climate Data	Units	Object Type
Exchange Information	Name		String
	Latitude		Double
	Longitude		Double
	Altitude	m	Double
	Meridian	hrs	Double
	Date		List<Date>
	Diffuse radiation horizontal Dh	W/m²	List<Double>
	Beam solar normal irradiance Bn	W/m²	List<Double>
	Temperature Ta	°C	List<Double>
	Surface temperature Ts	°C	List<Double>
	Wind speed FF	m/s	List<Double>
	Wind direction DD	°	List<Double>
	Relative humidity RH	%	List<Double>
	Precipitation RR	mm	List<Double>

	Cloud cover fraction N	Octas	List<Double>
Availability of the Information	Weather Stations, Weather Services, METEONORM		
Information Type	Climate data		
Scale	City		
Variability of the information	Hourly		
Data Formats	CSV, CLI, XML		
Tools	Platform APIs Client Libraries		
Required Precision	High		

Table 15 Building data needed by CitySim

CitySim Requirement:	District	Cardinality	Object Type
Exchange Information	Far field obstructions	1...1	**Far Field Obstructions**
	Wall type	1...*	**Wall Type**
	Material type	1...*	**Material Type**
	Occupancy day profile	1...*	**Occupancy Day Profile**
	Occupancy year profile	1...*	**Occupancy Year Profile**
	Building	1...*	**Building**
	Ground surface	1...1	**Ground Surface**
	Domestic hot water day	1...1	**Domestic Hot Water Day Profile**
	Domestic hot water year	1...1	**Domestic Hot Water Year Profile**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	City		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools (CityGML to CitySim XML)		
Required Precision	High		

CitySim Requirement:	Wall Type	Units / Cardinality	Object Type
Exchange Information	Identifier		Integer
	Name		String
	Layer (sequence of layers from outside to inside)	1…*	**Layer**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	District		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Group Type	Units / Cardinality	Object Type
Exchange Information	Identifier		Integer
	Name		String
	Layer (sequence of layers from outside to inside)	1…*	**Layer**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	District		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Layer	Units	Object Type

Exchange Information	Thickness	m	Double
	Thermal conductivity		Double
	Specific heat	J/kg · K	Double
	Density		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	District		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Building	Units / Cardinality	Object Type
Exchange Information	Heat tank	0…1	**Heat Tank**
	DHW tank	0…1	**DWH Tank**
	Cool tank	0…1	**Cool Tank**
	Heat source	0…1	**Heat Source**
	Identifier		Integer
	Infiltration rate		Double
	Minimum set point temperature		Double
	Maximum set point temperature		Double
	Irradiance cut off for the automated blinds		Double
	Blinds smooth transition		Double
	Simulate		Boolean
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		

Scale	Building
Variability of the information	Static
Data Formats	RDF, XML
Tools	Platform processing tools
Required Precision	High

CitySim Requirement:	Thermal Zone	Units / Cardinality	Object Type
Exchange Information	Volume	m^3	Double
	Total losses due thermal bridges	W	Double
	Occupants	1...1	**Occupants**
	Walls	1...*	**Wall**
	Roofs	1...*	**Roof**
	Floors	1...*	**Floor**
	Zone Surface	1...*	**Zone Surface**
	Situated on the ground floor		Boolean
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Occupants	Units	Object Type
Exchange Information	Number of occupants		Integer
	Yearly occupant profile type	1...1	**Occupancy Year Profile**

	Simulation type		Enumeration (Determisitc, Stochastic)
	Activity type	1...1	**Activity Type**
	Domestic hot water type	1...1	**Domestic Hot Water Profile**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Occupancy Yearly Profile	Cardinality	Object Type
Exchange Information	Identifier		
	Occupancy profile per day	365	List<**Occupancy Day Profile**>
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	District		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Occupancy Daily Profile	Cardinality (Units)	Type
Exchange Information	Identifier	Integer Identifier	
	Occupancy rate per hour for a day	24 (n/a)	List<Double>

Availability of the Information	User manual input, Platform repository
Information Type	Simulation data
Scale	District
Variability of the information	Static
Data Formats	RDF, XML
Tools	Platform processing tools
Required Precision	High

CitySim Requirement:	Activity Type	Units	Type
Exchange Information	Identifier		Integer
	Name		String
	Activity	1…1	**Activity**
Availability of the Information	User manual input, Platform repository		
Information Type	Simulation data		
Scale	District		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Activity	Units	Type
Exchange Information	Name		String
	Probability of occurrence of activity per time-step	24	List<Double>
	Device type	1…1	**Device Type**
Availability of the Information	User manual input, Platform repository		
Information Type	Simulation data		

Scale	District
Variability of the information	Static
Data Formats	RDF, XML
Tools	Platform processing tools
Required Precision	High

CitySim Requirement:	Wall	Units / Cardinality	Object Type
Exchange Information	Type	1…1	**Wall Type**
	Vertex	3…*	List<Double>
	PV panel	0…1	**PV**
	Solar heater	0…1	**Solar Heater**
	U value		Double
	Short wave reflectance		Double
	Glazing ratio		Double
	Glazing G value		Double
	Glazing U value		Double
	Openable ratio		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Roof	Units / Cardinality	Object Type
Exchange Information	Type	1…1	**Roof Type**

	Micro wind turbine	0...1	**Micro Wind Turbine**
	Vertex	3...*	List<Double>
	U value		Double
	Short wave reflectance		Double
	Glazing ratio		Double
	Glazing G value		Double
	Glazing U value		Double
	Openable ratio		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Floor	Units / Cardinality	Object Type
Exchange Information	Type	1...1	**Wall Type**
	Vertex	3...*	List<Double>
	Conductance of the ground		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		

Required Precision	High

CitySim Requirement:	Zone Surface	Units / Cardinality	Object Type
Exchange Information	Area	m²	Double
	Type	1…1	**Wall Type**
	Vertical		Boolean
	Zone	1…1	**Zone**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Ground Surface	Units / Cardinality	Object Type
Exchange Information	Ground	1…*	**Ground**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Ground	Units / Cardinality	Object Type

Exchange Information	Identifier		Integer
	Short wave reflectance		Double
	Ground surface type		Double
	K factor (concrete surface is 0 and full watered green surface is 1)	[0,1]	Double
	Detailed simulation		Boolean
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Thermal zone		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

Table 16 Energy systems data needed by CitySim

CitySim Requirement:	Heat Tank	Units	Object Type
Exchange Information	Volume	m^3	Double
	Liquid density		Double
	Specific heat	J/kg·K	Double
	Thermal losses		Double
	Requested temperature range min		Double
	Requested temperature range max		Double
	Critical temperature		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		

Variability of the information	Static
Data Formats	RDF, XML
Tools	Platform processing tools
Required Precision	High

CitySim Requirement:	Cool Tank	Units	Type
Exchange Information	Volume	m³	Double
	Liquid density	Kg / m³	Double
	Specific heat	J/kg · K	Double
	Thermal losses		Double
	Requested temperature range min		Double
	Requested temperature range max		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	DHW Tank	Units	Type
Exchange Information	Volume	m³	Double
	Liquid density	Kg / m³	Double
	Specific heat	J/kg · K	Double
	Thermal losses		Double
	Requested temperature range min		Double

	Requested temperature range max		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Heat Source	Units / Cardinality	Object Type
Exchange Information	Boiler	0…1	**Boiler**
	Heat pump	0…1	**Heat Pump**
	CHP	0…1	**CHP**
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Boiler	Units / Cardinality	Object Type
Exchange Information	Maximum thermal power	W	Double
	Efficiency	%	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		

Information Type	Simulation data
Scale	Building
Variability of the information	Static
Data Formats	RDF, XML
Tools	Platform processing tools
Required Precision	High

CitySim Requirement:	Heat Pump	Units	Object Type
Exchange Information	Maximum thermal power	W	Double
	Technical efficiency		Double
	Source		Enumeration
	Pipes position		Enumeration
	Thermal diffusivity		Double
	Target temperature		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Building element		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

Table 17 Renewable Energy Systems

CitySim Requirement:	PV	Units / Cardinality	Object Type
Exchange Information	Total coverage of the wall	%	Double
	Pmp		Double
	Ac		Double

	Tref		Double
	TcNoct		Double
	muVoc		Double
	Vmp		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Wall		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Solar Heater	Units / Cardinality	Object Type
Exchange Information	Total coverage of the wall	%	Double
	Efficiency	%	Double
	Heat lost coefficient a1		Double
	Heat lost coefficient a2		Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Wall		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

CitySim Requirement:	Micro Wind Turbine	Units / Cardinality	Type

Exchange Information	Cut-in speed	%	Double
	Rated speed	m/s	Double
	Cut-out speed	m/s	Double
	Curve fitting coefficient c1		Double
	Curve fitting coefficient c2		Double
	Curve fitting coefficient c3		Double
	Atmospheric air density	Kg/m²	Double
	Alpha (terrain parameters)	[0,1]	Double
	Gamma (terrain parameters)	[0,1]	Double
Availability of the Information	Platform Repository, ECM Catalogue, BIM models, City models with domain extensions		
Information Type	Simulation data		
Scale	Wall		
Variability of the information	Static		
Data Formats	RDF, XML		
Tools	Platform processing tools		
Required Precision	High		

8.3 District Performance Indicators

Performance Indicators Calculated by EnergyPlus		Section	Variability of Information	Format	Scale	Unit
ENE01	Energy demand	Energy	Hourly	CSV	Building	kWh/m²
ENE02	Final energy consumption	Energy	Hourly	CSV	Building	kWh/m²
ENE03	Peak load and profile of electricity demand	Energy	Hourly	CSV	Building	kW
ENE04	Peak load and profile of thermal energy demand	Energy	Hourly	CSV	Building	kW
ENE05	Degree of energetic self-supply	Energy	Hourly	CSV	Building	kWh/kWh

ENE06	Net fossil energy consumed	Energy	Hourly	CSV	Building	kWh/m^2
ENE07	Total energy use per capita	Energy	Hourly	CSV	Country	kWh/hab · y
ENE08	Total residential electrical energy use per capita	Energy	Hourly	CSV	City	kWh/hab · y
ENE10	Total residential natural gas energy use per capita	Energy	Hourly	CSV	City	kWh/hab · y
ENE11	Total residential butane gas energy use per capita	Energy	Hourly	CSV	City	kWh/hab · y
ENE12	Energy consumption of public buildings per year	Energy	Hourly	CSV	District	kWh/m^2
ENE13	Energy Use from District Heating	Energy	Hourly	CSV	District	kWh/year
ENE14	Energy Use from Biomass	Energy	Hourly	CSV	District	kWh/year
ENE15	Energy Use from PV	Energy	Hourly	CSV	District	kWh/year
ENE16	Energy Use from Solar Thermal	Energy	Hourly	CSV	District	kWh/year
ENE17	Energy Use from Hydraulic	Energy	Hourly	CSV	District	kWh/year
ENE18	Energy Use from Mini-Eolica	Energy	Hourly	CSV	District	kWh/year
ENE19	Energy Use from Geothermal	Energy	Hourly	CSV	District	kWh/year
CON01	Local thermal comfort	Comfort	Hourly	CSV	Building	
CON02	Percentage outside range	Comfort	Hourly	CSV	Building	%
CON04	Indoor air quality	Comfort	Hourly	CSV	Building	
CON05	Visual comfort	Comfort	Hourly	CSV	Building	
ENV4	Primary energy consumption	Environ mental	Hourly	CSV	Building	MJ · a

Performance Indicators		Section	Variability of	Format	Scale	Unit

Calculated by CitySim		Information				
ENE01	Energy demand for heating	Energy	Yearly	TXT	District	Wh
	Energy demand for cooling	Energy	Yearly	TXT	District	Wh
	Domestic hot water	Energy	Yearly	TXT	District	J
	Fuel consumption	Energy	Yearly	TXT	District	J
	Electric	Energy	Yearly	TXT	District	J
	NRE	Energy	Yearly	TXT	District	MJ
ENV1	Global Warming Potential	Environ mental	Yearly	TXT	District	
ENE01	Energy demand for Heating	Energy	Hourly	TXT	Building	Wh
	Energy demand for Cooling	Energy	Hourly	TXT	Building	Wh
	Fuel consumption	Energy	Hourly	TXT	Building	MJ
	Electric consumption	Energy	Hourly	TXT	Building	kWh
ENE16	Solar Thermal Production	Energy	Hourly	TXT	Building	J

Performance Indicators Calculated by NEST		Section	Variability of Information	Format	Scale	Unit
ENV1	Global Warming Potential	Environmen tal	Yearly	TXT	District	GWP/year
ENV2	GWP Investment	Environmen tal	Yearly	TXT	District	GWP
ENV3	Global Warming Potential Reduction	Environmen tal	Yearly	TXT	District	GWP/year
ENV4	Primary Energy Consumption	Environmen tal	Yearly	TXT	District	MJ/year
ENV5	Energy investment	Environmen tal		TXT	District	MJ
ENV6	Energy Payback Time	Environmen tal	Yearly	TXT	District	year
ECO01	Operational Cost	Economic		TXT	District	€/year

ECO02	Investment	Economic		TXT	District	€
ECO03	Life Cycle Cost	Economic		TXT	District	€/year
ECO04	Return of investment	Economic		TXT	District	year

Performance Indicators Calculated by OptEEmAL		Section	Variability of Information	Format	Scale	Unit
ENE09	Energy demand converted by renewable sources	Energy		XML	District	%
ECO01	Operational Energy Cost	Economic	Yearly	XML	Building	€/m²
ECO03	Life Cycle Cost	Economic		XML	District	€/m²
ECO04	Return of Investment	Economic		XML	District	year
ECO05	Total Energy Cost	Economic		XML	District	€/year
SOC01	Energy poverty	SOCIAL		XML	District	%
URB01	Percentage of building with EPC	URBAN		XML	District	%
URB02	Percentage of building compliant with Passivhaus standards	URBAN		XML	District	%
URB03	Percentage of building compliant with EnerPhit standards	URBAN		XML	District	%
URB04	Percentage of building compliant with nZEB standards	URBAN		XML	District	%
GLO01	KWh Energy Saved / Euro Invested	GLOBAL		XML	District	kWh · a / €

8.4 Project Data

Project Data Requirement:	Project Data	Units / Cardinality	Type
Exchange Information	Name	NA	Text

	Description	NA	Text
	Location	NA	Text
	Contact Person	1...1	**User Data**
	User List	1...N	**User Data**
Availability of the Information	User's Input		
Information Type	Project Description		
Scale	District		
Variability of the information	Very Low (project data can be edited by the contact person, but it is very unlikely)		
Data Formats	Text		
Tools	NA		
Required Precision	Low		

Project Data Requirement:	Users Data	Units / Cardinality	Type
Exchange Information	Name	NA	Text
	e-mail Address	NA	Text
	User Name	NA	Text
	Password	NA	Text
	Project List	1..N	**Project Data**
	Role in a Project	NA	Predefined Value
Availability of the Information	User's Input		
Information Type	IPD group related to the project		
Scale	NA		
Variability of the information	Very Low (User data can be edited, but not very often)		
Data Formats	Text		
Tools	NA		
Required Precision	Low		

Project Data Requirement:	Users Preferences and Barriers	Units / Cardinality	Type
Exchange Information	Goals / Targets	NA	List of Predefined Values
	Boundaries	NA	List of Predefined Values
	Barriers	NA	List of Predefined Values
	Project	1..1	**Project Data**
Availability of the Information	User's Input		
Information Type	User preferences and barriers and boundaries identified for the district retrofitting (heritage value of buildings, legislative constraints, etc.)		
Scale	District		
Variability of the information	Very Low (They Could be modified after the diagnosis of the current situation)		
Data Formats	TEXT , PREDEFINED CODE		
Tools	NA		
Required Precision	Medium-High		

Project Data Requirement:	Prioritization Criteria	Units / Cardinality	Type
Exchange Information	Weight	0-1	Decimal
	DPI	1..1	**DPI**
Availability of the Information	User's Input		
Information Type	The prioritization criteria is a kind of ponderation that the user gives to the different DPIs, according to his/her criteria.		
Scale	District		
Variability of the information	Very Low (It Could be modified after the diagnosis of the current situation)		
Data Formats	TEXT		
Tools	NA		
Required Precision	Medium-High		

Project Data Requirement:	List of DPIs	Units / Cardinality	Type
Exchange Information	List of DPIs	NA	**DPI**
	Project	1..1	**Project Data**
Availability of the Information	User's Input		
Information Type	Performance Indicators		
Scale	District		
Variability of the information	Very Low (They Could be modified after the diagnosis of the current situation)		
Data Formats	TEXT		
Tools	NA		
Required Precision	NA		