D5 - FIEMSER Data Model

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Summary

This deliverable, produced at month 9 of the project, results from the work achieved in task T1.4 “FIEMSER Data Model Definition” which is part of WP1 dealing with system specifications.

The main goal of this Work Package is to provide FIEMSER project with specific requirements and to define the different components through a joint design methodology that involves the overall architecture model as well as components interfaces and communication protocols analysis. It provides a Technical Specification for the next work packages.

The main objective of task T1.4 is to complement the design of the architecture developed in task T1.3 with the modelling of the information coming from outside (weather conditions, electricity prices, gas prices…), the data to be exchanged between the main components of the FIEMSER system, and the data to be exchanged with loads, generators and storage devices.

The followed methodology consisted in (1) categorizing the data handled in Use Cases (see deliverable D3), (2) modelling data in each identified category and, (3) merging the resulting sub-models into a holistic data model for FIEMSER.

Complementary, an analysis of the state-of-the-art has been made through a review of ongoing R&D projects on ICT4EE in Buildings with a focus on data modelling, and available standards in building information modelling (IFC, gbXML) have been examined, in order to build our modelling activity on the most relevant results of related research work and existing standards for information modelling.

It is planned that this modelling work will be disseminated towards the relevant standardisation bodies (as a proposal for possible standard extension), and communicated to analysed R&D projects to get their feedback on the appropriateness of the model to their own concerns.

Contents

Abbreviations

FIEMSER	Friendly Intelligent Energy Management System for Existing Residential Buildings
IFC	Industry Foundation Classes
IAI	International Alliance for Interoperability
gbXML	Green Building XML
UML	Unified Modelling Language
BIM	Building Information Model
ICT4EE	ICT for Energy Efficiency

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Tableaux

1. Introduction

This deliverable is associated to Task 1.4 FIEMSER data model definition, which is the last task of WP1 dealing with FIEMSER specifications.

The main objective of this task is to complement the design of the architecture developed in Task 1.3 with the data modelling of the information exchanged between the main parts of the system.

Data models are defined for information coming from outside (weather conditions, electricity prices, gas prices…), data to be exchanged between the main components of the architecture, and data to be exchanged with loads, generators and storage devices.

This modelling activity builds on previous work and other approaches like: IFC and gbXML data models for the building sector, as well as work done in other related R&D projects.

This report contains 5 main chapters in relationship with:

- The methodology adopted to elaborate the FIEMSER Data Model
- The categorization of data
- The elaboration of sub-model for each data category
- The state-of-the-art relatively to (1) information modelling in related R&D projects, and (2) building information standards
- The merging of previous sub-models into a holistic and consistent FIEMSER Data Model

Both deliverables D4 (FIEMSER System Architecture) and D5 (FIEMSER Data Model) should be read conjointly to get the full technical specifications of the FIEMSER system, its components, and the interactions between them. In particular, according to the SOA approach chosen for the FIEMSER system, the web services defined in D4 for each FIEMSER component, and their associated API functions, will be implemented by invoking methods defined for some objects of the FIEMSER Data Model in D5.

The object/relational mapping of these objects to the FIEMSER data base will be achieved through a specific framework like Hibernate. With such a framework database accesses are not to be explicitly coded since they are replaced by high-level object handling functions. The principle is that the operations requested by the services (defined in D4) will directly call methods on objects (and will not be translated into database queries, as in a more traditional approach). Moreover it allows addressing the required data persistency while preserving the high-level object approach for the implementation of the various processes.

2. Methodology

2.1 General approach

The elaboration of a data model is often a complex task, not only when data are numerous and varied, but also because of the different views that can be chosen to analyse the role played by these data in the related business processes, and to structure them accordingly.

The methodology chosen by the FIEMSER consortium to elaborate the so-called FIEMSER Data Model followed a bottom-up approach, starting from the description of specific parts (sub-models) and merging the produced sub-models into a holistic and consistent model. This allowed every partner to contribute to the elaboration of the Data Model, by assigning them the responsibility of one or several sub-models corresponding to their area(s) of expertise.

More precisely, the methodology comprised 4 four steps:

1. Categorization of data: several categories of data have been identified, by referring to the defined Use Cases corresponding more or less to a specific functional view of the system.

2. Modelling of data in each category: this was achieved by following the UML class diagram approach (see below), complemented by a description of classes and relationships following a common template in a tabular form.

3. Analysis of the state-of-the-art, including:

   - Review of ongoing R&D projects on ICT4EE in Buildings with a focus on data modelling: this was achieved by filling a template that makes easier the comparison between the different approaches chosen by the projects.

   - Analysis of relevant standards in the Building domain: especially the IAI/IFC and gbXML standards.

4. Merging produced sub-models in a global FIEMSER Data Model, which implies identification of common concepts and possible inconsistencies.

2.2 UML Diagram Class

Unified Modelling Language (UML) class diagrams are the pillar of object-oriented analysis and design. UML class diagrams show the classes of the system, their interrelationships (including inheritance, aggregation, and association), and the operations and attributes of the classes. Class diagrams are used for a wide variety of purposes, including both conceptual/domain modelling and detailed design modelling that translate the models into programming code.

For our purpose, we use class diagrams for a conceptual modelling of FIEMSER data, showing static relations between objects.

In a class diagram, classes are represented with boxes which contain three parts:

- The upper part holds the name of the class
- The middle part contains the attributes of the class
- The bottom part gives the methods or operations the class can take or undertake

UML allows different types of relationship. We will only use the following ones:

Association: An association represents the static relationship shared among the objects of two classes. It is graphically represented as a line connecting two classes. An association can be named, and the ends of an association can be qualified with role names, ownership indicators, multiplicity, visibility, and other properties. We will mainly use the multiplicity property (also named cardinality).

Aggregation: An aggregation is more specific than an association. It is an association that represents a part-whole or part-of relationship. Aggregation can occur when a class is a collection or container of one or several classes, but where the existence of the contained classes (the “components”) do not depend on the container: in other terms, if the container is destroyed, its contents are not. In UML, it is graphically represented as a *hollow diamond shape* on the containing class end of the line that connects the contained class to the containing class.

Composition: A composition is a stronger variant of the aggregation. It means that if the container is destroyed, normally every instance that it contains is destroyed as well. It is graphically represented with a *filled diamond shape* on the containing class end of the line that connects the contained class to the containing class.

Generalization: A generalization relationship indicates that one of the two related classes (the *subclass*, or *child*) is considered to be a specialized form of the other (the *superclass*, or *parent*). The superclass is said to be a generalization of the subclass, which in return is a specialization of the superclass. The UML graphical representation of a generalization is a *hollow triangle* shape on the superclass end of the line that connects it to one or more subclasses. Subclasses normally inherit the properties defined for the superclass.

The consortium chose to adopt StarUML, an Open Source modelling software tool, for the development of the FIEMSER class diagrams.

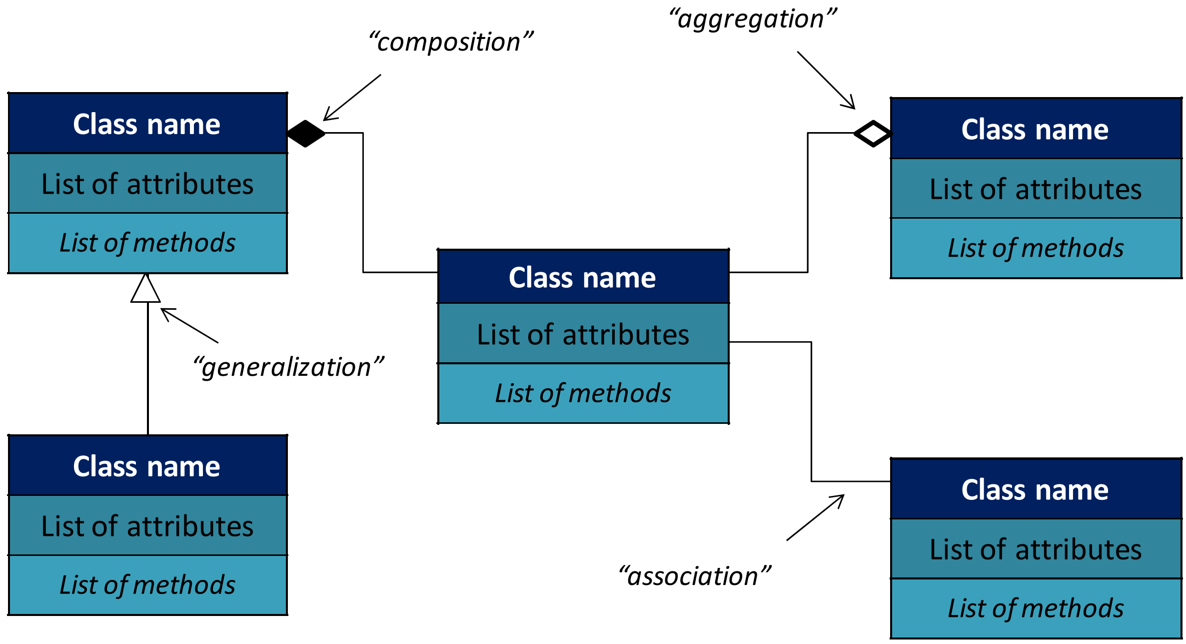


Figure 1: UML Class Diagram (graphical view)

2.3 Class description

In order to describe classes, their attributes and how their related to each other, it has been decided to follow a tabular template as shown below:

Entity name				Related views	
Definition					
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		

Tableau 1 – Table used to describe classes, attributes and relationship

“Related views” refers to the functional views where this object class is used.

“Data type” can be: Boolean, string, integer, float, date, time, list (allowing a sequence of values or more complex objects). By convention, we will state that the “time” attribute also includes the date.

In order to lighten the presentation, “Unit” is considered here as a characteristic of the attribute (and filled with the most commonly used unit for this attribute), but at time of the implementation, a specific Unit attribute will be created in case different units need to be handled (e.g. an energy can be measured in Wh or kWh).

As introduced above, possible “Relation types” are: association, aggregation, composition, and generalisation.

3. Data categorization

This section describes the different kinds of data to be stored in the FIEMSER database.

Starting from the definition of Use Cases (see deliverable D3) and data exchanged between system parts to perform FIEMSER processes, 8 main data categories have been identified as shown in the table below, each one corresponding to a specific functional view of the system.

Abbrev.	Data Category	Content
ENV	**Environmental and contextual data**	• Location, climate zone, shadowing, building orientation, etc. • Weather data, energy prices, etc.
BIM	**Energy-focused BIM (Building Information Model)**	• Space organisation / Envelope & partition (characteristics) • Home equipments (appliances, generators, storages…) (location, type, characteristics…)
WSN	**WSN-related data**	• Sensors & Actuators (location, characteristics, configuration data…) • Data collected from sensors (equipments operation, building usage) • Log of activations (control orders sent to actuators)
USR	**User preferences**	• Usage profile, definition of scenes, including comfort set-points and use of appliances • Control rules and energy strategy
SCH	**Resources scheduling data**	• Scheduling of resources
ADV	**Advices**	• Orders, and associated advices, created as a result of an event, usually associated to an action of the user and some other actions suggested by the system
EPI	**Energy performance indicators**	• Log of consumptions • Performance indicators
RGH	**User Access Rights**	• User rights regarding the access to FIEMSER functionalities

Tableau 2 – Data Categories

It should be noted that the above-defined categories do not constitute disjointed sub-sets of data. Indeed the same data can belong to more than one functional view. Nevertheless this bottom-up approach allows dividing the complex modelling work into more elementary tasks.

The following sub-sections present the sub-models built up for the identified data categories. These models result from an iterative process including intermediate milestones where produced sub-models have been merged to harmonize the definition of concepts and relations, and identify possible inconsistencies. Sub-models were then refined, merged again, and so on till the final production of a comprehensive and consistent global FIEMSER data model.

The UML class diagram approach has been chosen for data modelling (see previous section).

4. Sub-models

This section presents the data sub-models corresponding to the different categories defined in the previous chapter.

4.1 Environment

4.1.1 Introduction to the model

The Environment diagram describes the data model used to represent the environment of the building, which includes its physical environment and its relation with this environment (location, orientation, shades…), the local climate and, the economical environment (energy prices). For this latter information, the model focuses on forecast data (for weather or energy price).

The model also includes the main characteristics of the external online resources able to provide the requested information.

The main classes described in the diagram are:

- WeatherForecast class: This class acts as a container that collects the hourly evolution of weather parameters during a certain period of time.

- DayAheadPrices class: This class is analog to the previous one, but for energy prices. Different types of energy may be considered in the PrimaryEnergySource class. Prices also depend on the type of contract concluded with the energy supplier. In a multi-dwelling building, it is assumed that a specific contract (per each used energy type) may be concluded for each dwelling, as well as for the common building areas.

4.1.2 Graphical overview

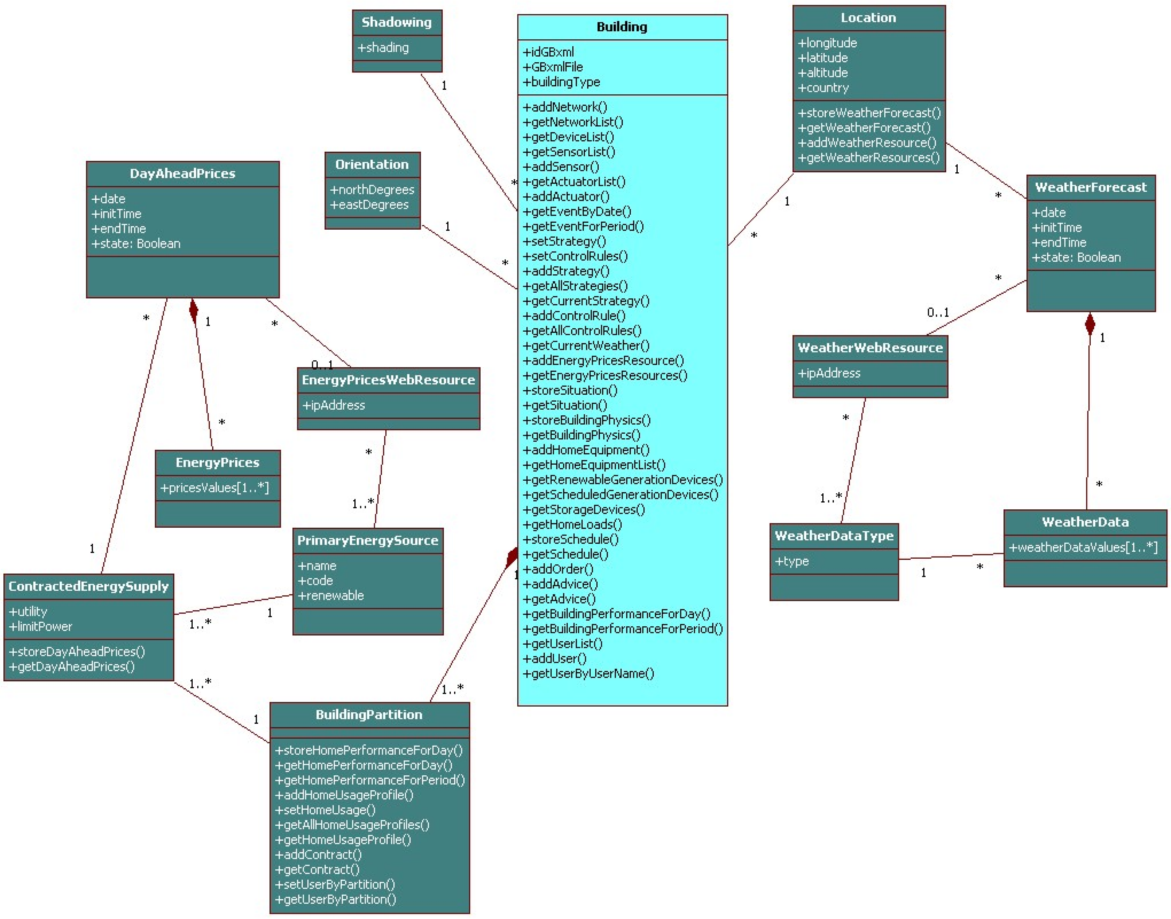


Figure 2: Class Diagram for Environmental Data

4.2 Energy-focused BIM

4.2.1 Introduction to the model

To facilitate the reading, this part has been decomposed in two class diagrams:

- The first one is related to the building spaces organisation, including the definition of homogeneous thermal zones. But attributes about geometries are not included because it is assumed that this information will remain in the gbXML file. Indeed (see further section on Building Information standards), the gbXML standard has been chosen as way to represent all “static” energy-related building information. As a consequence, the following FIEMSER diagram includes direct links with gbXML objects that are relevant for the energy simulations. In case of multi-dwelling buildings, the BuildingPartition class gathers dwellings and common building areas (e.g. parking areas).

- The second one models the home equipments hierarchy.

The equipments diagram describes the data model used to represent information about the resources used in the building. The resources described are loads that consume energy for offering a service to the user, generators that provide part of the energy required by the building, and storage devices that are used to provide flexibility in the application of the most convenient energy management strategy. The main classes described in this diagram are:

- Load, Mechanism, Storage and Generator classes: These classes are used to represent the functional characteristics of each type of home equipment and the classes have been specialized to hold the details of more specific types of equipment.

- OperationMode and DetailedOperationMode classes: These classes represent in detail the operation mode that can be selected for certain type of devices. For example a washing machine can have different operation modes that have different energy consumption characteristics and which can be selected by the user.

- DetailedLosses class: This is a class that holds information about the value of the losses depending on the jump of the main property of the storage device. For instance, for a heat tank the value of the losses will depend on the temperature jump between the fluid inside the tank and its surroundings.

- DetailedEfficiency class: This class stores the detail efficiency of a generator depending on the power at which it is operated. Other classes like PrimaryEnergySource have been considered as relevant and are described within the diagram.

4.2.2 Graphical overview

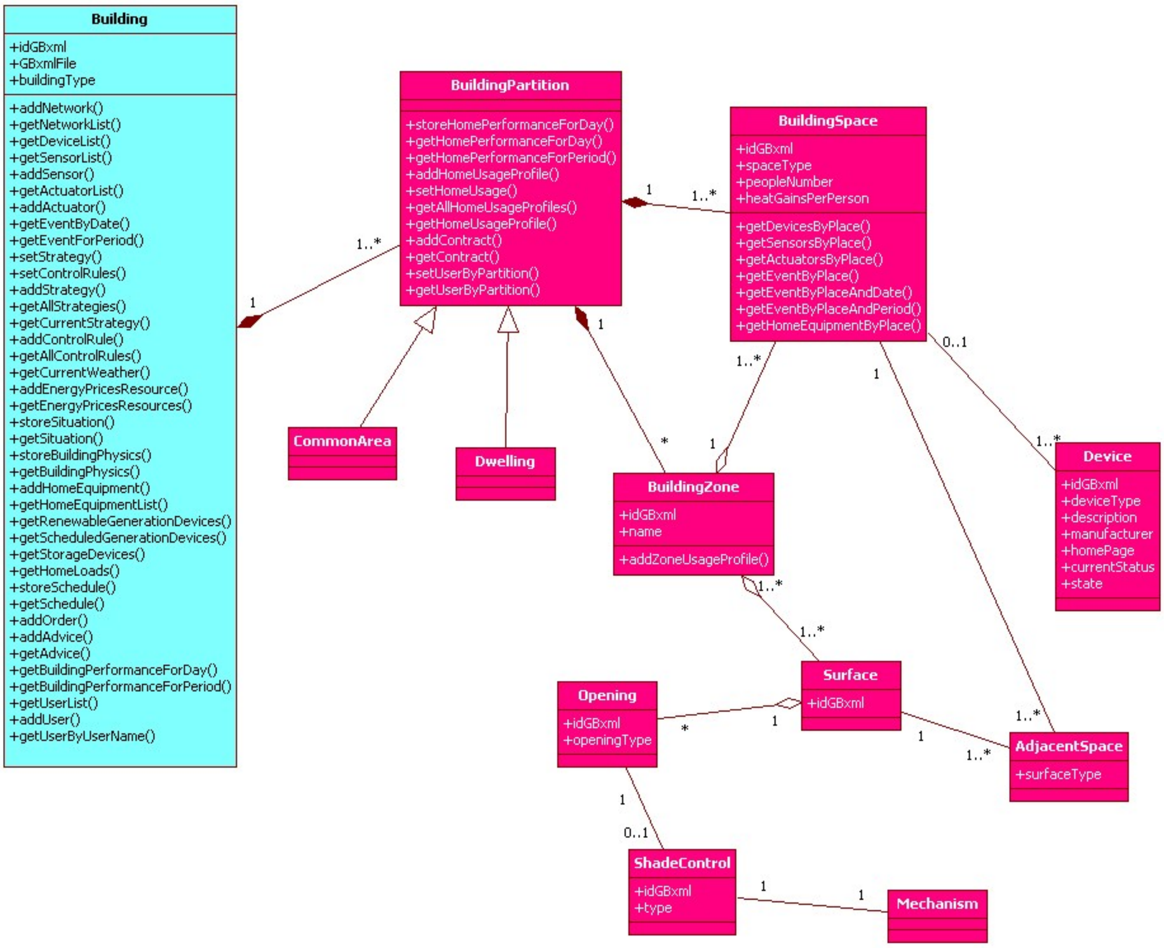


Figure 3: Class Diagram for Energy-focused BIM (Organisation of Spaces)

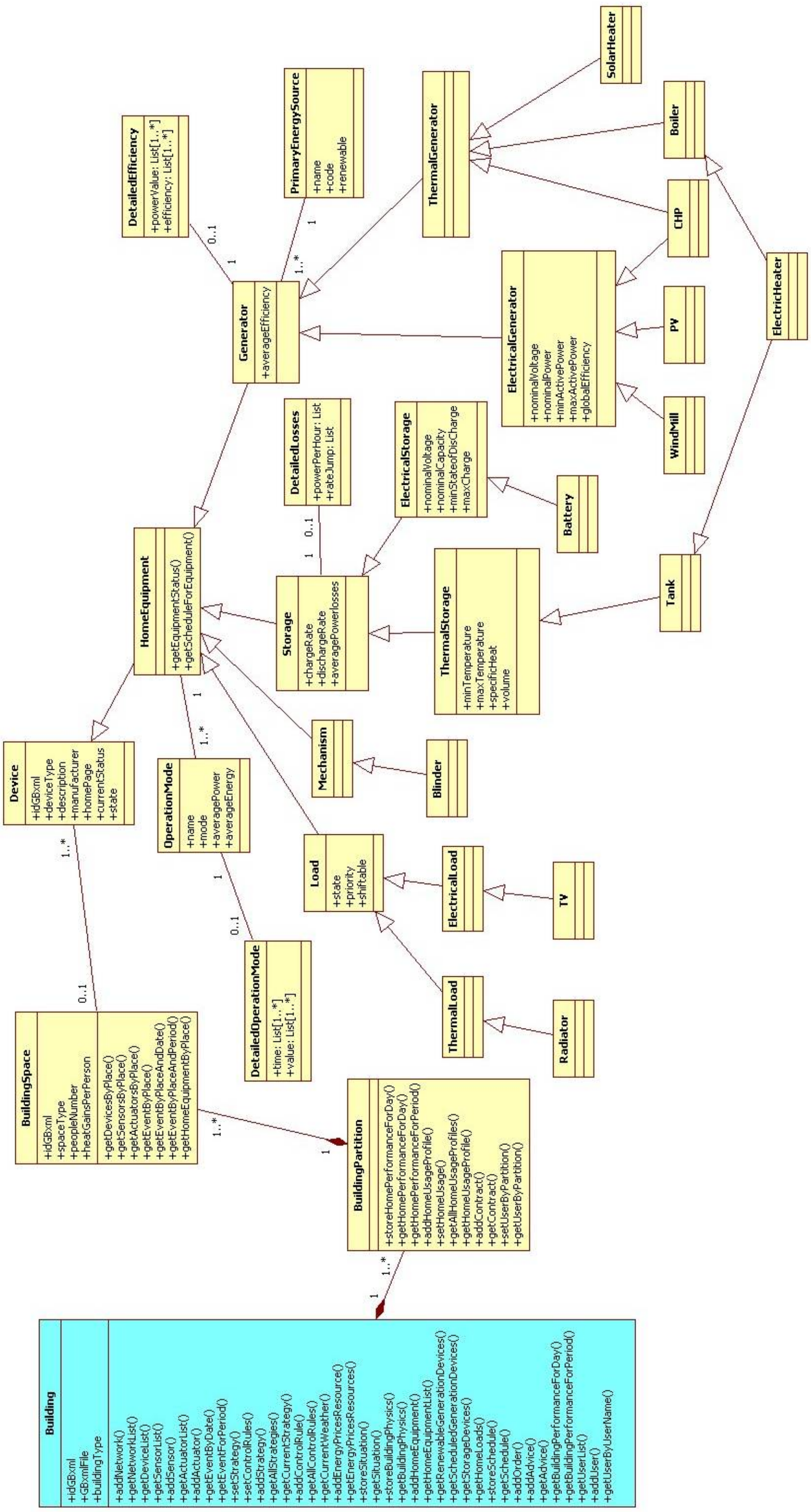


Figure 4: Class Diagram for Energy-focused BIM (Home Equipments)

4.3 WSN-related data

4.3.1 Introduction to the model

The WSN Model represents the FIEMSER's interface to the building's sensing and acting infrastructure. This interface is handled by CtrlDevices, i.e. the devices that can be controlled and monitored directly by FIEMSER. Each CtrlDevice can be interfaced with a number of HardwareComponents (either sensors or actuators), and handles a number of software and network protocols. FIEMSER configures the sensing and acting infrastructure by sending configurations instruction to the device in charge of the specific sensors and actuators. Each instruction, as well as any events raised by the hardware, is logged by the sensing and acting component (respectively as ControlScheduleLog and EventLog). Finally, this component maintains an estimate (CtrlDeviceEnergyConsumption) of the energy consumed by every CtrlDevice.

4.3.2 Graphical overview

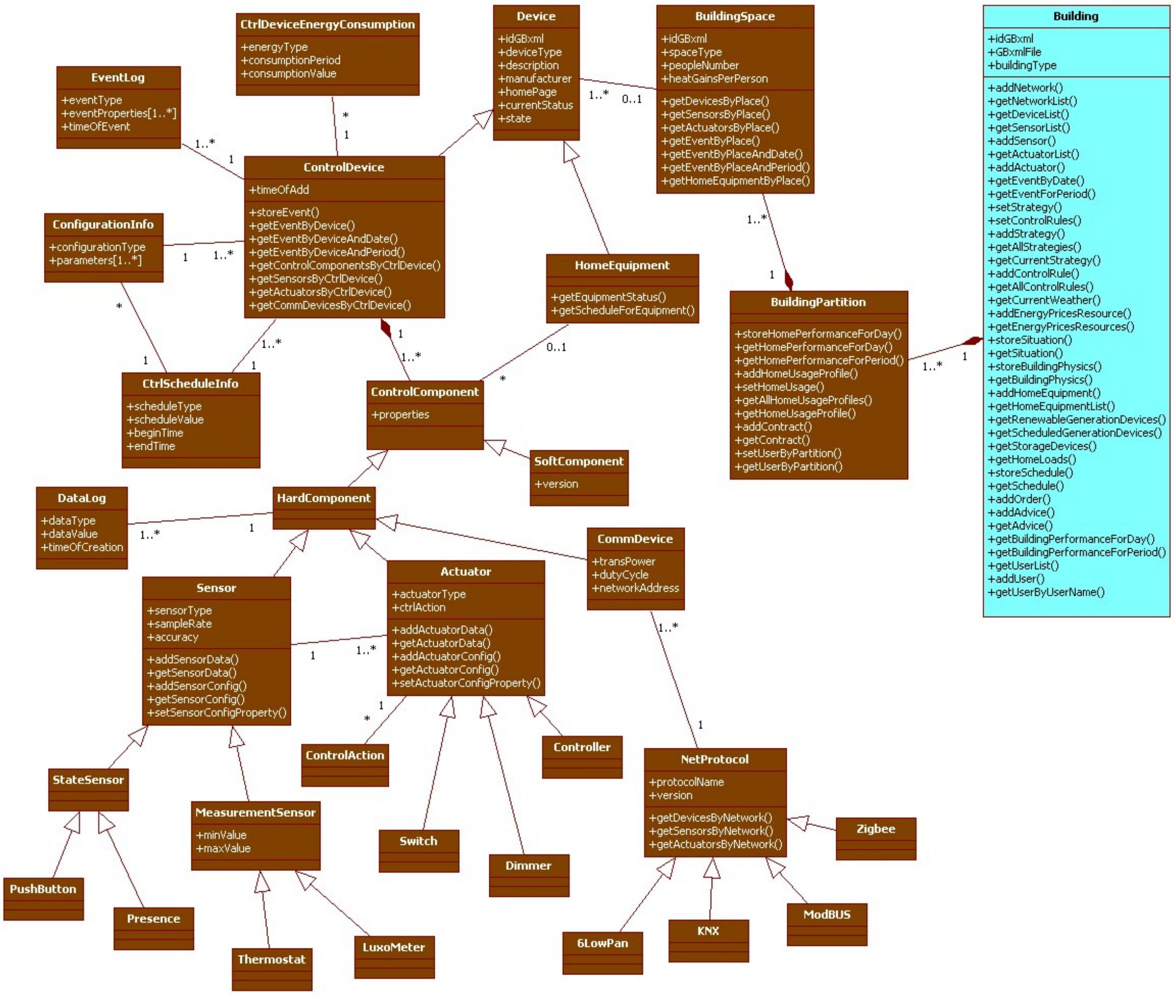


Figure 5: Class Diagram for WSN-related Data

4.4 User preferences

4.4.1 Introduction to the model

The User Preferences diagram describes the data model used to represent the daily planning of the building usage by the end-users. It comprises the definition of daily usage profiles at level of building zones, each profile describing the sequence of scenes (e.g. dinner), the loads involved, and the comfort set-points (temperature, luminosity…).

In addition, the model also includes the user choice of the energy strategy (possibly for each day), and of the control rules associated to devices.

The main classes described in the diagram are:

- HomeUsageProfile class: This class allows defining different profiles for the daily usage of a BuildingPartition (in case of a multi-dwelling building this is either a dwelling or a common building area). It is composed of a set of ZoneUsageProfile that detail the usage of each building zone.

- Scene class: This class allows defining usage scenarios, i.e. specific usages of the building, in terms of comfort set-points and appliances usage.

- GlobalStrategy class: This class describes the global energy strategy chosen for the whole building. Possible choices include: maximise energy efficiency, maximise cost efficiency, maximise locally used energy, maximize use of local renewable energies.

4.4.2 Graphical overview

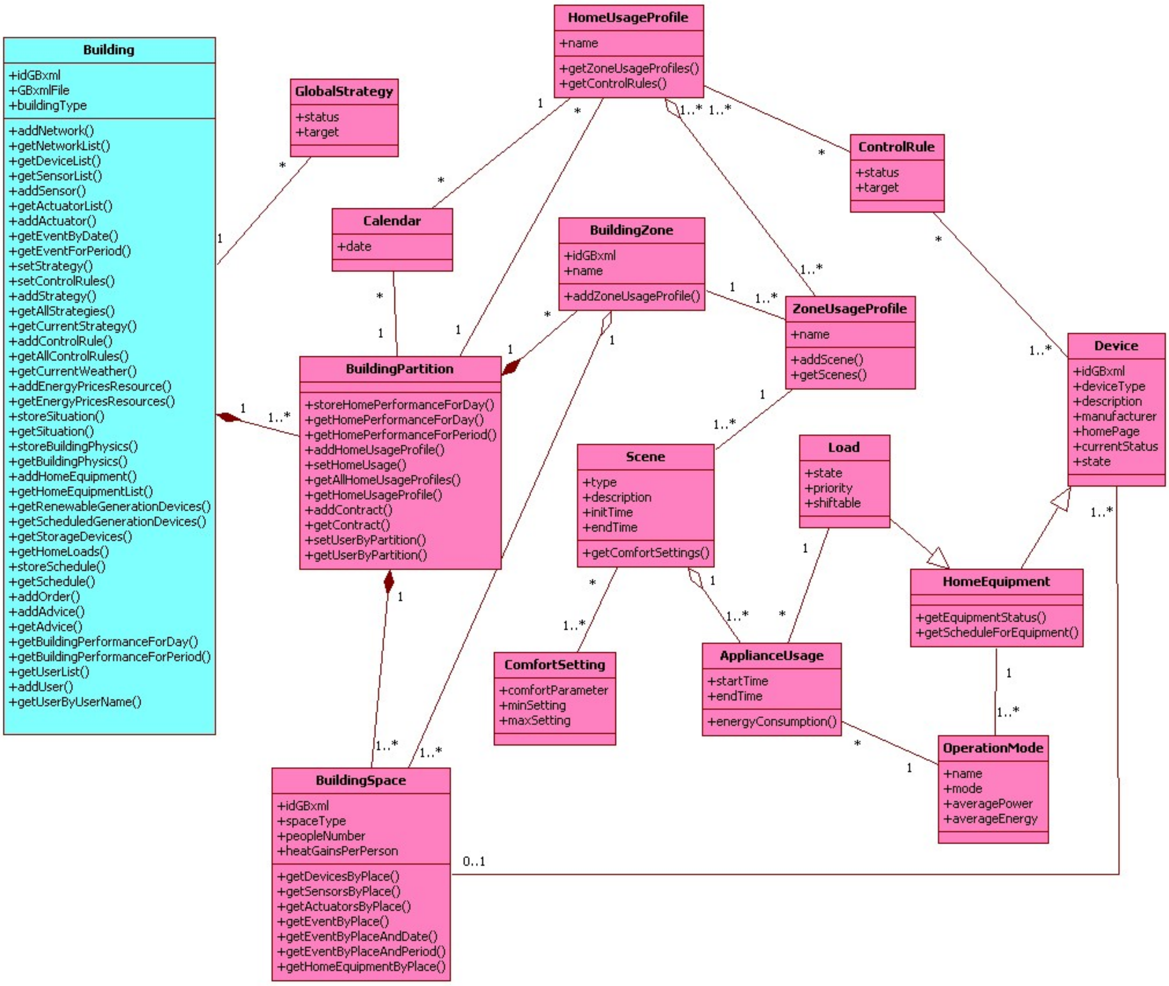


Figure 6: Class Diagram for User Preferences

4.5 Resources scheduling

4.5.1 Introduction to the model

The Scheduling diagram describes the data model used by the system to represent the daily planning of the usage of the resources of the building. Then it includes in detail the overall building energy usage planning, as well as the individual use of each resource. The main classes described in this diagram are:

- BuildingProgrammedSchedule class: This class represents the daily schedule of resources usage within a building. It holds a link with the HomeUsageProfile and related classes that have to be taken into account during the planning process.

- TemperatureSchedule class: This class allows the representation of the estimated temperature evolution in the different zones of the building.

- ResourceSchedule class: This class allows the representation of the power consumption/generation of the devices that exist within the building. The specialization of the class into load, generation and storage is also described, as well as a more detailed specialization for devices that have to be scheduled in switching actions or certain property evolution values. This schedule holds a link with a corresponding device and the operating details of it.

4.5.2 Graphical overview

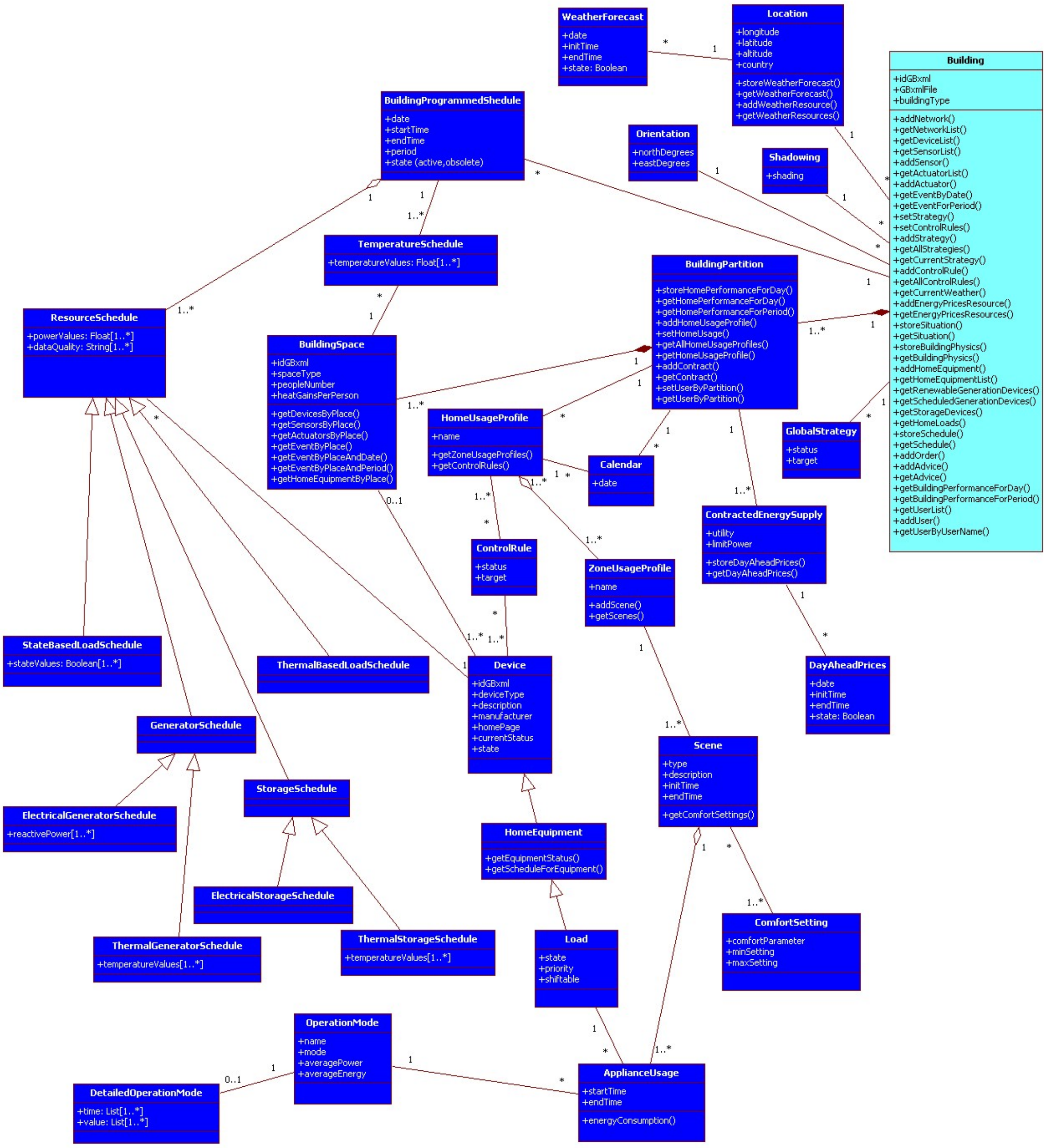


Figure 7: Class Diagram for Resources Scheduling

4.6 Advices

4.6.1 Introduction to the model

The Advices diagram describes the data model used by the system to represent the advices given to the user about ways to improve the energy efficiency of the building. The main classes described in the diagram are:

- Order class: This class allows the representation of the advice into orders that should be executed by the actuators if the users are willing to follow the advice. This class holds a link with the class ControlRule to show the rule responsible for the creation of the order.

- Advice class: This class stores a textual description of the message to be displayed to the User.

- ControlAction class: This class represents the specific control actions associated to every order and it also has a link with the Actuator that has to implement the action. Two types of control actions have been identified: SwitchingCTRLAct, which is used to change the state of a device, and DimmingCTRLAct, which is used to change the value of the property under control.

4.6.2 Graphical overview

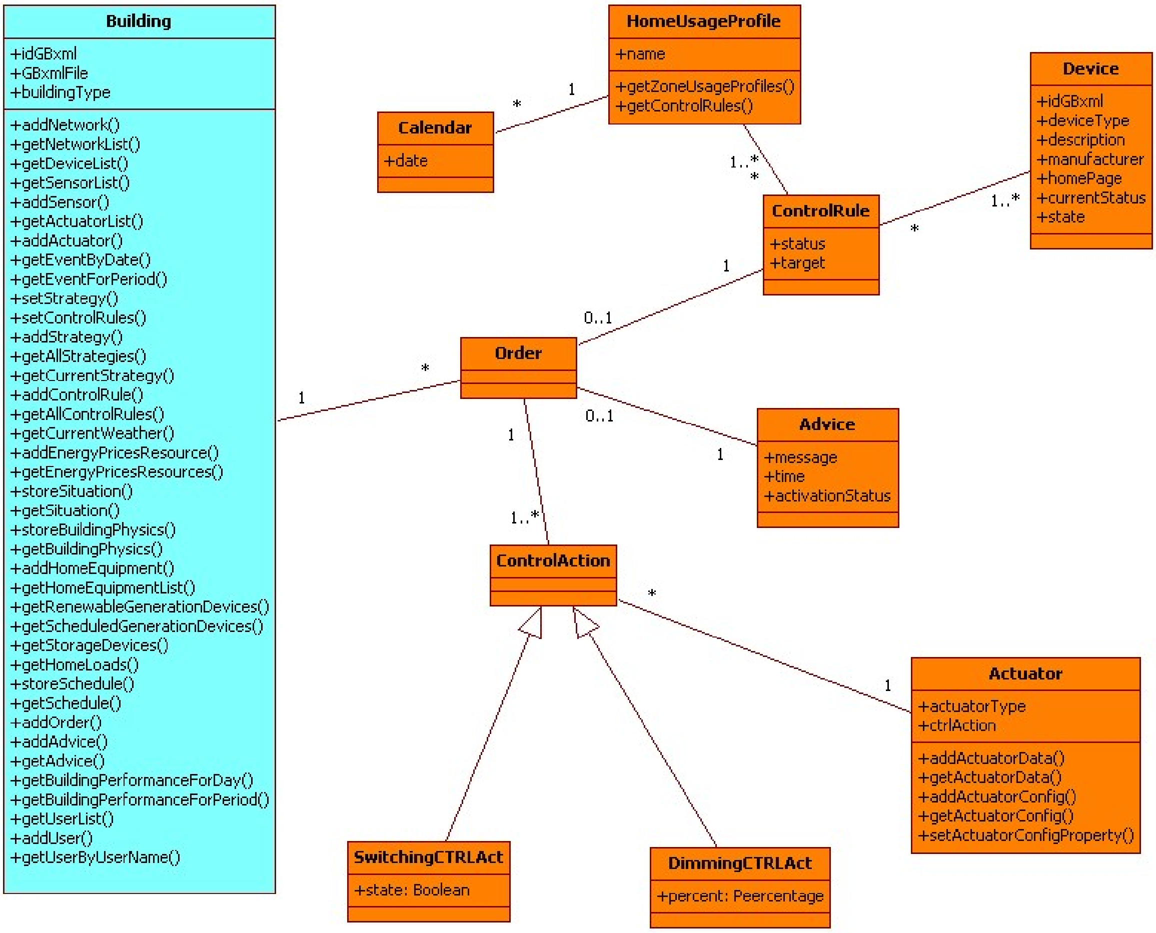


Figure 8: Class Diagram for Advices

4.7 Energy performance indicators

4.7.1 Introduction to the model

The performances diagram describes the data model to represent the control devices together with their link with the equipment they operate upon, as well as, details of the operation of the control devices, represented by logged data about their operation. The daily measurements to be displayed to the user are also described in this diagram. The main classes described in this diagram are:

- DataLog class: This class stores the details of the operation of sensors and actuators.

- Sensor and Actuator classes: These classes represent the characteristics of both devices and their link, by identifying the sensor that signals the operation of an actuator. The link between a control device and the home equipment it acts upon is reflected in the diagram. Some examples of specialization of the sensor and actuator are also represented in the diagram.

- HomeDailyMeasurementLog class: This class holds the daily detailed energy consumption/generation of a BuildingPartition. This log of measurements can belong to the physical building or to a reference one that is used for comparison purposes. The BuildingDailyMeasurementLog has methods that compute the overall building energy performance from HomeDailyMeasurementLog.

4.7.2 Graphical overview

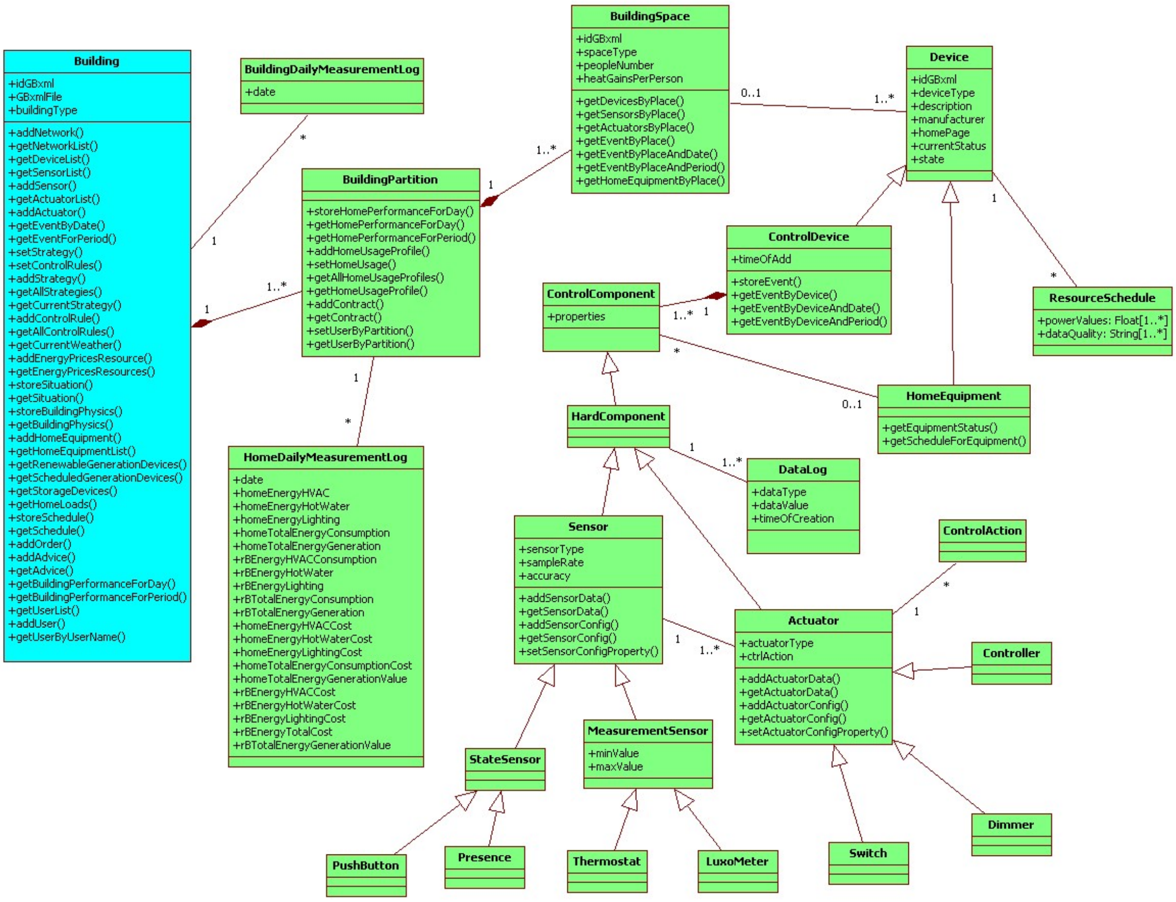


Figure 9: Class Diagram for Energy Performance

4.8 User Access Rights

4.8.1 Introduction to the model

The User Access Model represents users, groups of users, and their different permissions to access and operate upon the FIEMSER system. Users can belong to one or more groups, to which different permissions can be associated. Each permission is associated to a Permission Type (e.g. Edit, List, Add, Remove...) and to a Functional Area (describing functional areas in the Admin GUI tools, such as Monitoring, Device Operations, Advices etc...). The user can perform an operation belonging to a given permission type within a given functional area only if its group is associated to a permission associated to that permission type and to that functional area. Besides, each user is associated to the building partition(s) that he owns or occupies.

4.8.2 Graphical overview

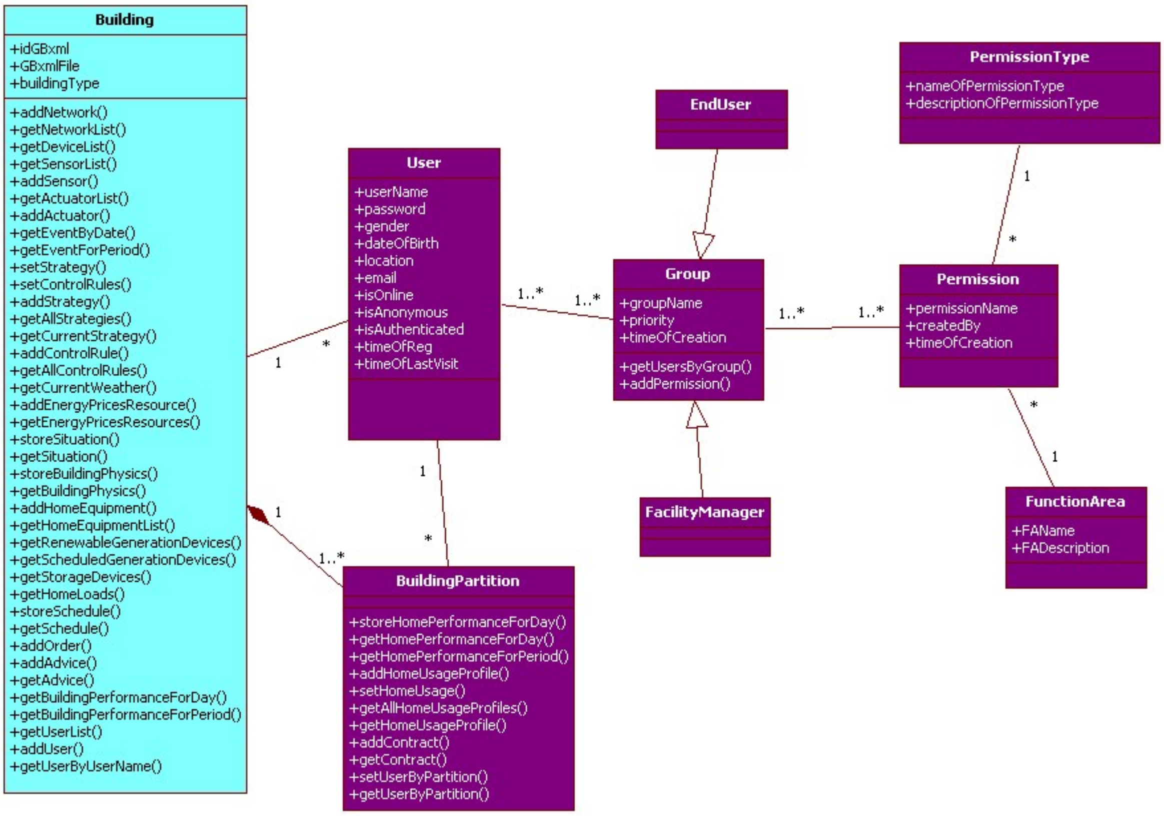


Figure 10: Class Diagram for User Rights

5. State-of-the-art

This section presents a comparative survey of past and on-going work on modelling of data for Building Energy Management Systems (BEMS) through an analysis of relevant European R&D projects. The purpose is to take benefit from other R&D project results for our own data modelling work, and have some preliminary insights on the appropriateness of the FIEMSER model to meet their specific needs.

This section also includes a state-of-the-art in relevant standards for building information, especially relatively to energy efficiency issues. It essentially analyzes two major initiatives: IFC and gbXML.

5.1 R&D projects

A set of R&D projects (mainly European FP7 projects) addressing ICT and Energy Efficient Buildings, have been selected and analyzed from the point of view of data modelling:

Each project has been described by following a common template to allow easier comparison.

5.1.1 EnPROVE

	EnPROVE - Energy consumption prediction with building usage measurements for software-based decision support
Funding programme (E.g. European ICT, French ANR…)	EU FP7 – ICT for Energy Efficiency
Duration (from … to …)	From February 2010 to January 2013
Project web site	http:\\ www.enprove.eu
Coordinator (Mr, Mrs … from …)	Dr. Rui Neves-Silva (Uninova)

<u>Short summary</u>:

The objective of EnPROVE is to develop a software model for predicting the energy consumption of a specific building, with different scenarios implementing energy-efficient technologies and control solutions, based on actual measured performance and usage data of the building itself. The key hypothesis of EnPROVE is that it is possible, from adequate gathering and assessing data on how a structure performs and is being used from an energy viewpoint, to build highly accurate and specific energy consumption models relevant for prediction of alternative scenarios.

The EnPROVE software tools will support the decision maker in orientating retrofit investments towards the most efficient energy saving solutions by taking care of actual building conditions and usage. Potential technological solutions will include options for reducing, generating, and storing energy. Applying user-defined criteria on resources and restrictions, new prediction algorithms will allow identifying when the return on investment will be realized.

EnPROVE will be able to develop tools, interoperable with existing CAD or Facility Management tools, to model the energy consumption from monitored data, predict the performance of alternative scenarios and support the decision maker in finding the optimal point for the investment.

Which types of building are considered in the project (e.g. single houses, dwelling buildings, office buildings…)?

Main focus is on existing office buildings.

Which information is taken into account and how it is modelled with relation to the following topics? (Indicate the standards used if relevant):

Building physics (spaces, wall composition, etc.)	EnPROVE will enhance existing CAD and Facility Management (FM) software with energy features to make easier the integration of the energy management system from the initial stages of the building refurbishment process. CAD and FM software plug-ins will be developed that will assess the full life cycle of energy saving services before their realization and including the influence of user's interaction. The integration will focus on IFC-compliant CAD tools, so that building physics will be retrieved from standard BIM (Building Information Model) representations. Regarding the building domain, EnPROVE identifies two sub-domains: the BIM, and partition areas, which define the building areas to be audited.
HVAC, lighting equipments and other relevant devices and appliances (detail what kind of devices are considered)	EnPROVE system primarily targets electricity powered HVAC and lighting system. Each equipment is described with a set of static properties (depending on its type). It belongs to one or several functional domains (lighting, heating, cooling, ventilation, and other electrical appliances). It may be associated to an interaction device (e.g. command module), sensor(s), and activity data (info collected regarding its activity).
Sensors (location, characteristics, configuration data…)	Sensors are used in EnPROVE to monitor energy consumption (of equipments) and building usage (e.g. presence, window/blind usage). Some are also used to collect info on the environment (inside/outside context) (e.g. temperature, air quality).
Control strategies	Assessment of alternatives for building renovation takes account of different advanced energy control strategies that are made available considering the installed devices. The starting point is the European standard EN15323 that provides a comprehensive list of technical measures addressing user- and utilization dependent scenarios.

User behaviour and preferences (e.g. occupancy and activity profiles, set-points…)	One of the challenges of EnPROVE is to define and populate a model regarding user behaviour and preferences, relevant for a better energy management. This approach should allow the system to provide accurate and specific building renovation recommendations.
Weather conditions (and weather forecast if relevant)	In order to have access to the latest weather resources all over the world, EnPROVE tools should be integrated with the weather databases like: International Weather for Energy Calculations provided by ASHRAE, Weather Bank, Typical Meteorological Year provided NCDC and NREL, European Test Reference Year provided by European Commission.
Energy prices	The market boundary conditions database contains the market environment conditions (i.e. energy and other cost factors), that are needed to guide decision making during the EnPROVE process execution.
Others	

What communication protocols are considered and/or integrated?

EnPROVE applications and modules integrate in order to share common information needed by the system. The integration architecture is based on the Service-Oriented Architecture (SOA). A deployed SOA-based architecture will therefore provide a loosely-integrated suite of services that can be used within multiple EnPROVE-related business domains.

SOA implementations rely on a mesh of software functionalities, namely services, as un-associated, loosely coupled functional modules that implement one action and have no direct function calls to each other. Instead of implementing direct calls in their source code the service modules use defined protocols that describe how services pass and parse messages. This is achieved by using description metadata such as XML files.

Are there one or several internal databases, and which information is stored in?

EnPROVE is composed of several internal databases required for information exchange and storage within the scope of business processes. They range from auditing brief and auditing result, to renovation solution and scenario calculation result,

Is there a link with some external databases?

The BIM (Building Information Model) representations have to be imported from an existing tool or external database into EnPROVE.

What kind of information is displayed to the end-user (energy performance indicators, recommendations for more EE behaviour, etc.?)

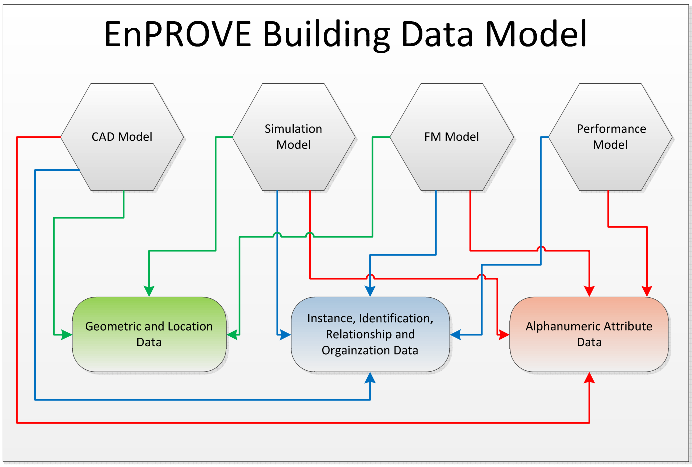
Three different users have access to the EnPROVE applications: the Investor (e.g. building owner), the Technical Consultant and the Auditing Contractor. Each of them has its own Interfaces that will give access to the applications used to perform the business processes they are involved in.

The Investor provides the key project/building data and investment constraints and, as a result of the assessment process, he gets advice for building upgrading (where to invest) together with KPI - Key Performance Indicators arguments (mostly economically driven) needed for the decision-support.

Other comments:

EnPROVE identifies 5 main categories of data:

1. Control Data
2. Configuration Data
3. External Plugin Model Data
4. User and System Interface Data
5. Application Model Data
    - Building Model Data, enabling several Building Model Views, and including:
        - CAD Model
        - FM Model
        - Performance Model
        - Simulation Model



Global view of the EnPROVE Building Data Model

- Auditing Model Data, including:
  - Sensor Raw Data
  - Sensor Physical Model Data
  - Usage Model Data
  - Usage Profile Model Data
- EPDSS Model Data, including:
  - Assessment Model Data
  - Scenario Model Data
  - Decision Model Data
  - Prediction Model Data
  - Renovation Solution Model Data

The envisioned Data Repositories are:

1. System Data Repositories
   - Renovation Solution Database
   - Solution Technology Database
   - Market Boundary Conditions Database
   - EnPROVE configuration data (EPDSS, Auditing, EnPROVE plugins)
2. Project Data Repositories
   - Building Model Database
   - Auditing Main Database
   - Auditing Results Database(s)
   - EPDSS Main Project Database
   - Scenario Calculation Result Database
   - Decision Support Cache
   - Renovation Solution Database

5.1.2 EnergyWarden

	EnergyWarden (EW) – Renewable Energy Sourcing Decisions and Control in Buildings
Funding programme (E.g. European ICT, French ANR…)	EU FP7 – ICT for Sustainable Growth
Duration (from … to …)	From January 2010 to December 2012
Project web site	http://www.energywarden.net/
Coordinator (Mr, Mrs … from …)	Mr Alexis Onoufriou (CNE Teccnology Ltd)

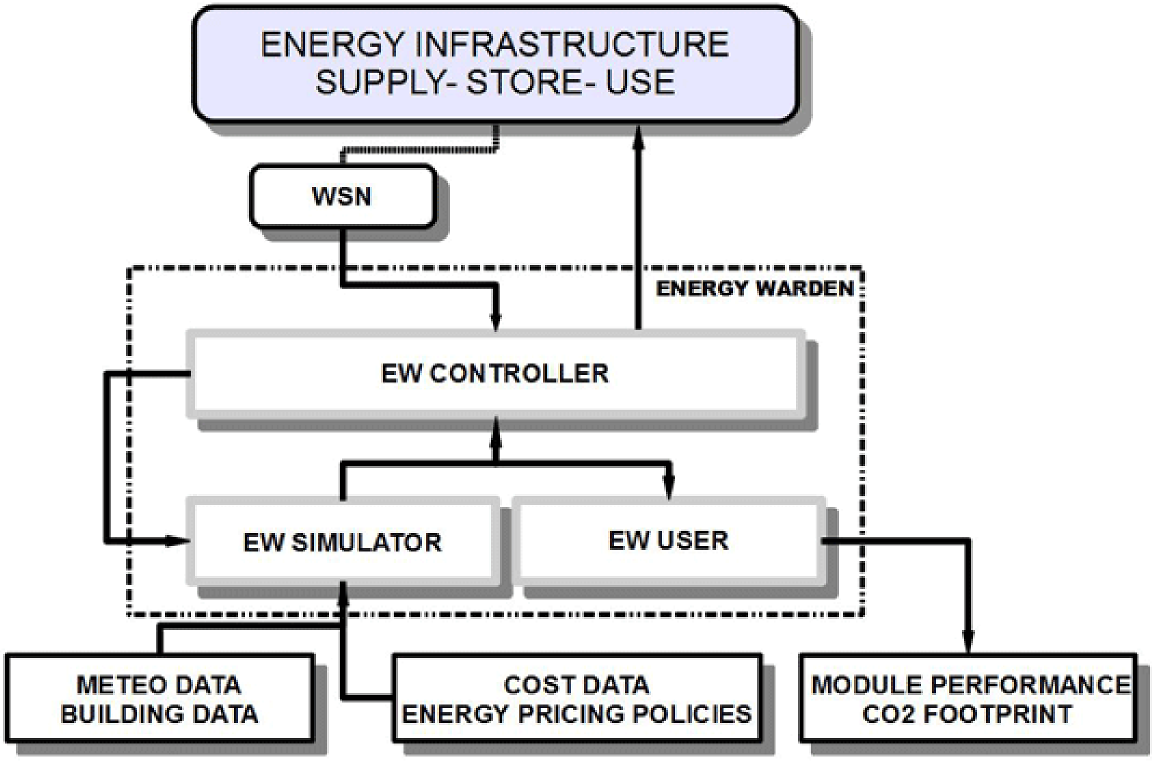
Short summary:

EnergyWarden (EW) project aims the development of tools for the management and control of renewable technology, deployed in the building domain. Real time sourcing decisions are also taken into account. The energy sourcing implies controlling the balance between energy supply, storage, use and feed-to-the-network. EW will develop and market three main products:

EW-Simulator: A simulator and modelling tool that will provide estimations of the renewable energy

EW-Controller: It will be based on an expert system / neural network approach and will provide real time control of the Renewable Energy Technology infrastructure.

EW-Policy. It is a software database driven application that supports conformance with European directives and related standards.



Which types of building are considered in the project (e.g. single houses, dwelling buildings, office buildings…)?

Existing and new buildings are considered, both residential and offices.

Which information is taken into account and how it is modelled with relation to the following topics? (Indicate the standards used if relevant):

Building physics (spaces, wall composition, etc.)	-
HVAC and/or lighting equipments and other relevant devices and appliances (detail what kind of devices are considered)	**Energy sourcing** – Solar/ thermal – Solar/ PV – Wind – Geothermal – Multiple electricity suppliers – Locally produced electric energy • **Energy store** – Batteries – Hot Water – Hydrogen/fuel cell – Phase changing materials • **Energy use** – local electricity loads – use Water heating – space Heating/Cooling – selling to the grid and district
Sensors (location, characteristics, configuration data…)	Wireless sensors and data loggers/ transmitters.

Control strategies	The real time controller (EW-C) will manage all in-situ energy modules and will define how network inflowing and locally produced energy is allocated between uses, stores, and possibilities to be fed back to the energy network. It will include a data collection module**,** low cost hardware including**,** primarily, which will be deployed at the building over a period of time and facilitate the collection of data, on which the sourcing decisions may be taken.
User behaviour and preferences (e.g. occupancy and activity profiles, set-points…)	Calculating in real-time user preferences e.g. income, ROI, etc.
Weather conditions (and weather forecast if relevant)	Meteorological data can be obtained on hourly basis. It consists of external air temperature, global solar radiation at a horizontal plane, local or meteorological wind speed, wind direction They are the entry to the EW-Simulator.
Energy prices	
Others	

What communication protocols are considered and/or integrated?

EW-C has been designed to be compliant with 802.14.5 (EWC.802) and BMS protocol.

Moreover, TCP/IP will be used in order to communicate with web interfaces.

Are there one or several internal databases, and which information is stored in?

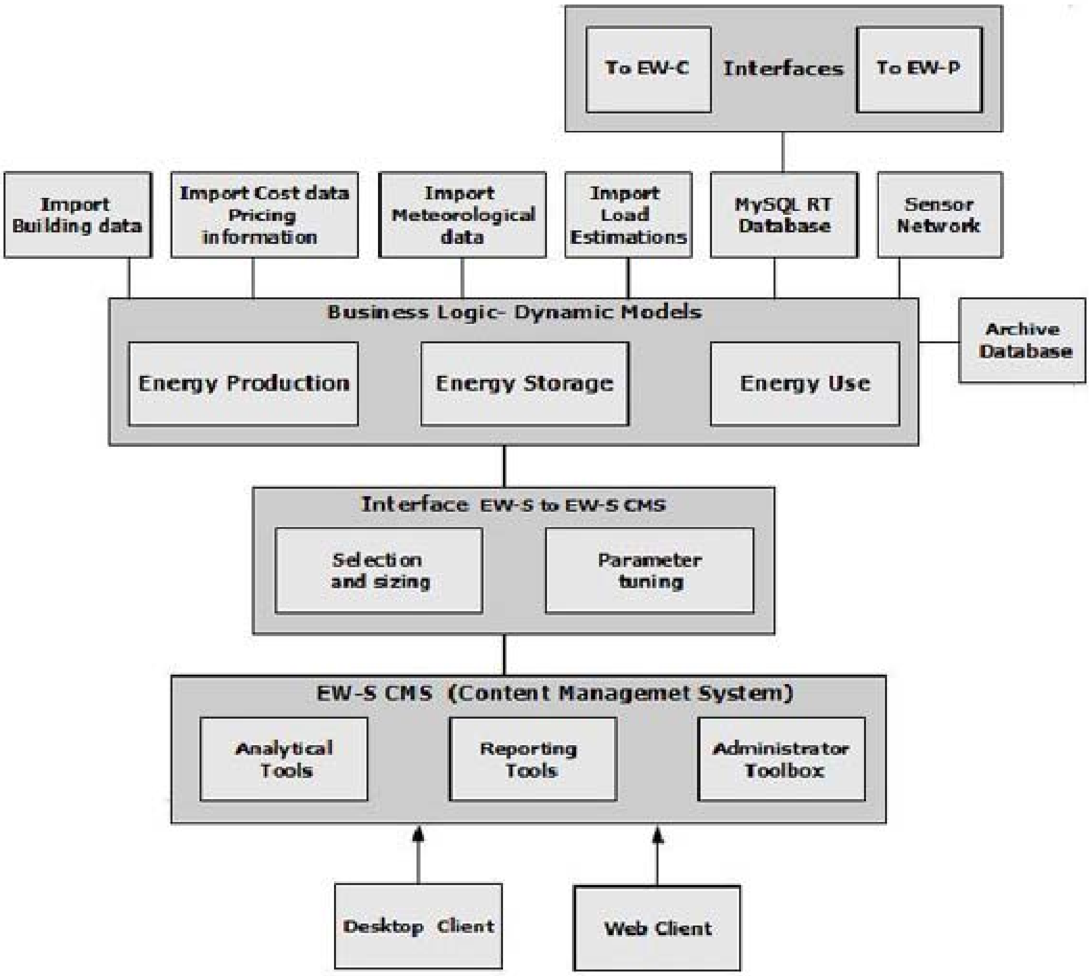
Apart from energy modules, the simulator will have modules for importing data, user interface, interface towards database and a module responsible for communication with EW-C.

The nature of communication between EW-S and EW-C has great impact on the development of the simulator. Since EW-C should manage energy flows inside a building in a real-time, there will not be enough resources to communicate directly with EW-S.

Therefore, EW-C will occasionally collect information from real-time database when needed.

EW-S will be also interfaced to EW-P, which presents higher level functionality that will support policy conformance, allowing monitoring building performance against existing policies and standards.

An archive database will also be available for storing the user profiles as well as overall communication between EW-Simulator and other modules.



Is there a link with some external databases?

Link to external web services for weather services (Meteo data)

What kind of information is displayed to the end-user (energy performance indicators, recommendations for more EE behaviour, etc.?)

Monitoring in real time the performance of producing and storage devices using:

– Sensor data

– Calculations based on EN and ISO standards of producing and storage devices

• Calculating in real-time user preferences e.g. income, ROI etc.

• Calculating in real-time CO2 savings for emissions trading schemes

- Support policy (directives, etc.) and subsidy schemes
  - – Promotion of electricity produced from renewable energy sources
  - – Support subsidy schemes with network connection for verification (Guarantee of Origin of electricity produced from RES)

Other comments:

Building renewable energy and building energy management are often considered in an isolated and therefore suboptimal way. EW provides for an integrated, though also modular, approach, bridging effectively these two broad areas

5.1.3 BuildWise

	BuildWise – Building a Sustainable Future: Wireless Sensor Networks for Energy and Environment Management in Buildings
Funding programme (E.g. European ICT, French ANR…)	Enterprise Ireland
Duration (from … to …)	From July 2010 to June 2012
Project web site	http://zuse.ucc.ie/buildwise
Coordinator (Mr, Mrs … from …)	MR. Prof. Karsten Menzel, Mr. Dr. Marcus Keane (Lead PIs)

<u>Short summary</u>:

Building accounts for 40% of Ireland's total annual energy translating to €3.5 billion (2004). The EPBD directive (effective January 2003) places an onus on all member states to rate the energy performance of all buildings in excess of 50 square meters.

Energy and environmental performance management systems for residential buildings do not exist and consist of an ad-hoc integration of wired building management systems and monitoring & targeting systems for non-residential buildings.

These systems are unsophisticated and do not easily lend themselves to cost effective retrofit or integration with other enterprise management systems.

The objective is to develop an integrated wireless energy and environmental management technology platform to support life cycle facilities management of buildings. This comprises simple context sensitive user interface to the data warehouse for facility management activities. It also supports the development of customized monitoring and targeting activities that explicitly link environmental, energy, and economic life cycle analysis. In addition a novel computer aided design tool for the design of power efficient and reliable indoor wireless sensor networks for use in Building Management Systems will be developed. The tool will also simplify the installation of such network, as it will determine the optimum positions of sensor nodes.

Which types of building are considered in the project (e.g. single houses, dwelling buildings, office buildings…)?

The project principally targets the operational life cycle of large public and private buildings such as offices, schools, hospitals and apartments complexes.

Which information is taken into account and how it is modelled with relation to the following topics? (Indicate the standards used if relevant):

Building physics (spaces, wall composition, etc.)	The ERI (Environmental Research Institute) building located at University College Cork will be considered as the place, where the BuildWise system is verified and validated. The building is a straightforward design consisting of three floors (lower ground, ground, and first floor). This long and rectangular building is unshaped and faces directly south. Areas that do not require natural daylight are located centrally within the main circulation routes. All lab rooms are located on the south facing side of the building and in the lower ground floor. The south face of the building has a higher area of glazing that other facades and the internal airflow is encouraged to distribute the passive solar gain collected here. There are large breakout spaces located here where elevated temperatures wouldn't cause occupant discomfort and the heat is gradually diffused to other areas of the building. Additionally, during warmer weather, the stairwells will act as thermal stacks to draw warm air out of the building. Occupant level windows are fitted with solar control glass. This glass has a transmission rate of 20% and limited glare (avoiding the blanket use of blinds). The building uses a concrete frame construction with cast in situ walls, floors and roof to give it a high thermal mass. The U-values of the construction are typical values under Part-L building regulations and codes. However, the infiltration rates have been given particular attention. An air-tightness test confirmed a figure of just under 5m3/h at 50 Pa.
HVAC and/or lighting equipments and other relevant devices and appliances (detail what kind of devices are considered)	Within the project scope, multiple types of energy consumption equipments and facilities will be considered, including motorized windows, valves, alarms, water pipe, electrical appliances, fans, filters, ventilator, air handling units, heat pumps, solar panel, fume cupboard, and lighting units.

Sensors (location, characteristics, configuration data…)	Sensors are specified within the IFC model, comprising CO2, fire, fume, water flow, gas, heat, humidity, light, moisture, movement, pressure, smoke, sound, temperature, etc.
Control strategies	Control of the devices is not considered within the scope of BuildWise. However, several control strategies are developed within BuildWise scope, e.g. building performance monitoring and management, which deals with the benchmark definition and its specification of building operation through data collection by the deployed wireless sensor network. The energy performance on building operation is then improved based on the identified problems, which lead to the repairing process. Another control strategy introduced for BuildWise noteworthy is the specification of sensor measurement and placement strategy. The developed Wireless Sensor Network Design Tool can determine the optimal sensor location for deployment to ensure the required communication capability.
User behaviour and preferences (e.g. occupancy and activity profiles, set-points…)	Context-sensitivity is defined and considered as a crucial system feature to be taken into account for BuildWise. In order to support and satisfy the requirements of BuildWise, four context aspects are proposed and defined for context-sensitive information management, including the role of the user, environment and condition, location, and user activity. Users are the people involved in the environment, which is to be monitored and analyzed by BuildWise system.
Weather conditions (and weather forecast if relevant)	The information of weather condition will be retrieved through the wireless sensor network installed on site.
Energy prices	The database deployed for BuildWise should contain the information about price for electricity, gas, water, and other energy form, based on the hourly or daily variation.
Others	

What communication protocols are considered and/or integrated?

Since Tyndall platform developed will be selected as the prototype for wireless sensor network used for BuildWise, several communication protocols and standards are applied and integrated into the platform. The WSN is based on 1) an existing wireless sensor network protocol (Zigbee) to support rapid prototyping of BuildWise, and 2) a simple power efficient, self-configuring protocol stack aimed at addressing potential limitations of the standard protocols.

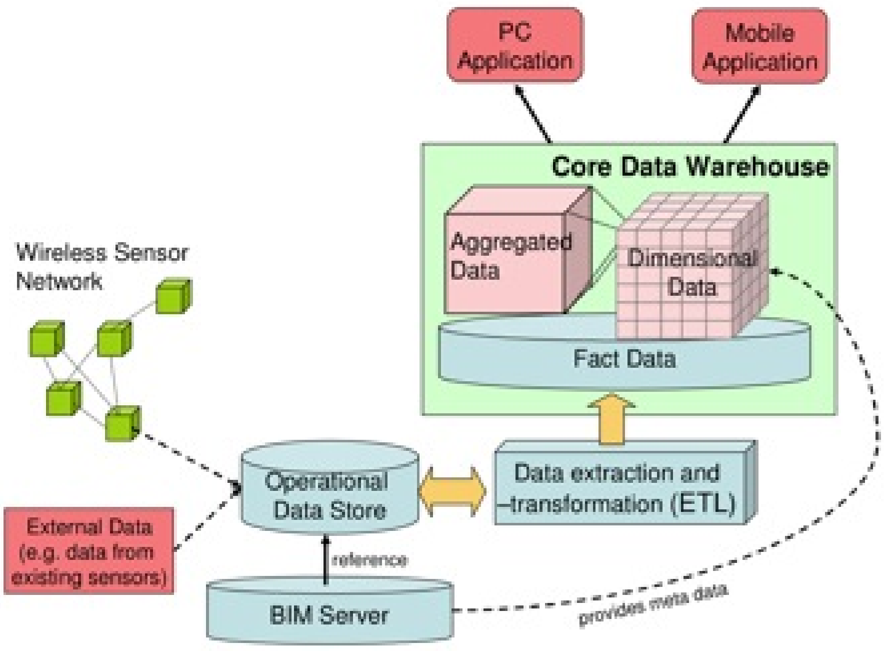
Are there one or several internal databases, and which information is stored in?

The Building Information Model is introduced to implement the acquisition and storage of data warehouses that aggregate the data to support best practise facilities management. Data warehouse shown in the figure below is a data management platform developed to support energy performance evaluation and facility management activities. Several databases will be created and developed, including:

1. Building information database: storage and management of physical building information representing basic and specific features

2. Benchmark database: Storage and management of generic performance parameters of building operations, analysis results, and control strategies.

3. Sensor measurement database: Storage and management of environment data collected by the wireless sensor network, as well as the sensors deployed in the system. E.g. Weather condition, room temperature, occupancy, etc.



Data warehouse architecture for BuildWise

Is there a link with some external databases?

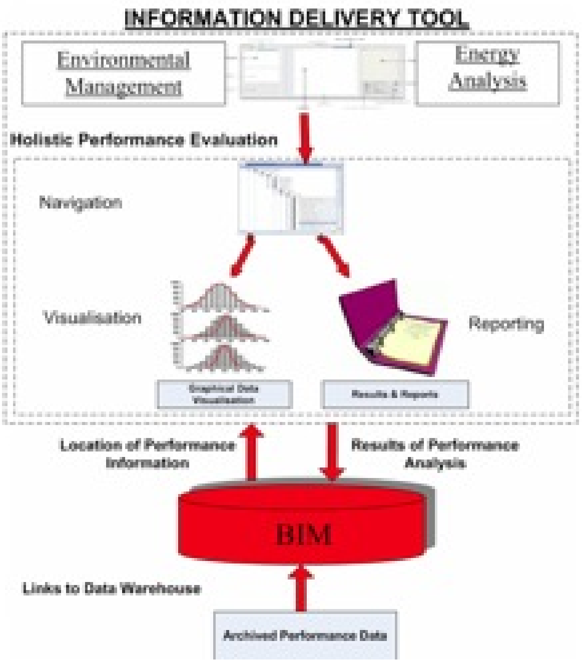
The data warehouse consists of four databases, which are interconnected with each other, they are

- Operational data store: Integration of multiple data sources
- Data extraction, transformation and loading device (ETL)
- Fact data, the primary repository for the long-term storage of historical sensor data.
- Dimensional data, grouping, configuration, and selection of fact data to help retrieve relevant multi-dimensional information.

What kind of information is displayed to the end-user (energy performance indicators, recommendations for more EE behaviour, etc.?

Two different types of user interfaces are introduced and developed within BuildWise, including

- Desktop application for Performance Evaluation: Advanced decision support in delivering building function (Maintaining the desired environment conditions for the building); Optimisation of plant and system operation when delivering building function; Optimization of energy consumption when delivering building function.



Specification for an Environmental and Energy management tool that accesses performance information through an interoperable building information model

- Mobile application for onsite facility management services, which allow for supporting on site facility management activities of the maintenance and repair staff, identifying problem and deciding on repair process.

5.1.4 ENERsip

	ENERsip – ENERgy Saving Information Platform for generation and consumption Networks
Funding programme (E.g. European ICT, French ANR…)	EU FP7, small-medium scale research project
Duration	From January 2010 to June 2012
Project web site	http://www.enersip-project.eu
Coordinator	Mrs. Leire Bastida (ESI-Tecnalia)

Short summary:

ENERsip intends to optimize energy demand, by coordinating consumption and generation. The main objective of this project is to create an adaptive, customizable and service-oriented energy monitoring and control system by active and proactively coordinating energy, communication, control, computing and construction for near real-time generation and consumption matching in residential, commercial building and neighbourhoods. ENERsip will mainly focus and provide supports on monitoring usage patterns in households, controlling energy generation in green buildings, providing suggestion on how to optimize usage, integrating energy demand and generation at neighbourhood level, and providing mechanism to integration with other energy grids. The development of an overall control architecture and the focus on open service oriented platform, implementation with SOA and Web Service technology provide a novel mechanism for energy efficiency in buildings towards end user demand, new local energy business models, and utility company service. The outcome and adoption of ENERsip will reduce overall intense economic dependence on energy, obtaining a consumption reduction of energy of 30%.

Which types of building are considered in the project (e.g. single houses, dwelling buildings, office buildings…)?

The project will be looking at energy positive[1] buildings and their neighbourhoods, including residential, industrial and commercial buildings, i.e. not only an individual building, but also an area of building grid, which will be related to a smart-grid infrastructure.

[1] The energy amount autonomously generated will be more than that consumed.

Which information is taken into account and how it is modelled with relation to the following topics? (Indicate the standards used if relevant):

Building physics (spaces, wall composition, etc.)	It targets at residential, industrial as well as commercial buildings, which incurs a high dynamic and composition of building characteristics. However, it does not consider the building physics within the project scope.
HVAC and/or lighting equipments and other relevant devices and appliances (detail what kind of devices are considered)	The consumption incurred by multiple types of household appliances will be monitored within the project scope, e.g. lamps, electrical heater, television, HVAC, and water use.
Sensors (location, characteristics, configuration data…)	Multiple types of sensors will be selected and installed for energy monitoring, including comfort sensors enabling the measurement of air quality, humidity, luminosity, movement, and temperature, power generation meter, NLIM-Non intrusive load meter to measure electricity consumption, as well as weather condition related sensors, e.g. ambient humidity, rain gauge, solar & UV irradiation, temperature probe, and wind direction and speed.
Control strategies	The consumption reduction is achieved by coordinating the actual users' needs with the in-buildings and neighbourhood positive-energy generation facilities. ADR (Automated Demand Response) points will be deployed for network communication, enabling information exchange among disparate building infrastructures. Actuator will be developed to control the individual appliance so as to achieve the overall energy consumption reduction.
User behaviour and preferences (e.g. occupancy and activity profiles, set-points…)	Within the in-home domain, users activities on appliances usage will be collected to generate a detailed consumption pattern of each user, which will be partially applied to indicate and generate energy reduction policy.
Weather conditions (and weather forecast if relevant)	Weather condition is considered as one aspect for data input for generating energy efficient solution.

Energy prices	Tariffs, real-time prices, demand response parameters, distributed system operator. For utilities companies, ENERsip platform will help them meet key business drivers, like lowering operation costs, and optimizing the whole business process through AMR (Automatic meter reading) techniques introduced.
Others	The ENERsip adopts and presents a Service-Oriented Architecture (SOA), which exposes software functions as usable, customized and advanced service, which can be discovered and invoked throughout the network. The use of SOA allows sharing of data and applications, and provides a flexible and standard mechanism to re-use the services, which facilitate collaboration between companies.

What communication protocols are considered and/or integrated?

Communication infrastructures consist of both in-building level and neighbourhood level within ENERsip architecture. In-building communication infrastructure that implements short range of wireless or wired network, standards or specifications e.g. 6LoWPAN, Z-Wave, Ethernet, Zigbee, PLC, will be considered and applied. At neighbourhood level, communication infrastructure that implements short / medium range wireless/wired networks like Wi-Fi for short range, and WiMAX, GPRS, EDGE, UMTS for long range communication, will be applied to interconnect residential meters with WAN cover area. More, the Automated Demand Response (ADR) protocol will be applied to enable to support the energy network to seamlessly communicate with each sub-infrastructure under open standards, which can be e.g. OpenADR protocol.

Are there one or several internal databases, and which information is stored in?

Apparently, database will be designed and built for real-time energy consumption monitoring, data including electricity usage, occupancy mode, HVAC usage, and water usage.

Is there a link with some external databases?

External databases will be involved within the ENERsip platform, such as data regarding day calendar, weather history and forecast.

What kind of information is displayed to the end-user (energy performance indicators, recommendations for more EE behaviour, etc.?)

Two end-users are involved in the ENERsip platform.

On one side, ENERsip platform allows energy consumers to understand their behavioural patterns on appliances through near real-time energy consumption monitoring. A detailed consumption pattern of each appliance will be generated to help make energy saving policy while maintaining desired comfort levels for house owners.

On the other side, the platform also allows utility companies (energy grid operators) to acquire data information, thus attain three key business objectives, including lowering operational costs, ensuring sustainability by monitoring key assets for instant fault reporting, and optimizing the whole process around customer management.

From a general perspective, the following information will be displayed to the end-users.

- Real-time energy consumption and generation information
- Environment condition and current tariff recommended consumption pattern
- Personalized added savings and user ecological footprint
- Ubiquitous service access

5.1.5 IntUBE

IntUBE Intelligent Use of Buildings' Energy Information	IntUBE – Intelligent Use of Energy Information
Funding programme (E.g. European ICT, French ANR…)	EU FP7 – ICT for Energy Efficiency
Duration (from … to …)	From May 2008 to April 2011
Project web site	http:\\www.intube.eu
Coordinator (Mr, Mrs … from …)	Mrs Mia Ala-Juusela (VTT)

Short summary:

IntUBE will develop an Energy Information Integration Platform, integrating energy-related ICT applications and tools which support or enable energy efficiency service provision. These include tools for measuring and analysing building energy profiles based on user comfort needs, which will offer efficient solutions for better use and management of energy use within buildings over their lifecycles. Intelligent Building Management Systems will be developed to enable real-time monitoring of energy use and optimisation. They will, through interactive visualisation of energy use, offer solutions for user comfort maximisation and energy use optimisation. Neighbourhood Management Systems will be developed to support efficient energy distribution across groups of buildings. These will support timely and optimal energy transfers from building to building based on user needs and requirements. New Business Models to make best use of the developed Management Systems will be created.

Which types of building are considered in the project (e.g. single houses, dwelling buildings, office buildings…)?

Main focus is on existing buildings, both residential and offices.

Which information is taken into account and how it is modelled with relation to the following topics? (Indicate the standards used if relevant):

Building physics (spaces, wall composition, etc.)	The IntUBE Energy Information Integration Platform (EIIP) contains 3 servers : BIM, SIM and PIM (for Building Information Model – Simulation Information Model, and Performance Information Model) The BIM server is related to the building physics (Building Information Model). Three main approaches for protocols used for the BIM aspects have been identified: IFC, gbXML & CityGML. They all have their pros and cons (looking at various aspects ranging from technicalities to current commercial software application support). It has been decided not to be limited by any of them by developing our own ontologies using future-proof semantic web technology (reusing existing IFC or gbXML interfaces where possible when integrating specific client software applications)
HVAC and/or lighting equipments and other relevant devices and appliances (detail what kind of devices are considered)	The SIM server is used for running simulations. In IntUBE, for some specific needs at the beginning of the project, Revit has been used. Eventually for the final IntUBE platform, the simulation software VABI (commercial software from VABI software), that interfaces with the BIM and PIM servers, will be used. HVAC and lighting equipments are modelled in VABI according to its terminology.
Sensors (location, characteristics, configuration data…)	Real-time data from sensors are stored in the PIM server of the IntUBE platform.
Control strategies	Some control strategies are developed within IntUBE (e.g. efficient management of blinds to optimize indoor temperature and energy consumption). The main added value of the platform comes from the smooth communication between BIM, SIM and PIM data. This allows to easily compare simulated and real-time data and therefore gives a wide spectrum for richer services and functionalities.

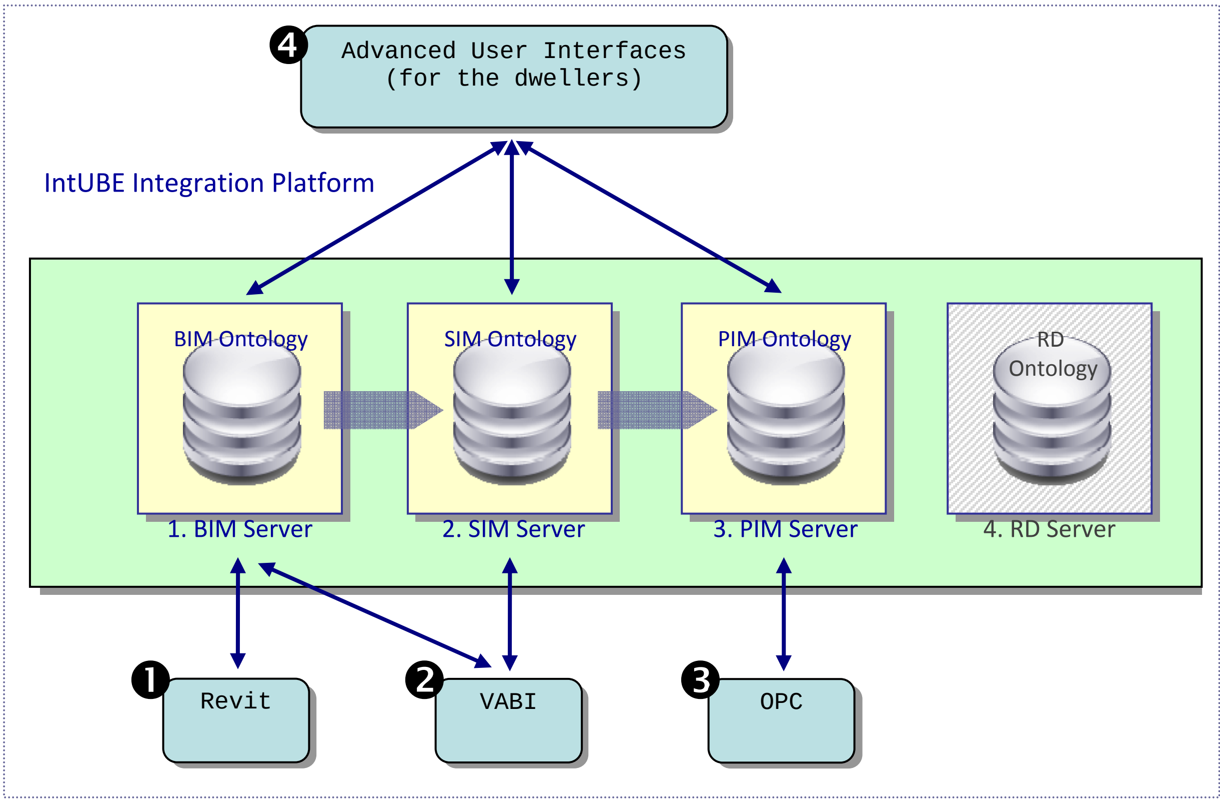
User behaviour and preferences (e.g. occupancy and activity profiles, set-points…)	The main data considered for the user behaviour and preferences are his presence at home and the set temperature. As an example of rich functionality using the IntUBE platform (and its 3 servers), a user interface to influence user behaviour will be demonstrated in the social housing pilot building in Spain. This user interface will not only suggest actions to the dweller to reduce energy consumption, but it will also predict its impact thanks to the SIM server. Then, the real-time data obtained through the PIM server can be compared to this prediction, and the simulation engine can be refined accordingly.
Weather conditions (and weather forecast if relevant)	Use of external web services providing hourly data (temperature, humidity, cloud cover, wind direction and speed, etc.), given as an input to the SIM server.
Energy prices	An average price is considered for each type of energy (no variation in time).
Others	

What communication protocols are considered and/or integrated?

The communication protocol used for communication between sensors and the PIM server is mainly ZigBee.

Are there one or several internal databases, and which information is stored in?

As stated before, 3 servers are included in the IntUBE platform: BIM, SIM and PIM. A 4th server containing Reference Data (RD server) was initially planned but will eventually not be supported for the implementation (see picture below).



Is there a link with some external databases?

Link to external web services (e.g. weather services)

What kind of information is displayed to the end-user (energy performance indicators, recommendations for more EE behaviour, etc.?)

For the demo scenario in Spain, the information that will be provided is:

- Weather forecast (used for simulation and as an attractive factor for the dweller for using/looking at the application).
- Advice for opening / closing the blinds and opening / closing the windows when leaving the apartment in the morning. The interface also displays the estimated impact (on indoor temperature & heat consumption) if the proposed action is taken into account by the dweller.
- At the end of the day, the user interface displays simultaneously the simulated data and the actual recorded temperature and consumptions, and provides information to the dweller on achieved savings (if any).

5.1.6 ITOBO

	ITOBO – Information and Communication Technology for Sustainable and Optimised Building Operation
Funding programme (E.g. European ICT, French ANR…)	Science Foundation Ireland – 07/SRC/I1170, Strategic Research Cluster
Duration (from … to …)	From 01.12.2010 to 30.11.2012
Project web site	http://zuse.ucc.ie/itobo
Coordinator (Mr, Mrs … from …)	Mr. Prof. Eugene C. Freuder & Mr. Dr. Ken Brown (University College Cork)

Short summary:

ITOBO will undertake research in information and communication technology that will enable us to develop a holistic, methodological framework for life cycle oriented information management and decision support in the construction and energy management sectors. The domain specific goal of ITOBO is to develop an anticipating smart building that operates on an energy efficient and user-friendly basis while reducing its maintenance cost.

ITOBO will contribute to the holistic development of Network Enabled Building Management System through 1) Hardware Design 2) Wireless Systems integration and network protocol development 3) Constrained based decision support 4) N-dimensional Information Modelling 5) Facilities Management with access to sophisticated built infrastructure cooperation with standardisation bodies. Thus, ITOBO will

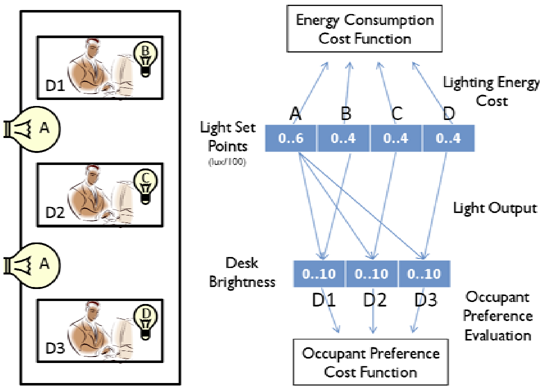
- Enhance the management of large-scale, complex networks, services, and mobile users through introducing new network and management protocols.
- Develop frameworks and algorithms to support mixed-initiative configuration for energy efficient buildings.
- Design a system architecture that will support scale-free composition of service coalitions.
- Support seamless end-to-end network composition and service operation through sensor and RFID hardware with dynamic features.

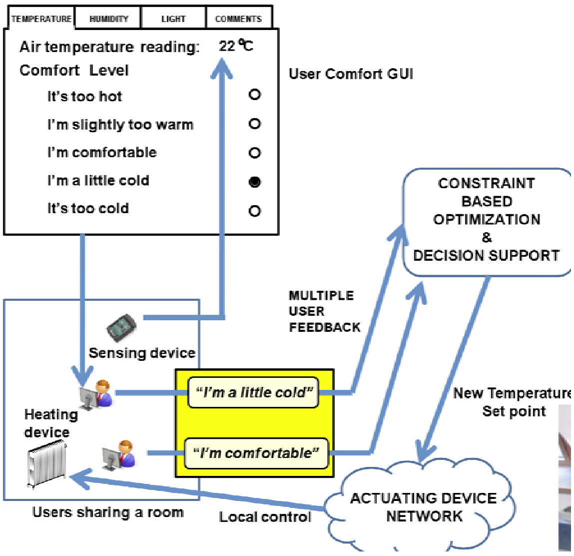
Which types of building are considered in the project (e.g. single houses, dwelling buildings, office buildings…)?

Multiple types of buildings are considered within ITOBO scope, including commercial buildings, industrial buildings as well as residential buildings.

Which information is taken into account and how it is modelled with relation to the following topics? (Indicate the standards used if relevant):

Building physics (spaces, wall composition, etc.)	ITOBO incorporates itself with a holistic, consistent, and integrated Building Information Model (BIM), which includes Building Product Model (IFC), Building Performance Model (IFCext), and Building Process Model (IFC)
HVAC and/or lighting equipments and other relevant devices and appliances (detail what kind of devices are considered)	As all the forms of energy consumption resulted in building operation are considered to be measured and optimized, multiple forms of appliance and device are relevant with the project scope, comprising light equipment, HVAC equipment, as well as other electrical appliances.
Sensors (location, characteristics, configuration data…)	Miniature Tyndall motes that integrate with multiple sensors will be used in the monitoring process for data measurement, which involves light level, CO2 intensity, indoor temperature, ambient temperature, air relative humidity, electricity consumption, light electricity consumption, door or windows status, water flow rate in the pipe, and water flow temperature. At the same time, it is noteworthy that a Wireless Sensor Planning Tool for is designed and developed, the purpose of which is to facilitate, visualize and optimize wireless device deployment.

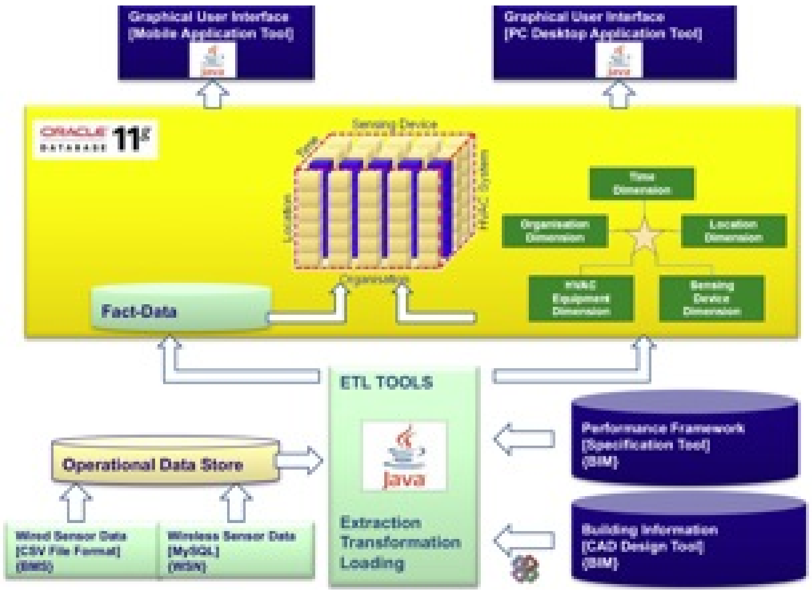
Control strategies	Towards energy consumption efficiency in buildings, ITOBO proposes a combination of sensor and actuation network within system operation, which allows the control and management for monitored appliances, devices, and facilities, based on the developed constraint based optimization and decision support framework. A primary example is preference based lighting level control, which concerns the lighting devices control with information of user comfort, occupancy, and ambient light.  *Customized optimized lighting control of ITOBO*

User behaviour and preferences (e.g. occupancy and activity profiles, set-points…)	ITOBO focuses on energy consumption efficiency within the building domain without penalizing the user comfort. Thus, user behaviour and preference are of critical importance for energy usage optimization process. One leading example observed in the ITOBO is the temperature control scenario, where multiple user feedbacks are considered as the data input for constraint based optimization and decision support to generate optimized energy policy.  *Constraint based optimization and decision support of ITOBO*
Weather conditions (and weather forecast if relevant)	The monitoring process of energy consumption takes place solely within the building domain, where the deployed wireless sensor network will perform data measurement. Therefore, ITOBO will not consider weather condition and forecast as inputs relevant with the project context.
Energy prices	ITOBO focuses on real energy consumption that takes place at building domains. Thus, energy price variation will not be considered as input parameter. However, energy cost might be involved in the operation of constraint based optimization and decision support system
Others	

What communication protocols are considered and/or integrated?

Since power efficiency and energy awareness are addressed within the overall project objectives, power efficiency standard for wireless sensor network will be adopted and applied into the sensor networking. In the context of ITOBO, the primary objective is to improve IEEE 802.15.4 standard, which is the currently most significant commercial adopted protocol stack for sensor networks. MeshMAC protocol is applied with the multiple purposes, including improving the flexibility and robustness of the mesh topology, distributed computation of the packet scheduling on large scale networks, improving longevity of overall network lifetime, and enabling energy efficient WSN routing.

Are there one or several internal databases, and which information is stored in?



Data aggregation & integration of ITOBO

As shown in the figure above, several databases are presented and illustrated. The BIM model that contains building information and performance framework, operational data store which contains both wired and wireless sensor data, as well as the fact data that transferred and processed by Extraction and Transformation Loading engine.

Is there a link with some external databases?

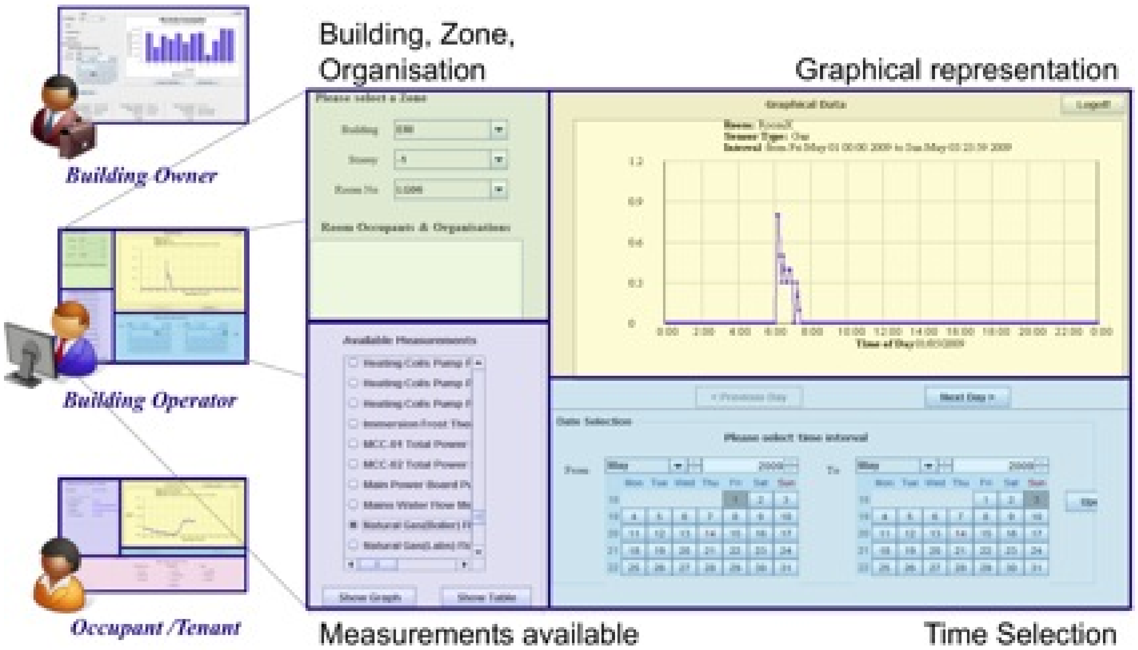
No.

What kind of information is displayed to the end-user (energy performance indicators, recommendations for more EE behaviour)

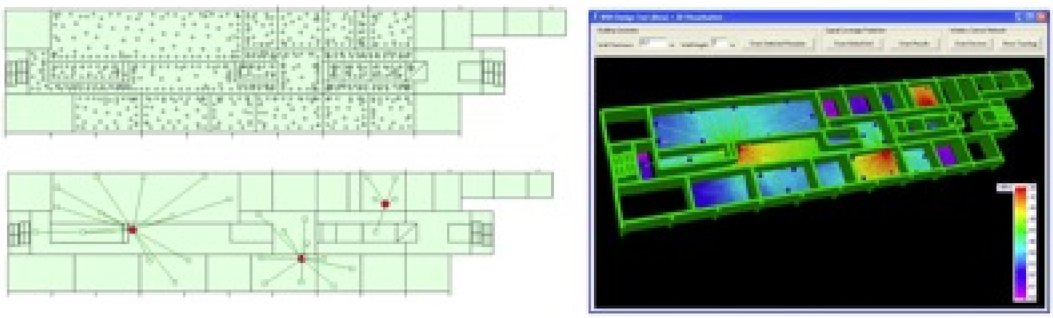
ITOBO graphical interfaces are designed and developed in the form of both mobile and desktop platforms. Multiple end-user interfaces are created for different stakeholders such as

building owners, building operator, and occupant. The graphical interfaces shown in the figure below allow them to monitor energy consumption based on the parameter selections, e.g. building position, type, organisation, measurement parameter, and time period.
Another user interface applied in ITOBO is design interface, e.g. Wireless Sensor Network Design Tool used for sensor node placement within building areas shown in the figure below, the features of which include:

- Predefined sensor locations
- Optimisation of data link positions for reliable communications between sink and sensors
- Network topology currently consider single hop, and star topologies
- Visualization of positions and radio link characteristics



Graphical user interface used in ITOBO



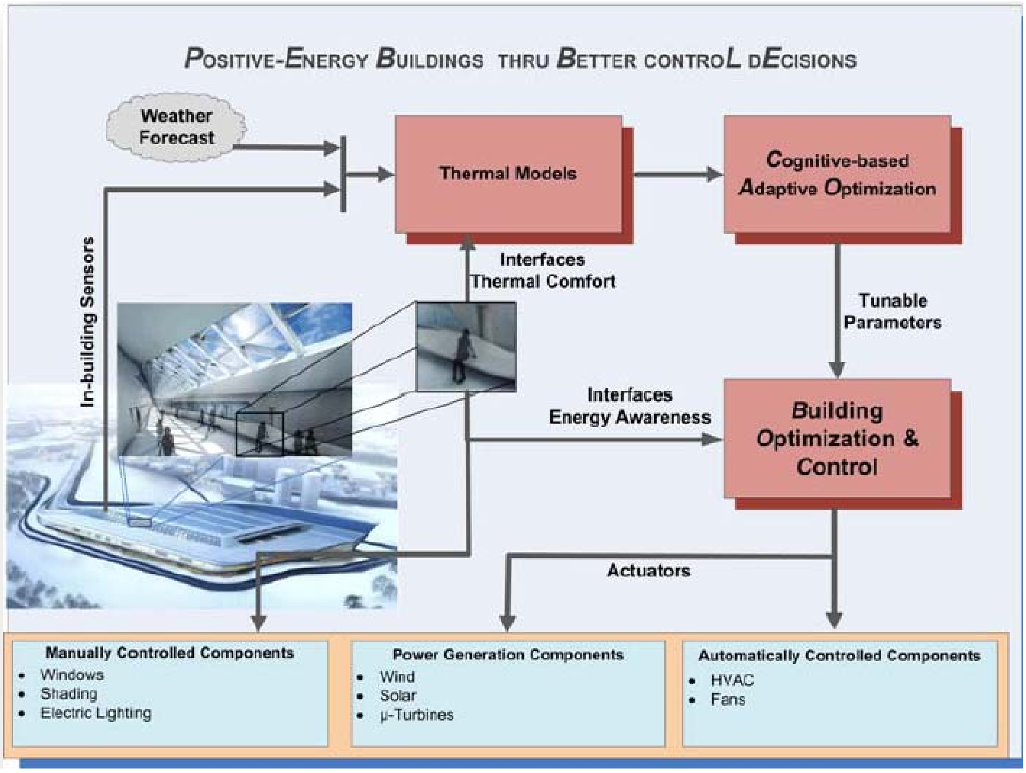
Wireless Sensor Network Design Tool applied in ITOBO

5.1.7 PEBBLE

	PEBBLE - Positive-Energy Buildings is attained thru Better ControL dEcisions
Funding programme (E.g. European ICT, French ANR…)	EU FP7 ICT for Energy Efficiency
Duration (from … to …)	From January 2010 to December 2012
Project web site	http://www.pebble-fp7.eu/
Coordinator (Mr, Mrs … from …)	Mr Dimitrios V. Rovas (Technical University of Crete)

Short summary:

PEBBLE project proposes a control and optimization ICT methodology that combines model-based predictive control and cognitive-based adaptive optimization for energy efficiency. There are three essential ingredients to the PEBBLE system: thermal simulation models, that are accurate representations of the building and its subsystems; sensors, actuators, and user interfaces to facilitate communication between the physical and simulation layers; and generic control and optimization tools that use the sensor inputs and the thermal models to take intelligent decisions. Building occupants have a dual sensor-actuator role in the PEBBLE framework: communicating their thermal comfort preferences to the PEBBLE system, and receiving information for enhancing their energy-awareness. The PEBBLE system will be demonstrated and evaluated in three located at different places across Europe.



Which types of building are considered in the project (e.g. single houses, dwelling buildings, office buildings…)?

Existing and new buildings are considered, but focused on new buildings (residential and office)

Which information is taken into account and how it is modelled with relation to the following topics? (Indicate the standards used if relevant):

Building physics (spaces, wall composition, etc.)	Thermal models for the building that: • at the simulation level, are accurate and efficient representations of the building; • incorporate all passive and active building subsystems, as well as all energy-generation elements; • and, given local weather data and/or weather prediction models: • can be used to predict thermal response, energy requirements, and estimate thermal comfort.

HVAC and/or lighting equipments and other relevant devices and appliances (detail what kind of devices are considered)	**Energy sourcing** – Solar/ thermal – Solar/ PV – Wind – Geothermal – Multiple electricity suppliers – Locally produced electric energy • **Energy store** – Batteries – Hot Water – Hydrogen/fuel cell – Phase changing materials • **Energy use** – local electricity loads – use Water heating – space Heating/Cooling – selling to the grid and district
Sensors (location, characteristics, configuration data…)	Low power and wireless sensors that facilitate information interchange between the physical and the simulation layers.

Control strategies	Efficient and robust Building Optimization and Control tools, that: • use sensor inputs and thermal models to evaluate potential scenarios; • take in (almost) real-time, decisions for the operation of the building subsystems; • operate with the goal of *maximization of the NEB* while retaining building conditions at user-acceptable comfort levels.
User behaviour and preferences (e.g. occupancy and activity profiles, set-points…)	Thermal comfort preferences
Weather conditions (and weather forecast if relevant)	Use of external web services providing hourly data (temperature, humidity, cloud cover, wind direction and speed, etc.)
Energy prices	The GCEI (Generation - Consumption Effectiveness Index) sets a common energy or cost based denominator allowing the system to compare various energy-saving solutions.
Others	

What communication protocols are considered and/or integrated?

Interoperability is achieved through the use of wireless, interoperable and scalable communication technologies, capable of utilizing components from different suppliers.

Are there one or several internal databases, and which information is stored in?

No information available.

Is there a link with some external databases?

Link to external web services (e.g. weather services)

What kind of information is displayed to the end-user (energy performance indicators, recommendations for more EE behaviour, etc.?)

Building occupants have a dual sensor-actuator role in the PEBBLE framework: communicating their thermal comfort preferences to the PEBBLE system, and in return the PEBBLE system returns information with the goal of enhancing energy-awareness of the users.

5.1.8 SmartCoDe

	SmartCoDe (Smart Control of Demand for Consumption and Supply to enable balanced, energy-positive building and neighbourhoods)
Funding programme (E.g. European ICT, French ANR…)	European Union 7th Framework STREP Programme
Duration (from … to …)	From January 2010 to December 2012
Project web site	http:// www.fp7-smartcode.eu
Coordinator (Mr, Mrs … from …)	Mr. Peter Neumann (Edacentrum GmbH, Germany)

Short summary:

Future buildings and neighbourhoods are expected to combine a manifold of Energy using Products ("EuP") ranging from electrical lighting to HVAC with locally available renewable energies (e.g. Solar, wind) and with locally available storages (e.g. car batteries). An intelligent management of energy in such a local grid would enable customers to participate in the energy market and even contribute to the stability of the power grid. The problem is that such an energy management requires fine-grained infrastructure and expensive hardware. To date, this limits applicability of energy management to large consumers in the industrial and commercial parts. The objective of SmartCoDe is to:

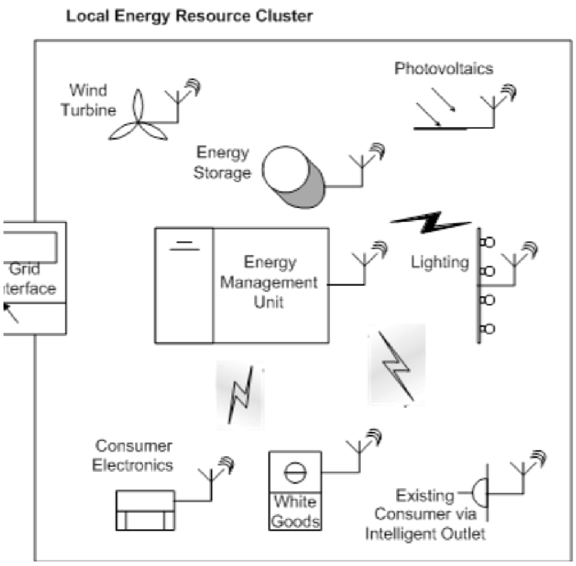
- Raise energy awareness, enabling the end user to minimize the energy consumption
- Reduce energy consumption in small buildings via intelligent and secure Energy Management
- Reduce peaks in end-user energy consumption / supply curve
- Enable an increasing share of renewable energy sources
- Developing an inexpensive hardware/software solution to implement in existing energy consuming components with the ability of communication and remote control

Which types of building are considered in the project (e.g. single houses, dwelling buildings, office buildings…)?

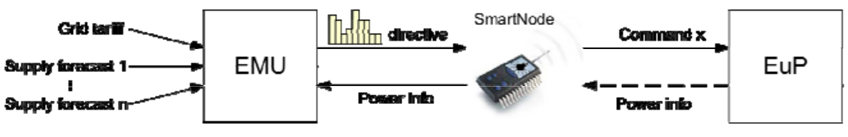
The scope of SmartCoDe is targeting at private and small commercial buildings, and their neighbourhoods, namely local grids.

Which information is taken into account and how it is modelled with relation to the following topics? (Indicate the standards used if relevant):

<table>
<tr><td>Building physics (spaces, wall composition, etc.)</td><td>As far as the information related to SmartCoDe disseminates, neither building information models nor building physics have been introduced, designed or developed for building energy management.</td></tr>
<tr><td>HVAC and/or lighting equipments and other relevant devices and appliances (detail what kind of devices are considered)</td><td>EuP (Energy using product) and LEP (Local energy provider). All the household appliances and devices that consume energy, and the equipments for energy storage. For energy consumption, electricity and HVAC consuming appliances are considered, which include heating boiler, wash machine, fridge, luminaries, cooking oven, electrical outlets, heating pump. For energy generation, equipments such as solar panels, photovoltaic panels, wind turbine, and energy storage batteries, etc. is considered.



Local energy generation and consumption cluster</td></tr>
</table>

Sensors (location, characteristics, configuration data…)	Multiple sensors that measure room temperature, humidity, wind speed direction, solar radiation, solar temperature, electricity outlet meter, gas meter, water flow meter and luminance are considered within the scope of SmartCoDe. For communication purpose, transceivers that incorporate with optimized and improved standard will be analyzed and applied. The transceiver selected for the first version of the model belongs to the Atmel AT86RF230 family, which operates in the 2.4 GHz band.
Control strategies	The basic control strategies to energy management in SmartCoDe can be described as 1) The EMU (Energy management unit) gets information from power supply (e.g. grid tariff or supply forecast) 2) It gets information on power consumption from local database 3) It controls the EuPs (Energy using products) in the network using this information with the goal of energy saving, energy cost reduction and energy load balancing. A decentralized approach is thus incorporated into the system architecture due to multiple advantages, including less communication overhead, robustness to communication breakdown or EMU crash, distributed computation for energy saving, and local control and management possibility  *A decentralized approach for SmartCoDe operation*
User behaviour and preferences (e.g. occupancy and activity profiles, set-points…)	SmartCoDe considers user demand as the data inputs for EMU (Energy management unit). Therefore, it does concern user activity information, especially occupancy or presence detection used for energy management process.
Weather conditions (and weather forecast if relevant)	Weather condition and forecast information will be considered into EMU (Energy management unit).
Energy prices	Grid tariff, especially energy generation forecasting, will be considered as the data input for the overall energy management unit used by SmartCoDe. It is noteworthy to mention, that software based energy generation forecast approach is introduced to analyze e.g. wind speed to forecast energy generation of wind turbine.
Others	

What communication protocols are considered and/or integrated?

For wired communication, Modbus, RS485, RS232 Mbus, and etc. For wireless communication, SmartCoDe has analyzed multiple available and commercial Zigbee stacks that are going to be selected for implementation. NXP/Jennic JN5148 has been confirmed for SmartCoDe demonstrator due to the competing features versus other product providers.

Are there one or several internal databases, and which information is stored in?

Multiple forms of energy consumption are the primary data sources that have to be stored in the database. More, energy generation and storage information are also the other data sources that have to be stored in the database.

Is there a link with some external databases?

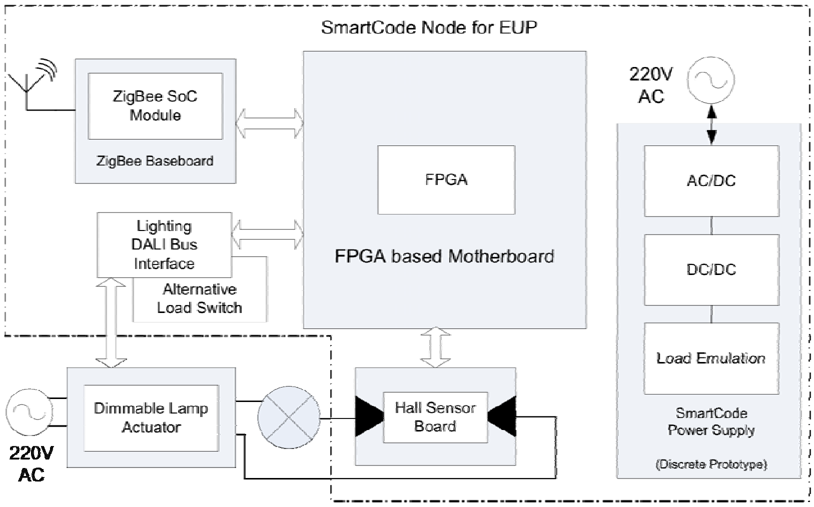
No.

What kind of information is displayed to the end-user (energy performance indicators, recommendations for more EE behaviour, etc.?)

The display of management data, energy data analysis, and forecasting data will be provided to the end-users. It is also provisioned, that interface to global energy provider, and that of energy consumption driven by the global availability of energy will be provided to the end-users.

Other comments:

An overview of the initial hardware demonstrator of SmartCoDe node is shown in the following figure. The actuator will be a dimmable lamp from Tridonic Adco and connects to the SmartCoDe node via the standardized DALI Bus Interface. The SmartCoDe node also monitors the actual power consumption with Hall Sensor Board. The wireless Zigbee interface is based on a Jennic / NXP Core Module that connects to the FPGA, where power measurement components are integrated.



Hardware demonstrator setup

5.1.9 BeyWatch

	BeyWatch - Building Energy Watcher
Funding programme (E.g. European ICT, French ANR…)	EU FP7 – ICT for environmental management and energy efficiency
Duration (from … to …)	From December 2008 to June 2011
Project web site	http://www.beywatch.eu/index.php
Coordinator (Mr, Mrs … from …)	Mr Pierre Y. Plaza Tron (Telefonica I+D)

<u>Short summary</u>:

BeyWatch will develop an energy-aware and user-centric solution, able to provide intelligent energy monitoring/control and power demand balancing at home/building & neighbourhood level. The main objectives of the project are to save energy by making consumers aware of their energy expenses and enabling them to intelligently control the home energy consumption. The electricity energy will be efficiently distributed at neighbouring level. Moreover BeyWatch aims to influence and improve the relationship between the utility, the electricity consumer and the home electricity producer, through Business Support Sofware. There are two main parts: BeyWatch Agent, which is in charge of single home or building, and BeyWatch Supervisor, which manages the energy consumption and power demand at neighbourhood.

Which types of building are considered in the project (e.g. single houses, dwelling buildings, office buildings…)?

Main focus is on existing_residential buildings, at local level, such as flat, home, office or single-building, as well as for larger geographical regions, such as large buildings, squares and neighbours.

Which information is taken into account and how it is modelled with relation to the following topics? (Indicate the standards used if relevant):

Building physics (spaces, wall composition, etc.)	The house walls and furniture are used as thermal energy storage.

HVAC and/or lighting equipments and other relevant devices and appliances (detail what kind of devices are considered)	HVAC Lighting Hot water tank CPS (Combined Photovoltaic and Solar system) Wet Appliance: Washing Machine, Dishwasher. Cold Appliance: Fridge, Freezer. Other appliances: Drier, Oven Consumer and Electronic and Communications devices: TV, DVD players. Other plugged devices
Sensors (location, characteristics, configuration data…)	The BeyWatch GUI is designed as a framework which includes encapsulated software modules called BeyWidgets. A BeyWidget is an individual application within the BeyWatch system which generates an interface to a specific functionality, covering a specific necessity. A BeyWidget is composed by four parts: • Models: contains the PHP files modelling the BeyWidget. • Views: contains the GUI of this BeyWidget, that is, files in PHP with the HTML content, CSS, JavaScript, icons… • Controllers: contains the PHP files that controlling it. • Descriptor: written in XML, contains the BeyWidget metadata
Control strategies	The software architecture of the Energy Management System will be based on APIs offered via Web Services. The GUI&BSS will have two Front End main views: Electricity Provider Front End End User Front end

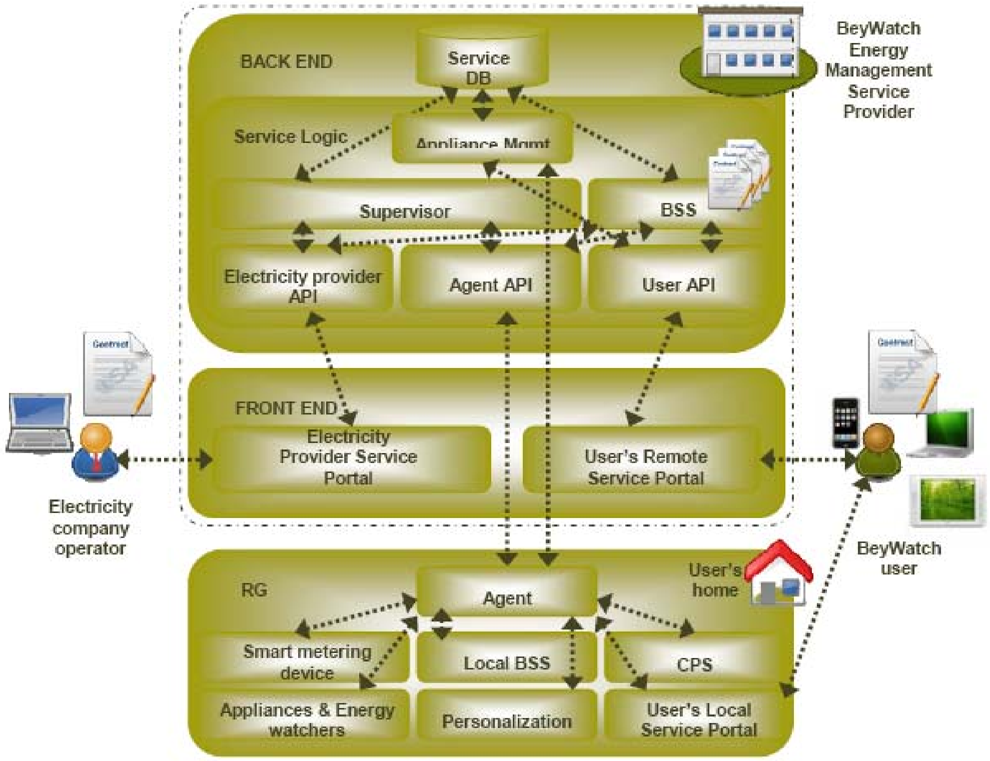
User behaviour and preferences (e.g. occupancy and activity profiles, set-points…)	End User Front-End • Service registration, information about different utilities, types of contract, tariffs, etc. • Multi-user ability for different family members depending on needs • Agent Front End – User required inputs • Devices and users profiling • Appliances and devices management, consumption and CO2 emissions information.
Weather conditions (and weather forecast if relevant)	Use of external web services providing weather forecast
Energy prices	Electricity Provider Front-End • Service registration • Contract alternatives specification (tariffs, possibility of buying user's electricity, etc) • Statistics and information about each contract type users, consumptions (instantaneous and historic) • Peak control graphics • Notifications/commands section (to Supervisor).
Others	

What communication protocols are considered and/or integrated?

Due to specific markets constraints for each manufacturer, the implementation will mix the following solutions: WiFi, 6loWPAN (IPv6, IPSO), ZigBee, PLC (specific solution or Homeplug Command and Control), etc.
Besides this, HTTP(S) protocol is used (Web services).

Are there one or several internal databases, and which information is stored in?

The Agent logic will be implemented as a piece of software manageable using the OSGi framework (a software bundle). This "Agent bundle" will rely on the services of a local Relational Database Management System (RDBMS) which is to be provided by the MySQL database (link #2 in figure below) to store and retrieve various kinds of data that are important to its algorithmic logic or for later (statistical) reporting to the Supervisor.



Is there a link with some external databases?

BeyWidgets implement communication with external systems across a defined API for these external services. This information produces an added-value service that helps to users to know if external factors have affected to the consumption profile in this time period (e.g. weather services)

What kind of information is displayed to the end-user (energy performance indicators, recommendations for more EE behaviour, etc.?)

Apart from the BeyWidgets dedicated to each specific appliance, the user will be able to operate with business-related tools.

The users could have access to:

• Their current and aggregated consumption data, for each one of their appliances.

• A tool to optimize their tariffs and get the best possible alternatives for their consumption profiles.

• The possibility to share their tariffs or profile with other users of BeyWatch System.

• A way to have access to green appliances interoperable with BeyWatch technology.

• Comparisons between current and past aggregated consumptions.

• In their role as an energy generator, a prosumer tariffs optimizer.

• A competition system by which they will be motivated to be as efficient as possible.

• Costs limitation tools.

5.1.10 BeAware

	BeAware – Boosting energy Awareness with adaptive real-time environments
Funding programme (E.g. European ICT, French ANR…)	EU FP7 – ICT for Energy Efficiency
Duration (from … to …)	From May 2008 to April 2011
Project web site	http://www.energyawareness.eu/beaware
Coordinator (Mr, Mrs … from …)	Mr Giulio Jacucci (Helsinki University of Technology, TKK)

<u>Short summary</u> (10 lines max):

BeAware has created a solution to motivate and empower citizens to become active energy consumers, by offering them the opportunity to raise awareness of their own power consumption in real time. EnergyLife (the developed platform) includes a mobile phone application and an ambient interface that makes use of the home lighting and lamps as a means to communicate with the user. By combining novel yet advanced technologies such as wireless sensor networks, service-oriented architectures, and ambient and mobile interfaces, residential energy consumers can be targeted effectively. Energy Life is a service platform that will ensure scalable, deployable innovation in the consumer power market, enabling a service to:

- Monitor consumption and understand the effects of different choices
- Share consumption practices in groups and communities – thus creating opportunities for learning better practices or incentives for adopting virtuous behaviours.

The net power energy saving at home is expected to be around 15%. The first integrated prototype, consisting of a mobile application and an ambient interface, will be tested in eight households during the spring 2010. Four households are placed in Italy (Catania) and four in Finland (Helsinki). In each site, studies will be carried out in a home environment. The research is highly multidisciplinary and combines a variety of approaches in the area of user studies, user-centred design and evaluation.

Which types of building are considered in the project (e.g. single houses, dwelling buildings, office buildings…)?

The project focuses on residential buildings.

Which information is taken into account and how it is modelled with relation to the following topics? (Indicate the standards used if relevant):

Building physics (spaces, wall composition, etc.)	This kind of information is not considered in the project.
HVAC and/or lighting equipments and other relevant devices and appliances (detail what kind of devices are considered)	Sensors measure and help regulate the power consumption of household appliances like lights, oven, washing machine, TV set, refrigerator and computers.
Sensors (location, characteristics, configuration data…)	BeAware is developing innovative wireless sensors, which allow measuring the power consumption of individual appliances in near-to-real-time, and identify the type of appliance (for example oven, refrigerator and water boiler) and its specific fingerprint with low energy consumption.
Control strategies	N/A
User behaviour and preferences (e.g. occupancy and activity profiles, set-points…)	User energy awareness is measured through the evolution of the household energy consumption. It is anticipated that most households could cut their bills by 15 per cent if they were made aware of their energy consumption.
Weather conditions (and weather forecast if relevant)	Use of external web services providing hourly data (temperature, humidity, cloud cover, wind direction and speed, etc.), given as an input to the SIM server.
Energy prices	Energy prices are considered for the estimation of the energy bill (and the savings through eco-behaviours).
Others	

What communication protocols are considered and/or integrated?

The technology layers developed (wireless sensors, web service platform, mobile and ambient interfaces) are “open”, which paves the way for higher interoperability with technology components and layers developed by other vendors.

Are there one or several internal databases, and which information is stored in?

This information is not available.

Is there a link with some external databases?

Weather web services.

What kind of information is displayed to the end-user (energy performance indicators, recommendations for more EE behaviour, etc.?)

To support energy awareness increase, BeAware includes:

1. visualization of detailed data attained through pervasive sensing,
2. aesthetic displays using novel interfaces, and
3. theoretically informed implementation of feedback that address behaviour change.

The problem of these three distinct streams is that they tackle separately three aspects that should be addressed at the same time respectively: detailed data sensing, engagement through novel user interfaces, and psychological and anthropological approaches to behaviour change. BeAware aims at bridging these three areas by proposing a system that addresses detailed information provision, engagement through novel UI and theoretically informed feedback strategies.

Other comments:

1. A common problem when working on energy consumption indicators is obtaining the baseline. Simulation could help in obtaining this baseline, according to day light duration for instance.

2. The EnergyLife application client is a Web application adapted for touch screen enabled mobile devices. The current platforms are iPhone and iPod Touch, since they support the new web standards (HTML5, CSS3 with 3D manipulation) used in the application. The application client communicates with a server that delivers the data present in the application. The server is connected wirelessly via a base station to a variety of plug sensors in the households that send instantaneous power continuously with a lag of 1 to 2 minutes.

The carousel is part of an Energy Awareness application that displays the detailed power consumption for each appliance (see figure). Therefore each card in the carousel represents an appliance or electrical device in the house. In addition, the card can be tapped on and turned to offer additional information and functionality for the given appliance.

5.1.11 DEHEMS

DEHEMS	DEHEMS – Digital Environmental Home Energy Management System.
Funding programme (E.g. European ICT, French ANR…)	EU FP7 ICT for Energy Efficiency
Duration (from … to …)	From June 2008 to November 2010
Project web site	http://www.dehems.eu/
Coordinator (Mr, Mrs … from …)	Mr David Carter (Manchester City Council)

<u>Short summary</u>

The objective of the EU-funded Project DEHEMS is to improve the state-of–the art in intelligent meters, moving from 'energy input models' - which monitor the level of energy used - to an ‘energy performance model’ which also looks at how the energy is used.

The project applies sensor data in areas such as household heat loss and appliance performance, as well as energy usage monitoring to give real-time information on emissions and the energy performance of appliances and services. Users will be able to make changes to appliances/services remotely from their mobile phone or PC and will provide specific energy efficiency recommendations for the household. This will allow a personalised approach on climate change, thus supporting new policy actions such as the "Personal Carbon Allowances" and increased localised generation and distribution of energy.

Which types of building are considered in the project (e.g. single houses, dwelling buildings, office buildings…)?

Focus on existing residential buildings. DEHEMS introduces the concept of living labs. They are not traditional research labs or test beds (functionality and usability tests). They are an “innovation platform” that brings together and involves end-users, researchers, industrialists, policy makers, and so on at the earlier stage of the innovation process.

Which information is taken into account and how it is modelled with relation to the following topics? (Indicate the standards used if relevant):

Building physics (spaces, wall composition, etc.)	–

HVAC and/or lighting equipments and other relevant devices and appliances (detail what kind of devices are considered)	Household appliances: • Fridge • Washing Machine • Dishwasher
Sensors (location, characteristics, configuration data…)	Each household sends the readings of their 10 sensors to the gateway (one per household). Collected data is submitted to a central system, the aggregator, one for each large region, The Transmitter and Sensor Jaw The transmitter and sensor jaw does not require out any electrical wiring. It is connected to the electricity supply to by clipping around the intake supply to your property. Data Collector The data collector stores your energy usage and sends it to your dashboard on the internet.
Control strategies	DEHEMS enables real-time analysis of electricity usage for households, or even for individual appliances, helping people make better decisions about energy efficiency in the home
User behaviour and preferences (e.g. occupancy and activity profiles, set-points…)	Recollected data will be classified as following: • Positive impact on energy use • Negative impact on energy use • Good/Best energy user • Bad/Worst energy user • Event detection: start of use, end of use, change of state
Weather conditions (and weather forecast if relevant)	Temperature, humidity, air quality, natural light / artificial, etc.
Energy prices	N/A
Others	

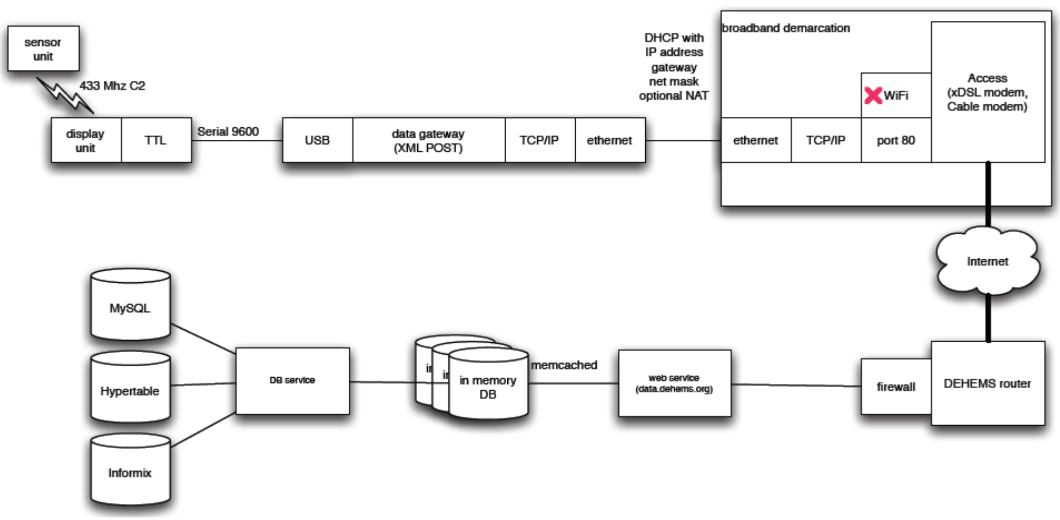
What communication protocols are considered and/or integrated?

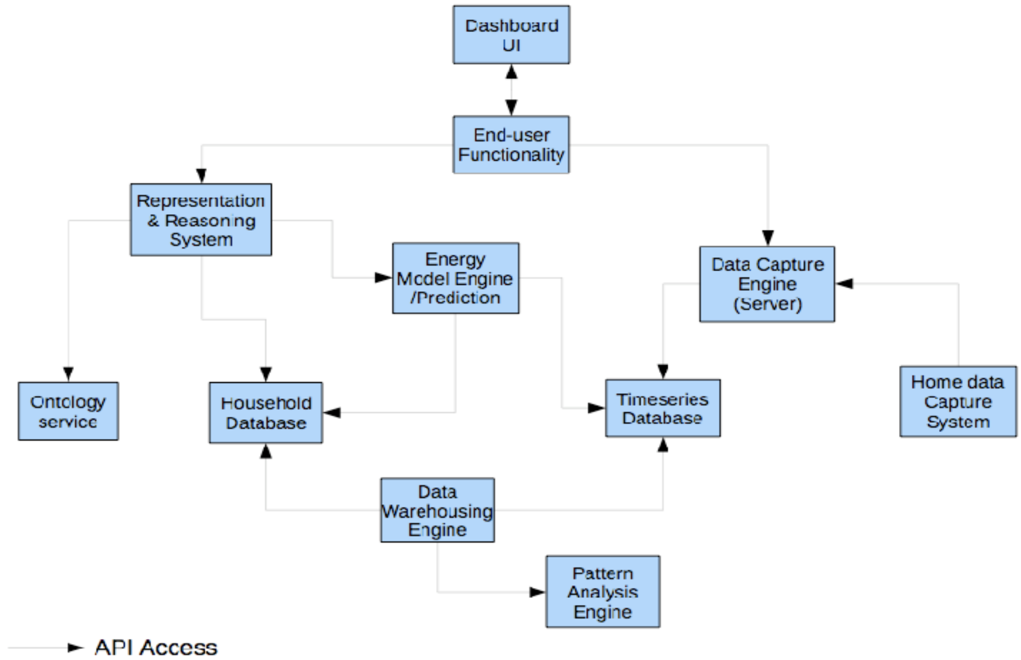
433MHz packet radio, Powerline, Bluetooth, TCP/UDP IP.

Devices Profile for Web Services (DPWS) is used, but in this case, it supports event subscription, allowing devices to register with each other to receive notification when a specific event occurs. The subscription capability can be exploited to reduce amount of data traffic. For example events like start and stop of an appliance can be subscribed, and device sends energy consumption rate of appliance and its start and stop time to server. Knowing start stop time and energy consumption rate of an appliance following formula is used to calculate energy consumption.

Are there one or several internal databases, and which information is stored in?

The DEHEMS project has to offer a solution for storing and retrieving sensor data in a responsive way. Both collection speed and aggregation speed for reasonable data streams of sensor data have been tested. The tests were performed on various database models, with their associated representations, including relational databases, key-value stores, column stores, self-tuning databases, as well as time-series enabled database systems. These experiments confirmed that column stores and key-value stores perform better than relational databases, while time-series databases outperform all the others.





Is there a link with some external databases?

Link to external web services (e.g. weather services)

What kind of information is displayed to the end-user (energy performance indicators, recommendations for more EE behaviour, etc.?)

All user interfaces should adhere to the basic principles of the EU-wide eAccessibility approach to web-based interfaces known as Design for All.

Provided information includes:

- Real time projections for the total extra/saving for the next bill compared to the last bill.
- Real time energy usage for the household, compared to the neighbourhood average, measured in cost, CO_2 and kWh
- The patter of energy usage over the day for the household, compared to the neighbourhood average, measured in cost, CO_2 and kWh

5.1.12 Conclusion

Through the previous analysis, two kinds of projects have been roughly identified:

- Projects that develop sensing networks to monitor the building operation and usage in order to provide services such as energy analysis, performance evaluation, decision-support to energy management, or simply energy awareness and suggestions for energy efficiency improvement and energy conservation.
- Projects that also include active control modules in order to control some individual appliances or provide more holistic and efficient energy management systems, reducing primary energy demand and/or energy costs. A shared principle is to integrate user behaviour and weather prediction models to anticipate energy needs and optimize control.

FIEMSER clearly belongs to the second group, but it shows some specific and significant features:

- It addresses all kinds of energy, thermal and electrical, as well as all kinds of energy generating and consuming devices, in order to deliver energy control algorithms in a holistic and optimised way according to the chosen global strategy (minimize overall energy costs, maximize the use of locally produced energy, etc.).
- It anticipates energy demand by taking into account not only weather forecast, but also usage profiles from dwellers, with the capability to revise its energy management strategy in real-time depending on the actual conditions.
- Besides, the project anticipates the future deployment of IPv6 by building its developments over the use of 6LowPAN which is the application of IPv6 over low-power personal area networks with constrained resources.
- Finally, the project extends the current approach in the display of energy consumption indicators to the end-users, by the integration of standard TV sets in the energy management system.

Despite their differences in the targeted objectives and R&D approaches, the analysed projects show some similarities, especially in terms of handled objects. The knowledge of these points of commonality has proved to be quite useful in the context of the elaboration of the FIEMSER data model.

Targeted buildings range from residential to industrial and commercial buildings of large size (private or public like offices, schools or hospitals). Considered buildings are new or existing ones. Connection to the local grid is most often considered for the global optimization of resources, and some projects are also addressing groups of buildings in the context of grid-connected buildings.

Most of the analyzed R&D projects identify common sets of data:

- Data resulting from the auditing of the building (through sensors)
- Data on the building physics, possibly extracted from BIM (Building Information Model) representations, through IFC files or other standardized formats, and including the description of equipments

- Data on the building environment, including weather data (and weather forecast if relevant) and economical data (real-time energy prices for electricity, fuel, gas, water, etc., based on a hourly or daily variation)
- Data on the control strategies and the building energy performance
- Data on the user profiles and activities (associated to usage patterns)

Besides, other data model may be defined depending on the specific applications targeted in the projects such as: scenario data model, prediction model, decision model, renovation solution model, etc.

All these data may be grouped in several databases, where operational data store (log of sensor or actuator data) are often separated from other categories of data. Links are also often implemented between BIM and data warehouses.

For the monitoring of building operation and usage, many types of sensors are used, including: temperature, air quality (CO2), water flow meter, gas flow meter, electric power or energy meter, humidity, luminosity, movement, pressure, noise, rain gauge, solar & UV irradiation, wind direction and speed, etc.

Sensors are mainly deployed in wireless networks, but wired networks are also considered in some projects. Related communication protocols are 6LoWPAN, IEEE 802.15.4, Zigbee, ModBus, PLC protocols, DALI, etc.

Diverse equipments are considered:

- Energy generators, including the use of renewable energy sources: boilers, solar panels, photovoltaic panels, CHP, wind turbines, geothermal, heat pumps
- Energy consumers: heat emitters, air conditioning, ventilation system, domestic hot water, lighting, household and other electrical appliances (wash machines, dishwashers, driers, fridges, cooking ovens, fans, heat pumps…)
- Energy stores: batteries, water tank, fuel cells, phase changing materials (more rarely considered)
- Other types of equipment taking part in the energy demand: windows, blinds… that may be manually or automatically controlled.

Simulation tools are used in some projects, but not all of them. The case being, they require relevant modelling of the building and its physics (with a focus on energy aspects).

User preferences are most often integrated through comfort settings. User behaviour (i.e. building usage), when it is taken into account, most often results from the identification of pattern usages.

Weather forecast, when relevant, is based on the use of external web services providing hourly values for temperature, humidity, solar irradiation (sometimes extrapolated from information on cloud cover), wind speed and direction, etc.

User interfaces are most often desktops, sometimes TV, but some mobile applications are also envisaged (e.g. for onsite facility management services). Novel interfaces (e.g. using home lighting and lamps as a means to communicate with the user) are less frequently considered. Identified end-users are the building occupants in the first place and, depending on the provided services, facility managers, and utility companies. Commonly displayed information are the current and aggregated consumption data (globally or detailed by appliance), energy prices and savings, carbon fingerprint, electricity usage for households, suggestions for improvements, etc.

5.2 Building information standards

5.2.1 IFC

General Information

IAI/ buildingSMART – Industry Foundation Classes (IFC)
In the early 1990's the construction industry started to develop STEP compliant neutral and interoperable information models for the exchange of construction information. After developing some successful and unsuccessful information models, AutoDesk and other software vendors in North America created the Industry Alliance for Interoperability in 1994. This was then changed to International Alliance for Interoperability (IAI) in 1996 with the objective to develop a commonly agreed STEP compliant model for the AEC industry. It has now turned into the buildingSMART organization (http://www.buildingsmart.com), which brings together architects, engineers, constructors, product manufacturers and facilities managers, along with software vendors and progressive construction customers

One of the main goals of buildingSMART (through its Model Support Group) is to develop and maintain open international standards for Building Information Modelling (Open BIM). Thus a major output buildingSMART (formerly IAI) is a common data schema that makes it possible to hold and exchange relevant data between different software applications. The data schema comprises interdisciplinary building information as used throughout its lifecycle. The name of this format is Industry Foundation Classes (IFC). It is registered by ISO as ISO/PAS 16739 and is currently in the process of becoming an official International Standard ISO/IS 16739. IFC can be used to exchange and share BIM data between heterogeneous applications developed by different vendors without the necessity to support numerous native formats. As it is an open format, it does not belong to a single vendor and is therefore neutral and independent of a particular vendor's schedule and development direction.

Technological background & Market deployment

An early technical decision of the IAI was to base development work on the EXPRESS data definition language that had been developed as an ISO standard within the STEP project. In particular, the work on the development of the Building Construction Core Model within STEP effectively moved to the IAI. This led to the first release of the Industry Foundation Classes (IFCs), which consisted of specifications defining an object based data model for the AEC industry.

This first full release of the IFCs was issued by IAI in January 1997. Several further releases have been issued since, as shown in the figure below. IFC1.5 was the basis for the first commercial IFC compliant software applications. The latest official IFC release recommended for implementation is IFC2x3 (TC1 - Technical Corrigendum 1). The forth release of the IFC2x Platform (IFC2x4), including several extensions of IFC in building, building service and structural areas, is in development stage (the Release Candidate 1 was published in May 2010). From version 2x, a new architecture has been adopted. The model framework is made of a stable platform that is able to accept extensions.

The second release of the IFC2x Platform (IFC2x2) was an important release providing several extensions of IFC in domain areas.

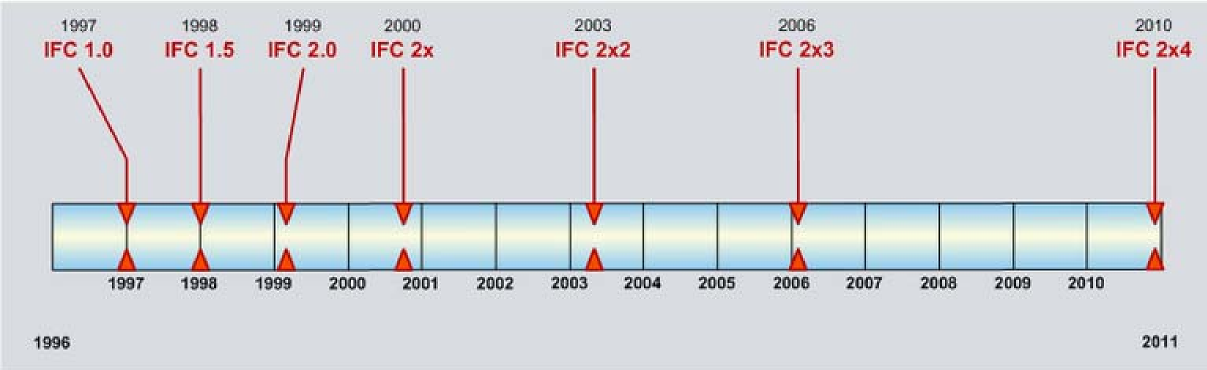


Figure 11: IFC release history
(extracted from http://www.iai-tech.org)

IFC specification formats
The IFC specification is written using the EXPRESS data definition language, defined as ISO10303-11 by the ISO TC184/SC4 committee. It is the same data definition language as used in STEP. It has the advantage of being compact and well suited to include data validation rules within the data specification. The IFC exchange file structure (*.ifc files) is the so called "STEP physical file" format, defined as ISO10303-21 by the same ISO TC184/SC4 committee. It is an ASCII file format used to exchange IFC between different applications.

In addition to the IFC-EXPRESS specification an ifcXML specification is published as well (since the IFC2x release). The ifcXML specification is provided as an XML schema. The ifcXML exchange file structure (*.ifcXML files) is the XML document structure. The XML schema is automatically created from the IFC-EXPRESS source using the "XML representation of EXPRESS schemas and data" (ISO10303-28). This ensures that both IFC-EXPRESS and ifcXML handle the same data consistently and that the *.ifc and *.ifcXML data files can be converted bi-directionally.

IFC compliant tools
Software applications correctly implementing IFC are said to be IFC compliant, as they allow to read and/or write *.ifc files. Many IFC-compliant software tools are available on the market, including CAD, cost estimation, energy simulation, structural design, HVAC design, constraint checking, and software development tools.

IFC Data Model

Based on STEP principles, the IFC data model is an object oriented model that separates the object identification and the associated properties, including potential different geometric representations and materials association. The following EXPRESS-G diagram (see Figure X2) presents the backbone of the IFC data model:

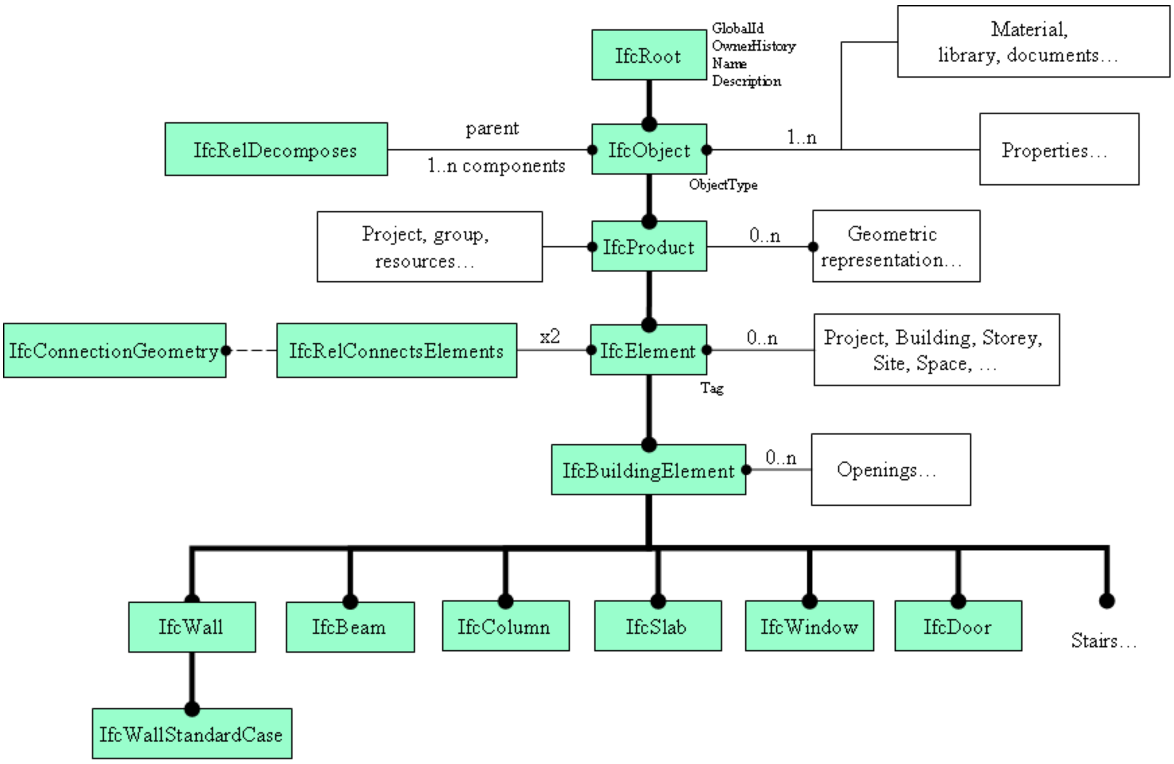


Figure 12: Backbone of the IFC data model (EXPRESS-G diagram)

In this EXPRESS-G diagram, thin lines represent relationships (association, composition, etc.) while thick ones represent inheritance (class hierarchy).

Example 1: IfcBeam is a subtype of IfcBuildingElement.
Example 2: IfcBuildingElement can have 0 to n openings.

The following example shows the EXPRESS definition of the entity *IfcBoilerTyp*e of the HVAC-related domain (*IfcHvacDomain*) which defines basic object concepts required for interoperability within the heating, ventilating and air conditioning (HVAC) domain:

ENTITY IfcBoilerType
SUBTYPE OF (IfcEnergyConversionDeviceType);
PredefinedType : IfcBoilerTypeEnum;
WHERE
WR1 : (PredefinedType <> IfcBoilerTypeEnum.USERDEFINED) OR ((PredefinedType = IfcBoilerTypeEnum.USERDEFINED) AND EXISTS(SELF\IfcElementType.ElementType));
END_ENTITY;

One principle is to have few attributes on each entity and use specific relationship entities between these entities for specifying aggregates.

The IFC2x version has defined the platform with a set of frozen entities. New evolutions of the IFC model are now defined on top of these entities with edition numbers. The following schema (Figure X3) presents the scope of the IFC2x platform:

Figure 13: Architecture diagram of IFC2x platform

In 2nd and following editions of IFC2x, new schemas have been added, in the frame of different extensions projects:

1. HVAC Performance Validation [BS-7]
2. HVAC Modelling and Simulation [BS-8]

3. Network IFC: IFC for Cable Networks in Buildings [BS-9]
4. Electrical Installations in Buildings [EL-1]
5. Code Compliance Support [CS-4]
6. Engineering Maintenance [FM-1]
7. Costs, Accounts and Financial Elements in FM [FM-8]
8. Material Selection, Specification and Procurement [PM-3]
9. Steel Frame Structures [ST-1]
10. Reinforced Concrete Structures [ST-2]
11. Precast Concrete Construction [ST-3]
12. Structural Analysis Model and Steel Constructions [ST-4]
13. IFC drafting extension [XM-4]

Link with product libraries - Property sets

There is a high demand from manufacturers for solutions allowing better integration of their product libraries in application tools (such as design tools), and supporting automated information exchange and sharing. Several initiatives have been launched to improve the situation by developing semantic links between product libraries and product data models, as well as infrastructures to better support access to product information from design or procurement tools. Generally speaking this raises the problem of convergence between classifications and product modelling.

In the construction domain, for instance, IFC-based implementation of product libraries have good prospect for meeting the industry requirements. Indeed, while IFC classes represent generic categories of element (e.g. wall, beam, space) with very few attributes associated with a class to transfer information relevant to a manufacturer, IFCs incorporate a mechanism called Property Sets (PSets) which allow information publishers to dynamically allocate new properties to an object they wish to describe. Since there are numerous alphanumeric attribute definitions depending on discipline, life-cycle stage, building regulation and region, there will never be a complete set of internationally standardized attributes. Therefore, IFC defined property sets intent to standardize a basic set of properties, whereas other property sets can be regionally defined, or agreed upon in projects. The current drawback, however, is that there is no specification of the semantics of PSet information outside that published in the IFC distribution (PSD - Property Set Definition - Schema for the definition of property sets and properties). As an example, below is the list of properties defined in the PSet attached to the common entity *IfcBoilerTyp*e:

- PressureRating
- OperatingMode
- Material
- HeatTransferSurfaceArea
- NominalPartLoadRatio
- WaterInletTemperatureRange
- WaterStorageCapacity
- IsWaterStorageHeater
- Weight

- PartialLoadEfficiencyCurves
- NominalEfficiency
- HeatOutput
- OutletTemperatureRange
- NominalEnergyConsumption

IFD (International Framework for Dictionaries)
IFD tries to provide access to product data information and definition data using a standardized dictionary access, thus building a bridge between instance models like IFC and dictionary databases like product type catalogues. In its simplest form IFD is a mechanism that allows for creation of multilingual dictionaries or ontology. IFD Library is one of the core components of the BuildingSMART technology, along with the IFC and IDM (see below).

IFD Library is a reference library intended to support improved interoperability in the building and construction industry. IFD Library provides a flexible and robust method of linking existing product databases to an IFC based Building Information Model. Due to the multilingual capabilities of IFD Library this linking is language independent as well. The concept for the IFD Library is derived from internationally-accepted open standards that have been developed by ISO (most importantly ISO 12006-3:2007). It can be used to provide a feasible method of linking existing knowledge systems to an IFC-BIM. IFD provides solutions that separate a given concept from the different names under which it can be named using several languages. It is not yet another dictionary; it provides a set of tools (through the use of relationships) that allow to connect a concept to a large and open set of words, definitions or properties depending on the scope or context in which this concept will be used.

The French Standard Dictionary for Construction (SDC), the Norwegian BARBi library and the Dutch LexiCon from STABU, are some examples of reference dictionaries that follow the IFD specification.

IDM and Model View Definition
Every implementation of an IFC exchange should follow a so called "Exchange Requirement". An Exchange Requirement document specifies which information needs to be present in an exchange/sharing of data at a certain stage in a project. The method used and propagated by buildingSMART to define such Exchange Requirements is the Information Delivery Manual**,** IDM (also ISO/DIS 29481).

Exchange Requirements are grouped into something called an "IFC Model View Definition" (MVD), i.e. a particular subset of the IFC schema dedicated to a set of exchange requirements. It thereby represents the software requirement specification for the implementation of an IFC interface to satisfy the exchange requirements. It should be noted that whereas the general exchange requirement is independent of a particular IFC release, the realization (or binding) within the model view definition is specific to an IFC release. Most currently available IFC compliant software have implemented the IFC coordination view, but there are other IFC view definitions, currently proposals, e.g. the structural analysis view, the early design view, or the FM HandOver view. Within each of these views, there can be several exchange requirements.

5.2.2 gbXML

General Information

The green building extensible mark-up language (gbXML) is an open, non-proprietary information model that was developed to facilitate intelligent information exchange, enabling integrated interoperability between building design models and a variety of engineering analysis tools.

The development of the gbXML was started in 1999 by the Green Building Studio and was funded by the California Energy Commission PIER Program and Pacific Gas and Electric. The first version of the gbXML was launched on June of 2000.

The gbXML information model is released in form of a XML (eXtended Markup Language) schema in which in a tree form hierarchy the data is stored. XML provides a robust, non-proprietary, persistent, and verifiable file format for the storage and transmission of text and data both on and off the Web (W3C, 2006).

Notwithstanding the consistent language format, the implementation of the actual data model or schema, with their associated semantics, can still vary significantly. This presents a challenge to advancing interoperability within the industry.

The application of gbXML is mainly on the energy simulation domain. In terms of geometry, in opposition to the IFC, gbXML only accepts rectangular shape, which is enough for energy simulation.

Technological background & Market deployment

As background for the gbXML schema definition many different available technologies and standards have been visited and include as core of the gbXML. Regarding to the type of technology or standard next categorization is possible to do:

Simulation Engines & Geometries:

Geometries in conjunction with simulation engines are the core for building design phases. Currently there are available many tools that allow the translation from geometries definition formats such as VRML, 3DMF, X3D, among others, to gbXML to be integrated on simulation engines.

VRML (Virtual Reality Modeling Language), 3DMF (3D Distribution Media Format) and X3D (XML Standard for representing 3D) are, three of them, file formats in which different tools orientated to the 3D design storage data.

gbXML schema for information exchange is compatible with the most extended simulation engines such as DOE-2.1e, DOE-2.2 or TRNSYS. DOE and EnergyPlus simulation engine are one of the most well-known simulation engines in the building design domain. Many high level tools such as Design Builder have incorporated these engines as their simulation mechanisms. TRNSYS, on the other hand, is a tool that has a wide acceptance at research environments and is used

XML Schema:

XML (eXtensible Markup Language) is a language that, regarding to concept behind, it is similar to the HTML but with a very different purpose. HTML is designed to show data as we are used to see in our browsers, on the other hand, XML is orientated to storage data.

One of the most time-consuming challenges for developers or IT technology users is to exchange data between incompatible systems. XML data is stored in plain text format. This provides a software- and hardware-independent way of storing data, meanwhile reduces the complexity of the compatibility between different systems.

The XML is built upon the W3C recommendations. W3C (World Wide Web Consortium) is the main international standards organization for the World Wide Web.

The W3C is jointly administered by the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL) in the USA, the European Research Consortium for Informatics and Mathematics (ERCIM) (in Sophia Antipolis, France), and Keio University (in Japan).

Even originally the XML specification was designed to exchange data at internet domain, more and more the interoperability among different systems is seen as a requirement. In this context XML specification is been adopted as a reference.

Data Bases:

Once covered the integration among the simulation engines and the visual tools, and the data format in which gbXML achieves this integration, it remains to mention, last but no least, that gbXML definition during its definition phase has visited/take into consideration many other works done at HVAC and Lighting engineering.

The most relevant databases that have been visited during the gbXML development, it is important to remark that this process is a live process, are, among others, ASHRAE 90.1, IAI-IFCs, FTC-Energy guide and EPA-EnergyStar databases.

Next table shows a summary of the different bodies that have been considered as core information provider in the gbXML development.

Organization	Description - Technological Contribution
International Alliance for Interoperability	Development of universal framework for information sharing
National Institute of Building Sciences	Umbrella organization for IAI and the buildingSMART Alliance

buildingSMART Alliance	Development of interoperable technology for design and construction
National Institute of Standards and Technology	Advanced Technology Program and Standard Reference Data
Capital Facilities Industry XML	The aim of this organization is wide-spread practical and cost-effective use of XML in the capital facilities industry.
World Wide Web Consortium (W3C)	Internet standard XML structures recommendations development
Object Management Group	Unified Modeling Language and Global Regulatory Information Database development.
International Building Performance Simulation Association	Building performance simulation for HVAC systems

In the previous paragraphs the technologies and previous works that could lead to enhance current building information models have been introduced.

These technologies or previous works are released as software tools that cover different stadiums of the building design phase.

Next categorization shows most relevant commercial brands that support gbXML.

CAD Tools

- Autodesk:
  - ADT 2005, 2006
  - Revit 6.1,7
  - Revit Building 8
- Graphisoft
  - Versions 8, 8.1, 9

Other brand names such as Bentley and Artifice have announce to support gbXML in different tools

Design and Simulation Tools

- Trane
  - TRACE 700
- Green Building Studio
- DOE2.2
- Energy Plus
- IES VE

Other design tools such as ECOTECT, Energy Soft, Elite Software or York have announced the coming support for the gbXML schema.

The reasons and motivations to incorporate gbXML in different tools or development environment are its simplicity to implement, wide availability of XML parser and the support that major CAD vendors are providing to gbXML.

Data Model Analysis

As already introduced the gbXML information model is presented in form of a XML schema that in form of tree incorporates the building information model (BIM).

Regarding to the different data representation capabilities the gbXML information model incorporates from 3D planar polygon representation to transportation types and schedules. This wide scope approach reflects the different technological knowledge that has taken part in the gbXML definition.

The tree form structured gbXML schema has as main branches or, in other words, as main information model deployment nodes next entries.

It is not the aim of this chapter to fully describe the gbXML schema, but to provide a global approach to the information included in it. In this context only most relevant nodes will be expanded:

3D Planar Polygon Geometry: Represents the 3D projection of a planar polygon. This node includes information to the physical shapes that compose the building.

2D Rectangular Polygon Geometry: Represents the representation of a basic 2D rectangular shape. In conjunction with the 3D elements is used to model the building shapes.

Opaque Constructions and Materials: This node includes information about different materials and construction parts. Due to their relevance in energy performance calculation and simulations the main child nodes or attributes for materials and construction items are introduced.

Element	
Name	Description
Construction	A Construction is a combination of layers, such as a wall or a roof
Main Child Nodes – Attributes	
Name	Description
U-Value	Overall conductance
Reflectance	Reflectance value of the construction
Transmittance	Transmittance value of the construction
Emittance	Emittance value of the construction
LayerId	Id of layer that composes the construction

Element	
Name	Description
Material	Physical characterization of the building
Main Child Nodes – Attributes	
Name	Description
R-Value	Resistance of material
SpecificHeat	Specific heat of the material
Density	Density of the material
Conductivity	Conductivity of the material

Glazing, Shades Operation: This node models the available shading devices and the operation that they allow.

Internal and External Equipment: Equipment nodes are used to incorporate the different device types that could be found both inside and outside of the building domain.

Next table show some of the information included in the equipment nodes.

Element	
Name	Description
ExtEquip	External equipment. This is generalized to be able to contain any type of external equipment
Main Child Elements- Attributes	
Name	Description
ElecLoad	Electric load. Includes information about the power
Performance	Used to represent part load performance. Could be an equation
FuelLoad	Units in which fuel is measured
Efficiency	Element used to provide information about the efficiency of the equipment. Includes many attributes
Power	Maximum consumption of energy (power input)

Lighting and Controls: Lighting and control nodes include the information required to model de lighting system and the type of control choices available.

Element	
Name	Description
LightingSystem	
Main Attributes	
Name	Description
LumensPerLamp	Number
InputWatts	Number
Lamp	Type of lamp used
CoefficientOfUtilization	The coefficient of utilization is the ratio of luminous flux on a work plane to the luminous flux emitted by the lamps alone.

Element	
Name	Description
LightingControl	
Main Attributes	
Name	Description
Illuminance	Illuminance level that the lights are maintained if daylighting controls present (lightControlTypeEnum not equal to on off)
MinPowerFactor	Fraction of power used at minimum setting
MaxPowerFactor	Fraction of power used at maximum setting

Weather Design Data: The weather design data nodes contain rich and extent information about the different weather parameters that may have been taken at the building and systems design phase. These data will have meaningful relevance at the different operation time scheduling.

Next table shows a summary of the information that is stored in this node.

Element	
Name	Description
Weather	
Main Child Elements- Attributes	
Name	Description
DDDBCool/Heat	Cooling/Heating design day dry bulb temperature
DDWBCool/Heat	Cooling/Heating design day wet bulb temperature
DDDBRangeCool/Heat	Cooling/Heating design day dry bulb temperature range
DDLoHrCool/Heat	Cooling/Heating design day hour of low temperature
DDPresureCool/Heat	Cooling/Heating design day atmospheric pressure

DDWindSpeedCool/Heat	Cooling/Heating design day wind speed
DDWindDirCool/Heat	Cooling/Heating design day wind direction
DDRainCool/Heat	Flag for rain on the cooling/heating design day. 0=no rain 1=rain
DDSnowCool/Heat	Flag for snow on the cooling/heating design day. 0=no rain 1=rain
DDMonthCool/Heat	Month the cooling/heating design day lands on. 1=Jan 12=Dec
DDDayCool/Heat	Day of the month that the cooling/heating design day occurs on
DDDayLightCool/Heat	Flag for daylight savings on the cooling/heating design day

Schedule: The schedule node provides a great flexibility in order to model the different types of day. The schedule includes the possibility of scheduling people presence or activity and different systems activity periods.

Next table shows some of the information that could be schedule, well by the schedule node or by any of its child nodes.

Element	
Name	Description
Schedule	List of year schedules that make up an entire calendar yea
Main Child Elements- Attributes	
Name	Description
YearSchedule	Set of week schedules all assigned for a particular time period during the year defined by the begin and end date elements. These must not span more than one calendar year
WeekSchedule	Set of day schedules all assigned to a unique particular period of the week using the day type attribute.
DaySchedule	Set of values that define the profile of one 24 hour period divided equally to the number of values entered
ShadeSchedule	
PeopleSchedule	

HVAC: HVAC systems are modelled in two main nodes. The AirLoop node, focused on air based systems and the HydronicLoop, focused on water based systems.

Next table sequence summarizes the information contained in the AirLoop and HydronicLoop nodes.

Element	
Name	Description
AirLoop	
Main Child Elements- Attributes	
Name	Description
TemperatureControl	Use this element to describe how the temperature is controlled. The temperatures specified in this element should be measured just upstream of the most critical piece of equipment (air handlers for a chilled water and hot water loops the chiller for the cooling water loop)
PresureControl	Use this element to describe how the air pressure is controlled. The temperatures specified in this element should be measured just upstream of the air handlers
OperationSchedule	Forecasted used of the AirLoop devices

Element	
Name	Description
HydronicLoop	
Main Child Elements- Attributes	
Name	Description
FlowControl	Use this element to describe how the temperature is controlled. The temperatures specified in this element should be measured just upstream of the most critical piece of equipment (air handlers for a chilled water and hot water loops the chiller for the cooling water loop)
TemperatureControl	Use this element to describe how the temperature is controlled. The temperatures specified in this element should be measured just upstream of the most critical piece of equipment (air handlers for a chilled water and hot water loops the chiller for the cooling water loop)
OperationSchedule	Forecasted used of the HydronicLoop devices

Vegetation Type and Location: Vegetation and Location nodes provide additional information. This additional information could be in some cases redundant but valuable for describing the modelled scenario.

Version and Change History: Especially meaningful for quality assurance protocols, version and change history provide information to track whole lifecycle of the information model.

FIEMSER Friendliness

The most exciting challenge for every wide scope development, no matter if it is an information model, a software development or a guide for fishing, is to try to cover as much as possible the application domain, on the other hand, the risk is to be too vague that it could become un-useful.

The gbXML information model being, even in building universe, a wide spectrum information model not focused in a single field such as energy simulation or 3D representation may suffer the risk of being no precise enough.

The use of the XML as language for the definition of the information models provides to the gbXML not only flexibility but extensibility to adequate to different domains.

From the FIEMSER point of view and based on the requirements definition, as collected in deliverable D3, the possibility to define different schedules and equipment types is a key option.

Equipment Types: Equipment types could be used at the FIEMSER project to include in the calculation modules the performance and actuation type of the available internal and external devices. Based on the description of the equipment, user preferences, outdoor conditions, applicable tariffs and other factors the FIEMSER calculation modules will schedule the operation periods for the deployed equipments.

The gbXML provides intEquipment and extEquipment in which information related to the equipment could be mapped.

Schedules: The flexibility to schedule usage profiles and activation periods is one of the core requirements for the FIEMSER runtime modules.

The gbXML includes nodes such as yearSchedule, daySchedule, or monthSchedule that could provide the required flexibility in order to describe different usage patterns. In conjunction the operationSchedule is a node that could cointain the different activation slices for the existing equipment.

Weather data: The weather data node does not make reference to the real time weather data, but to the data taken into account at design period. Anyway is very useful in order to make simulation and comparison among the forecasted and real building behaviour.

The forecasting the energy demand is one of the bases for the FIEMSER project. The forecasted energy demand will be used to determine the best schedule for the different producers and consumers deployed in the building.

Construction: To finalize this categorization, the construction node and its referenced nodes *Material*, are the structures that the gbXML information model have available to incorporate data related to the building physics.

Data such as, U-values, reflectance, transmittance or the specific heat, are parameters that play an important role at the energy demand calculation domain.

5.2.3 Conclusion

IFC is a widely used standard integrated as I/O data format by many software tools, including CAD or FM systems. It is more generic than gbXML due to its top-down approach, and more comprehensive since it covers the whole building life cycle.

In return, IFC suffers from a certain complexity (complex data schema, large data file).

On the other hand, gbXML, which results from a bottom-up approach, focuses on building thermal load properties. It is then simpler and easier to use and more efficient than IFC to integrate with thermal analysis software, thus allowing quicker implementations. The XML basis (data model in XML Schema and data format in XML) provides flexibility and extensibility, and data can be easily processed by XML parsers. Besides, gbXML is supported by many CAD, design and simulation tools. The limited features in terms of geometry (compared to IFC) are not an obstacle for FIEMSER since we are addressing buildings with standard geometrical features.

For all these reasons, we have decided to interface with gbXML, preferably to IFC, for the Building Information Model of FIEMSER.

This does not mean that we will ignore the BuildingSMART community in our further work. Indeed, it is planned that our modelling work will be disseminated (as a proposal for possible standard extension), not only towards the gbXML community, but also towards all relevant standardisation bodies, including BuildingSMART.

6. FIEMSER Data Model

In a previous section, different views of the FIEMSER Data Model have been presented, leading to what we called "sub-models".

The merging of these sub-models constitutes the global conceptual data model of FIEMSER.

It should be noted that, due to the chosen bottom-up approach, an important work of harmonization and disambiguisation has been needed to reach a consistent holistic model. Indeed, many objects are shared by different views (around 38 %), and the different authors of these views may not only choose different labels for the names of these objects and their attributes, but also (which is a much more difficult issue to solve) have different understanding of the underlying concept. Moreover, it is well known that several modelling choices can be made to vehicle the same knowledge.

The following table provides a synthesis of the 103 classes forming the FIEMSER Data Model, along with their short definition. It also mentions those classes which are shared by different views (see section 3 for the definition of the views abbreviations).

In the Appendix, a full description of each class is provided, following the template defined in the methodology section.

Class name	Class definition	Views
6LowPan	IPv6 for Low-Power Personal Area Networks (6LowPAN) provides a standard for network protocol that allows stateless compression of IP headers before their transmission, thus enabling the transmission of IP packets over low-power networks.	WSN
Actuator	Any actuating hardware installed on a control device.	WSN, ADV, EPI
AdjacentSpace	Identifies the type of surface according to the BuildingSpaces that are related through it.	BIM
Advice	Describes the advice to be provided to the user.	ADV
ApplianceUsage	Specifies the appliances (loads) involved in the scene, along with the period of operation.	USR, SCH
Battery	An electrical storage, based on a chemical solution.	BIM
Blinder	A mechanism that can be used to shade a part of a building from the sun radiation.	BIM
Boiler	A thermal generator that uses a fossil primary energy source.	BIM
Building	Defines the physical aspects of the building.	ENV, BIM, WSN, USR, SCH, ADV, EPI, RGH

BuildingDailyMeasurementLog	Stores data related to the actual energy consumption of the whole building and the simulated consumption of the same building with the same scenario(s), but without the control by FIEMSER.	EPI
BuildingPartition	Defines a part of a building managed by either a dweller (e.g. a flat) or a facility manager (e.g. a common building area).	ENV, BIM, WSN, USR, SCH, EPI, RGH
BuildingProgrammeScedule	Stores the schedule of the use of devices planned for a specific date. It identifies whether the plan is active or not and points to the schedules of all the devices planned.	SCH
BuildingSpace	Defines the physical spaces of the building.	BIM, WSN, USR, SCH, EPI
BuildingZone	Defines a functional area in the building that will be controlled as a unique zone.	BIM, USR
CHP	Equipments that simultaneously generate electrical and thermal energy.	BIM
Calendar	Contains calendar dates. It is used to date some information (e.g. home usage, daily energy measures).	USR, SCH, ADV
ComfortSetting	Defines the set-points for comfort parameters (temperature, luminosity, etc.).	USR, SCH
CommDevice	This entity identifies the communication devices used for data exchange within the FIEMSER scope.	WSN
CommonArea	Represents a common area in a multi-dwelling building (e.g. stairs, parking area…)	BIM
ConfigurationInfo	Specifies the configuration of a control device.	WSN
ContractedEnergySupply	Identifies the energy supply conditions by the utilities (electricity, gas…).	BIM, SCH
ControlAction	Describes the specific control actions that have to be executed by the actuators.	WSN, ADV, EPI
ControlComponent	Any component (hardware or software) installed on a control device.	WSN, EPI
ControlDevice	Represents a device directly connected to FIEMSER control infrastructure and used to monitor and/or control the environment and its appliances.	WSN, EPI
Controller	Actuator that can receive complex signal that may require processing for actuating on a device.	WSN, EPI
ControlRule	Contains the set of control rules that can be chosen for the devices of the energy management system.	USR, SCH, ADV
CtrlDeviceEnergyConsumption	Represents the energy consumed by the control device itself.	WSN
CtrlScheduleInfo	Describe the temporal properties for the configuration of a control device.	WSN

DataLog	Identifies all the data information collected by the sensor components, which are installed and observed within the FIEMSER environment.	WSN, EPI
DayAheadPrices	Contains the day-ahead energy prices applicable to each contract.	ENV, SCH
DetailedEfficiency	Provides detailed information about the generator efficiency according to its operation point when average values are not accurate enough.	BIM
DetailedLosses	Provides detailed information about storage losses according to the difference of internal and external conditions of the storage unit when average values are not accurate enough.	BIM
DetailedOperationMode	Provides a 2D graph about the power that is consumed or generated by the home equipment according to the operation mode when average values are not accurate enough.	BIM, SCH
Device	Describes any device installed in the Building.	BIM, WSN, USR, SCH, ADV, EPI
Dimmer	Actuator that modifies the value of its output upon the reception of a command.	WSN , EPI
DimmingCTRLAct	Describes a control action associated to an actuator that allows the change of the setting parameter in a percentage.	ADV
Dwelling	Represents a private apartment in a multi-dwelling building.	BIM
ElectricHeater	Equipments that heats up a fluid using electricity as its primary energy source and stores it in a tank.	BIM
ElectricalGenerator	Equipments that generate electrical energy.	BIM
ElectricalGeneratorSchedule	Describes the electricity generation schedule of a device by adding the reactive power generated.	SCH
ElectricalLoad	Loads that consume electrical energy.	BIM
ElectricalStorage	Equipments that store electrical energy.	BIM
ElectricalStorageSchedule	Describes the electricity generation/consumption schedule of a storage device.	SCH
EndUser	The end user is one type of user group existing in the FIEMSER system.	RGH
EnergyPrices	Stores the hourly evolution of energy prices.	ENV
EnergyPricesWebResource	Defines the characteristics of the web resources providing energy prices.	ENV
EventLog	Defines events related to the control device installed within the FIEMSER environment.	WSN
FacilityManager	The facility manager is one type of user group existing in the FIEMSER system.	RGH

FunctionArea	Identifies a specific functional area within the FIEMSER configuration utilities, including the area used to define system's advices, operate on devices, monitor the building, etc.	RGH
Generator	HomeEquipments that generate energy (thermal or electrical).	BIM
GeneratorSchedule	Describes the energy generation schedule of a generator.	SCH
GlobalStrategy	Represents an energy strategy that can be chosen for the energy management system.	USR, SCH
Group	Identifies a group of users sharing a set of access rights.	RGH
HardComponent	Any hardware component installed on the control device.	WSN, EPI
HomeDailyMeasurementLog	Provides data about the real energy consumption of each building partition and the simulated consumption of the same partition in the same scenario, but without the control by FIEMSER.	EPI
HomeEquipment	Any home appliance or mechanism to increase building energy efficiency.	BIM, WSN, USR, SCH, EPI
HomeUsageProfile	Defines different profiles for the daily usage of a building partition (typically a dwelling).	USR, SCH, ADV
KNX	KNX is an OSI-based network communication protocol for intelligent building, which covers the whole stack from presentation down to physical layer. It mainly supports several communication media, such as twisted pair, powerline, radio frequency and Ethernet.	WSN
Load	Sub-types of Home Equipments that consume energy (thermal or electrical).	BIM, USR, SCH
Location	Defines the location of the building.	ENV, SCH
LuxoMeter	Sensor that measures the light flux.	WSN , EPI
MeasurementSensor	Sensors that collect data about analog variables.	WSN, EPI
Mechanism	Control mechanisms that are installed in the home to increase its energy efficiency, but don’t generate or consume energy by themselves.	BIM
ModBUS	ModBus is a standardized communication protocol in the industry, where it is mainly used to interconnect industrial electronic devices that fulfil the needs of the building community prior to BACnet.	WSN
NetProtocol	Identifies all the entities that are related to the networking protocol used for communication purposes.	WSN
Opening	Identifies the openings in a surface, as windows, doors, etc. The opening can be just a hole.	BIM

OperationMode	Defines the operation modes available for each home equipment.	BIM, USR, SCH
Order	Links the control rule with the advice to be sent to the user and with the control actions that have to be executed if the user accepts the advice.	ADV
Orientation	Defines the orientation of the building.	ENV, SCH
PV	An electricity generator that uses the sun radiation as primary energy source.	BIM
Permission	Represents a single permission to perform a specific operation within a specific functional area.	RGH
PermissionType	Contains information about which kind of actions or operations are granted for the users during the interaction within the FIEMSER system.	RGH
Presence	Sensor that detects motion and changes state.	WSN , EPI
PrimaryEnergySource	Specifies the energy sources that are used in the system.	ENV, BIM
PushButton	Sensor that changes its state based on the pressure done by a user.	WSN , EPI
Radiator	A thermal load that has a heat exchanging role and is used for heating building spaces.	BIM
ResourceSchedule	Generalization of the schedules of all resources that described the power use/generation schedule.	SCH, EPI
Scene	Defines scenes (specific usages of the building, in terms of comfort and appliances usage).	USR, SCH
Sensor	Any sensing hardware installed on the Control Device (e.g. temperature, humidity, light sensors...).	WSN, EPI
ShadeControl	Represents a criterion to help determine if the shades will be open or closed.	BIM
Shadowing	Defines the main shading conditions on photovoltaic array.	ENV, SCH
SoftComponent	Any software component installed on the Control Device to deliver sensing/acting control behaviour.	WSN
SolarHeater	A thermal generator that uses the sun radiation as primary energy source.	BIM
StateBasedLoadSchedule	Describes the schedule of those resources that are represented by digital values, such as their on/off operation, along with the power they consume/generate.	SCH
StateSensor	Sensors that collect data about status.	WSN , EPI
Storage	HomeEquipments that store energy (thermal or electrical).	BIM
StorageSchedule	Describes the energy generating/consuming schedule of a storage device.	SCH

Surface	Defines the surfaces that delimit a BuildingSpace or a BuildingZone.	BIM
Switch	Actuator that changes state upon the reception of a signal.	WSN , EPI
SwitchingCTRLAct	Describes a control action associated to a switching operation that only changes the state of the actuator.	ADV
TV	An electrical load used for entertainment.	BIM
Tank	A thermal storage that stores a hot fluid.	BIM
TemperatureSchedule	Describes the schedule of temperatures for each specific BuildingSpace and according to the planned schedule for the building.	SCH
ThermalBasedLoadSchedule	Describes the thermal based loads, like the HVAC, electric heater, that have their consumption in kW and their control is based on the values assigned to the thermostat.	SCH
ThermalGenerator	Equipments that generate thermal energy.	BIM
ThermalGeneratorSchedule	Describes the thermal generation schedule of a device by adding the temperature values.	SCH
ThermalLoad	Loads that consume thermal energy.	BIM
ThermalStorage	Equipments that store thermal energy.	BIM
ThermalStorageSchedule	Describes the thermal generation/consumption schedule of a storage device by showing the evolution of the temperatures.	SCH
Thermostat	Sensor that measures temperature values.	WSN , EPI
User	Gathers users of the FIEMSER system.	RGH
WeatherData	Stores the hourly evolution of weather.	ENV
WeatherDataType	Stores the possible weather parameters.	ENV
WeatherForecast	Represents the weather forecast.	ENV, SCH
WeatherWebResource	Defines the characteristics of the web resources providing weather data.	ENV
WindMill	An electricity generator that uses the wind as primary energy source.	BIM
Zigbee	Zigbee is a suite of high level communication protocols that are used over IEEE 802.15.4 standard. It is a proprietary networking protocol that supports multiple wireless devices, using features from the underlying IEEE 802.15.4 communication medium.	WSN
ZoneUsageProfile	Define different profiles for the usage of a building zone.	USR, SCH

Tableau 3 – FIEMSER data model classes

7. Conclusion

This deliverable proposes a data model that organizes and defines the classes of objects handled in the FIEMSER system. To facilitate the understanding, this data model has been presented through different functional points of view. Besides, links with BIM representation (gbXML standard) has been established.

This data model is likely to evolve and be refined during further steps of the project to reflect details that might have been omitted at the current stage of development. But it already provides a sound basis for all subsequent developments, in particular the implementation of the FIEMSER Data Base and the development of interfaces with other FIEMSER components.

Although developed with a view of meeting the specific FIEMSER objectives, we believe that it is sufficiently generic to be re-used, totally or partially, by other applications addressing similar concerns in Building Energy Management Systems (BEMS). By the way, the analysis of some on-going R&D projects in that field has shown that many data are shared between them and with the FIEMSER project.

Since this FIEMSER Data Model is a public document, we envisage a large dissemination towards several communities:

- Firstly, the R&D projects that have been analyzed will be contacted again to get their feedback on the appropriateness of the model to their own concerns. This will certainly lead to some useful improvements of the model.
- Secondly, the model will be discussed in adhoc groups, like the forum on Data Models in ICT for Energy Efficiency in Buildings recently launched in the framework of the ICT4E2B Forum, with the objective to allow for a seamless model that operates from the building design phase to the building operational phase, merging BIM and BEMS data modelling requirements. Such a work could lead to propose extension to existing standards in the domain of the building information modelling (namely buildingSMART and gbXML).

Acknowledgements

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3. buildingSMART:

   - http://www.buildingsmart.com/
   - http://www.iai-tech.org/

4. Green Building XML: http://www.gbxml.org/http://www.gbxml.org/

5. ICT4E2B Forum: http://www.ict4e2b.eu/

Appendix: Description of the FIEMSER data model classes

Entity name	6LowPan		Related views		WSN
Definition	IPv6 for Low-Power Personal Area Networks (6LowPAN) provides a standard for network protocol that allows stateless compression of IP headers before their transmission. Such compression enables the transmission of IP packets over low-power networks.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
NetProtocol			Generalization		

Entity name	Actuator		Related views		WSN, ADV, EPI
Definition	Any actuating hardware installed on a ControlDevice.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
actuatorType	Definition of actuator (e.g. relay, analogue output)	String			
ctrlAction	Current definition of action applied for equipments	List[Parameters]			
Linked entities			Relation type		
HardComponent			Generalization		
ControlAction			Association		
Switch			Generalization		
Dimmer			Generalization		
Controller			Generalization		
Sensor			Association		

Entity name	AdjacentSpace			Related views	BIM
Definition	Identifies the type of surface according to the BuildingSpaces that are related through it.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
surfaceType	Describe the type of surface: wall, roof…	String			
Linked entities			Relation type		
BuildingSpace			Association		
Surface			Association		

Entity name	Advice			Related views	ADV
Definition	Describes the advice to be provided to the user.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
message	Text of the message to be sent to the user	String			
time	Time at which the message has been generated	Time			
activationStatus	This tells whether the activation of the order is pending or done or refused	String			[pending, done, refused]
Linked entities			Relation type		
Order			Association		

Entity name	ApplianceUsage			Related views	USR, SCH
Definition	Specifies the appliances (loads) involved in the scene, along with the period of operation.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
startTime	The time at which the load starts operating	Time			
endTime	The time at which the load ends its operation	Time			
Linked entities			Relation type		
Scene			Aggregation		
Load			Association		
OperationMode			Association		

Entity name	Battery			Related views	BIM
Definition	An electrical storage, based on a chemical solution.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities				Relation type	
ElectricalStorage				Generalization	

Entity name	Blinder			Related views	BIM
Definition	A mechanism that can be used to shade a part of a building from the sun radiation.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities				Relation type	
Mechanism				Generalization	

Entity name	Boiler			Related views	BIM
Definition	A thermal generator that uses a fossil primary energy source.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities				Relation type	
ThermalGenerator				Generalization	

Entity name	Building		Related views	ENV, BIM, WSN, USR, SCH, ADV, EPI, RGH	
Definition	Defines the physical aspects of the building.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
idGBxml	Identifier of the building object in the GBxml file	String			
GBxmlFile	Link with the GBxml file that contents all the geometry and building constructive data	String			
buildingType	Differentiates between the physical and the reference building	String			[physical, reference]

Linked entities	Relation type
GlobalStrategy	Association
Location	Association
Shadowing	Association
Orientation	Association
BuildingPartition	Aggregation
BuildingProgrammeSchedule	Association
User	Association

Entity name	BuildingDailyMeasurementLog		Related views	EPI	
Definition	Stores data related to the actual energy consumption of the whole building and the simulated consumption of the same building with the same scenario(s), but without the control by FIEMSER.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
date	Day of the measurement	Date			

Linked entities	Relation type
ThermalGenerator	Generalization

Entity name	BuildingPartition	Related views	ENV, BIM, WSN, USR, SCH, EPI, RGH
Definition	Defines a part of a building managed by either a dweller (e.g. a flat) or a facility manager (e.g. a common building area).		

Attribute name	Short description	Data type	Unit	Default value	Range of values
name	Name of the partition	String			

Linked entities	Relation type
Building	Composition
BuildingZone	Composition
BuildingSpace	Composition
Dwelling	Generalization
CommonArea	Generalization
ContractedEnergySupply	Association
Calendar	Association
HomeUsageProfile	Association
DailyMeasurementLog	Association
User	Association

Entity name	BuildingProgrammedSchedule	Related views	SCH
Definition	Stores the schedule of the use of devices planned for a specific date. It identifies whether the plan is active or not and points to the schedules of all the devices planned.		

Attribute name	Short description	Data type	Unit	Default value	Range of values
date	The date to which the schedule belongs	Date			
startTime	The initial time of the schedule	Time			
endTime	The final time of the schedule	Time			
Period	The length of each time step	Time			
State	The state of the schedule	Boolean			[0→obsolete 1→active]

Linked entities	Relation type
Building	Association
ResourceSchedule	Composition
TemperatureSchedule	Association

Entity name	BuildingSpace		Related views	BIM, WSN, USR, SCH, EPI	
Definition	Defines the physical spaces of the building.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
idGBxml	Identifier of the BuildingSpace object in the GBxml file	String			
spaceType	Identifies the use of this space (bedroom, kitchen…)	String			
peopleNumber	Number of people in the room	Integer			0 to 50
heatGainsPerPerson	Heat generated by each person	Float	W	100	50 to 1000

Linked entities	Relation type
BuildingPartition	Composition
BuildingZone	Aggregation
AdjacentSpace	Association
Device	Association

Entity name	BuildingZone		Related views	BIM, USR	
Definition	Defines a functional area in the building that will be controlled as a unique zone. It can be the aggregation of 1 or more BuildingSpaces.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
idGBxml	Identifier of the BuildingZone object in the GBxml file	String			
name	Name of the zone	String			

Linked entities	Relation type
BuildingSpace	Aggregation
BuildingPartition	Composition
ZoneUsegeProfile	Association
Surface	Association

Entity name	CHP		Related views		BIM
Definition	Equipments that simultaneously generate electrical and thermal energy.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
ElectricalGenerator			Generalization		
ThermalGenerator			Generalization		

Entity name	Calendar		Related views		USR, SCH, ADV
Definition	Contains calendar dates. It is used to date some information (e.g. home usage).				
Attribute name	Short description	Data type	Unit	Default value	Range of values
date	Calendar day	Date			
Linked entities			Relation type		
HomeUsageProfile			Association		
BuildingPartition			Association		

Entity name	ComfortSetting		Related views		USR, SCH
Definition	Defines the set-points for comfort parameters (temperature, luminosity, etc.).				
Attribute name	Short description	Data type	Unit	Default value	Range of values
comfortParameter	Name of the comfort parameter (e.g. temperature)	String			
minSetting	Minimum set value of the parameter	Float	°C	20	0 to 40
maxSetting	Maximum set value of the parameter	Float	°C	20	0 to 40
Linked entities			Relation type		
Scene			Association		

Entity name	CommDevice		Related views		WSN
Definition	This entity identifies the communication devices used for data exchange within the FIEMSER scope. It comprises both wired and wireless based communication devices.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
transPower	Transmission power for communication device	Float			
dutyCycle	Duty cycle configured for radio operation	Float	%		
networkAddress	Network address allocated for communication devices	String			
Linked entities			Relation type		
NetProtocol			Association		
HardComponent			Generalization		

Entity name	CommonArea		Related views		BIM
Definition	Represents a common area in a multi-dwelling building (e.g. stairs, parking area…)				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
BuildingPartition			Generalization		

Entity name	ConfigurationInfo		Related views		WSN
Definition	Specifies the configuration of a control device.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
configurationType	Type of configuration	String			[sensing, acting, event]
parameters	List of configuration parameters	List[Parameters]			
Linked entities			Relation type		
ControlDevice			Association		
CtrlScheduleInfo			Association		

Entity name	ContractedEnergySupply			Related views	BIM, SCH
Definition	Identifies the energy supply conditions by the utilities (electricity, gas…).				
Attribute name	Short description	Data type	Unit	Default value	Range of values
utility	Name of the utility that sypply the energy	String			
limitPower	Maximun power consumption	Float	kW		0 to 50
Linked entities			Relation type		
PrimaryEnergySource			Association		
BuildingPartition			Association		
DayAheadPrices			Association		

Entity name	ControlAction			Related views	WSN, ADV, EPI
Definition	Describes the specific control actions that have to be executed by the actuators.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
Order			Association		
Actuator			Association		
SwitchingCTRLAct			Generalization		
DimmingCTRLAct			Generalization		

Entity name	ControlComponent			Related views	WSN, EPI
Definition	Any component (hardware or software) installed on a Control Device.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
properties	Any property associated to the control component, e.g. data-sheet number	List[Parameters]			
Linked entities			Relation type		
HardComponent			Generalization		
SoftComponent			Generalization		
ControlDevice			Aggregation		
HomeEquipment			Association		

Entity name	ControlDevice		Related views	WSN, EPI	
Definition	Represents a device directly connected to FIEMSER control infrastructure and used to monitor and/or control the environment and its appliances.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
timeOfAdd	Time when the device was first added (discovered) in the network	Time			
Linked entities			**Relation type**		
Device			Generalization		
EventLog			Association		
CtrlDeviceEnergyConsumption			Association		
ControlComponent			Composition		
ControlScheduleLog			Association		

Entity name	Controller		Related views	WSN, EPI	
Definition	Actuator that can receive complex signal that may require processing for actuating on a device.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
Linked entities			**Relation type**		
Actuator			Generalization		

Entity name	ControlRule		Related views	USR, SCH, ADV	
Definition	Contains the set of control rules that can be chosen for the devices of the energy management system.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
status	Indicates whether the rule is currently applied or not	Boolean			[0→No 1→Yes]
target	Indicates the type of rule being used	String			[ActivateBlinders, ActivateWindows]
Linked entities			**Relation type**		
Device			Association		
HomeUsageProfile			Association		
Order			Association		

Entity name	CtrlDeviceEnergyConsumption		Related views		WSN
Definition	Represents the energy consumed by the control device itself. This information is needed by the Sensing and Acting component to guarantee quality of service (QoS) for power constrained devices. It is not something that we can always read from the device but it likely needs to be computed or estimated via software.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
energyType	Definition of different energy parameters (e.g. energy consumed, energy left estimated)	String			
consumptionPeriod	Time of period at which the device consumes	Time			
consumptionValue	Data value of energy	Float	W		
Linked entities			Relation type		
ControlDevice			Association		

Entity name	CtrlScheduleInfo		Related views		WSN
Definition	Describe the temporal properties for the configuration of a control device.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
scheduleType	Type of scheduling	String			[once, periodic, etc.]
scheduleValue	Data entity input for schedule parameters	Float			
beginTime	Time from when the scheduling must be valid	Time			
endTime	Time after which the scheduling instruction is not valid any more	Time			
Linked entities			Relation type		
ControlDevice			Association		
ConfigurationInfo			Association		

Entity name	DataLog			Related views	WSN, EPI
Definition	Identifies all the data information collected by the sensor components, which are installed and observed within the FIEMSER environment.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
dataType	Type of data to be stored	String			
dataValue	Data entity	Depends on the data type	E.g.: lx, °C, %		
timeOfCreation	Timestamp at which data are collected	Time	Time stamp		
Linked entities			**Relation type**		
HardComponent			Association		

Entity name	DayAheadPrices			Related views	ENV, SCH
Definition	Contains the day-ahead energy prices applicable to each contract.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
Date	Day for the prices	Date			
InitTime	Start of the period where prices are known	Time			
EndTime	End of the period where prices are known	Time			
State	Indicates if the prices are valid or obsolete	Boolean			
Linked entities			**Relation type**		
Building			Association		
EnergyPrices			Association		
EnergyPricesWebResource			Association		

Entity name	DetailedEfficiency			Related views	BIM
Definition	Provides detailed information about the generator efficiency according to its operation point when average values are not accurate enough.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
efficiency	Ordered list of values	List[float]	%		
powerValues	Ordered list of power generation values. Efficiency changes according to the power that is being generated.	List[float]	kW		
Linked entities			Relation type		
Generator			Association		

Entity name	DetailedLosses			Related views	BIM
Definition	Provides detailed information about storage losses according to the difference of internal and external conditions of the storage unit when average values are not accurate enough. For example, kW that are lost according to the difference between inside and outside temperature.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
energyPerHour	Ordered list of values	List[float]	kW		
rateJump	Ordered list of jumps (inside/outside storage unit conditions, i.e. ΔT) which is correlated with the list of values	List[float]			
Linked entities			Relation type		
Storage			Association		

Entity name	DetailedOperationMode			Related views	BIM, SCH
Definition	Provides a 2D graph about the power that is consumed or generated by the home equipment according to the operation mode when average values are not accurate enough.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
value	Ordered list of values.	List[float]	kW		
times	Ordered list of times, which is correlated with the list of values	List[float]			
Linked entities			Relation type		
OperationMode			Association		

Entity name	Device			Related views	BIM, WSN, USR, SCH, ADV, EPI
Definition	Describes any device installed in the Building.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
deviceType	Type of the device	String			[PC, TV, fridge...]
description	Short description of the device	String			
currentStatus	Indicates the status of the device within its lifecycle	Integer			[0→Error 1→OK 2→Removed 3→Uncompleted, etc.]
state	Operation mode	String			[On, Ready, Off, etc.]
manufacturer	Device's manufacturer	String			
model	Commercial reference	String			
homepage	Hyperlink to website for further information	String			
Linked entities			Relation type		
BuildingSpace			Association		
HomeEquipment			Generalization		
ControlDevice			Generalization		
EnergyConsumption			Association		
ControlRule			Association		
ResourceSchedule			Association		

Entity name	Dimmer	Related views	WSN, EPI
Definition	Actuator that modifies the value of its output upon the reception of a command.		

Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
Actuator	Generalization

Entity name	DimmingCTRLAct	Related views	ADV
Definition	Describes a control action associated to an actuator that allows the change of the setting parameter in a percentage.		

Attribute name	Short description	Data type	Unit	Default value	Range of values
percent	It tells the percentage to modify the parameter setting	Float	%		

Linked entities	Relation type
ControlAction	Generalization

Entity name	Dwelling	Related views	BIM
Definition	Represents a private apartment in a multi-dwelling building.		

Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
BuildingPartition	Generalization

Entity name	ElectricHeater	Related views	BIM
Definition	Equipments that heats up a fluid using electricity as its primary energy source and stores it in a tank.		

Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
Tank	Generalization
Boiler	Generalization

Entity name	ElectricalGenerator			Related views	BIM
Definition	Equipments that generate electrical energy.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
nominalVoltage	Voltage of the network where the device is connected.	Float	V		> 0
nominalPower	For dispatchable units, this value represents the economic active power basepoint; for units that are not dispatchable, this value represents the fixed generation value. The value must be between the operating low and high limits.	Float	kW		> 0
minActivePower	Minimum power than can be supplied	Float	kW		> 0
maxActivePower	Maximum power than can be supplied	Float	kW		> 0
globalEfficiency	This is the efficiency of the generator taking into account the complete system (battery, etc.)	Float	%		
Linked entities			**Relation type**		
Generator			Generalization		
WindMill			Generalization		
PV			Generalization		
CHP			Generalization		

Entity name	ElectricalGeneratorSchedule			Related views	SCH
Definition	Describes the electricity generation schedule of a device by adding the reactive power generated.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
reactivePowervalues	The reactive power values corresponding to the schedule	List[Float]	kVAR		
Linked entities			**Relation type**		
GeneratorSchedule			Generalization		

Entity name	ElectricalLoad			Related views	BIM
Definition	Loads that consume electrical energy.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
Load			Generalization		
TV (as an example)			Generalization		

Entity name	ElectricalStorage			Related views	BIM
Definition	Equipments that store electrical energy.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
nominalVoltage	Base voltage of the network where the device is connected.	Float	V		> 0
nominalCapacity	This value represents the economic active power basepoint	Float	kW		
minStateofDischarge	This is the minimum energy of the battery at which it can operate	Float	%		> 0
maxCharge	This is the maximum energy that the battery can store	Float	kWh		
Linked entities			Relation type		
Storage			Generalization		
Battery (as an example)			Generalization		

Entity name	ElectricalStorageSchedule			Related views	SCH
Definition	Describes the electricity generation/consumption schedule of a storage device.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
StorageSchedule			Generalization		

Entity name	EndUser			Related views	RGH
Definition	The end user is one type of user group existing in the FIEMSER system.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
Group			Generalization		

Entity name	EnergyPrices			Related views	ENV
Definition	Stores an hourly evolution of energy prices.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
EnergyPrices	List of prices for the related energy source	List[Float]	€/kWh		
Linked entities			Relation type		
DayAheadPrices			Association		

Entity name	EnergyPricesWebResource			Related views	ENV
Definition	Defines the characteristics of the web resources providing energy prices.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
ipAddress	IP address of the website				
Linked entities			Relation type		
DayAheadPrices			Association		
PrimaryEnergySource			Association		

Entity name	EventLog			Related views	WSN
Definition	Defines events related to the control device installed within the FIEMSER environment. It mainly reflects and identifies the detailed information of the control devices during their execution and operation.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
eventType	The type of the event that is associated and invoked by the control device installed in the environment	String			
eventDescription	The description of the event that is invoked during the device operation	String			
timeOfEvent	The time stamp at which the event is invoked or registered during the operation of FIEMSER	Time			
Linked entities			Relation type		
ControlDevice			Association		

Entity name	FacilityManager			Related views	RGH
Definition	The facility manager is one type of user group existing in the FIEMSER system.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
Group			Generalization		

Entity name	FunctionArea			Related views	RGH
Definition	Identifies a specific functional area within the FIEMSER configuration utilities, including the area used to define system's advices, operate on devices, monitor the building, etc.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
FAName	The name of the Functional Area defined by the FIEMSER system	String			[FAAdvice, FAControlDevice, FABuildingMonitor, FAHomeEquipment, FAPreferenceScenario, FAPreferenceHomeSetting, FAPerformance, FAResourceSchedule]
FADescription	The description of the Functional Area defined by the FIEMSER system	String			

Linked entities	Relation type
Permission	Association

Entity name	Generator			Related views	BIM
Definition	HomeEquipments that generate energy (thermal or electrical).				
Attribute name	Short description	Data type	Unit	Default value	Range of values
averageEfficiency	Average value of the generator efficiency	Float	%	100	> 0

Linked entities	Relation type
HomeEquipment	Generalization
DetailedEfficiency	Association
PrimaryEnergySource	Association
ThermalGenerator	Generalization
ElectricalGenerator	Generalization

Entity name	GeneratorSchedule		Related views		SCH
Definition	Describes the energy generation schedule of a generator.				
Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
ResourceSchedule	Generalization
ElectricalGeneratorSchedule	Generalization
ThermalGeneratorSchedule	Generalization

Entity name	GlobalStrategy		Related views		USR, SCH
Definition	Represents an energy strategy that can be chosen for the energy management system.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Status	Indicates whether the strategy is currently applied or not	Boolean			[Yes,No]
Target	Indicates the type of strategy	String			[EnergyEfficiency, CostEfficiency, MaxLocalEnergy, MaxLocalRenewables]

Linked entities	Relation type
Building	Association

Entity name	Group			Related views	RGH
Definition	Identifies a group of users sharing a set of access rights.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
groupName	The name of the group	String			
priority	The priority of the group (used by the GUI to order and list groups)	String			[Very High, High, Medium, Low, Very Low]
timeOfCreation	Timestamp of the time when the group was first created	Time			

Linked entities	Relation type
User	Association
EndUser	Generalization
FacilityManager	Generalization
Permission	Association

Entity name	HardComponent			Related views	WSN, EPI
Definition	Any hardware component installed on the control device.				
Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
Sensor	Generalization
Actuator	Generalization
CommDevice	Generalization
ControlComponent	Generalization
DataLog	Association

Entity name	HomeDailyMeasurementLog			Related views	EPI
Definition	Provides data about the real energy consumption of each building partition and the simulated consumption of the same partition in the same scenario, but without the control by FIEMSER.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
date	Day of the measurement	Date			
homeEnergyHVAC	Energy consumption in HVAC	Float	kWh		
homeEnergyHotWater	Energy consumption in hot water	Float	kWh		
homeEnergyLighting	Energy consumption in lighting	Float	kWh		
homeTotalEnergyConsumption	Total energy consumption in the home	Float	kWh		
homeTotalEnergyGeneration	Total energy generation in the home	Float	kWh		
rBEnergyHVACConsumption	Reference building energy consumption in HVAC	Float	kWh		
rBEnergyHotWater	Reference building energy consumption in hot water	Float	kWh		
rBEnergyLighting	Reference building energy consumption in lighting	Float	kWh		
rBTotalEnergyConsumption	Reference building total energy consumption	Float	kWh		
rBTotalEnergyGeneration	Reference building total energy generation	Float	kWh		
homeEnergyHVACCost	Energy consumption cost for HVAC	Float	€		
homeEnergyHotWaterCost	Energy consumption cost for hot water	Float	€		
homeEnergyLightingCost	Energy consumption cost for lighting	Float	€		
homeTotalEnergyConsumptionCost	Total Energy consumption cost in the home	Float	€		
homeTotalEnergyGenerationValue	Total Energy generation value in the home	Float	€		
rBEnergyHVACCost	Energy consumption cost for HVAC in the reference building	Float	€		
rBEnergyHotWaterCost	Energy consumption cost for hot water in the reference building	Float	€		
rBEnergyLightingCost	Energy consumption cost for lighting in the	Float	€		

	reference building				
rBEnergyTotalCost	Total Energy consumption cost in the home in the reference building	Float	€		
rBTotalEnergyGenerationValue	Total Energy generation value in the reference building	Float	€		

Linked entities	Relation type
BuildingPartition	Association

Entity name	HomeEquipment	Related views	BIM, WSN, USR, SCH, EPI
Definition	Any home appliance or mechanism to increase building energy efficiency.		

Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
Device	Generalization
Load	Generalization
Storage	Generalization
Generator	Generalization
Mechanism	Generalization
OperationMode	Association
ControlComponent	Association

Entity name	HomeUsageProfile	Related views	USR, SCH, ADV
Definition	Defines different profiles for the daily usage of a building partition (typically a dwelling).		

Attribute name	Short description	Data type	Unit	Default value	Range of values
name	Name of the profile (e.g. “working day”)	String			

Linked entities	Relation type
BuildingPartition	Association
Calendar	Association
ZoneUsageProfile	Aggregation
ControlRule	Association

Entity name	KNX			Related views	WSN
Definition	KNX is an OSI-based network communication protocol for intelligent building, and it covers the whole stack from presentation down to physical layer. It mainly supports several communication media, such as twisted pair, powerline, radio frequency and Ethernet.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
NetProtocol			Generalization		

Entity name	Load			Related views	BIM, USR, SCH
Definition	Sub-types of Home Equipments that consume energy (thermal or electrical).				
Attribute name	Short description	Data type	Unit	Default value	Range of values
shiftable	Capability of the load to be shifted	Boolean			
priority	Priority to feed this load when there are energy restrictions	Integer		0	> 0
Linked entities			Relation type		
HomeEquipment			Generalization		
ThermalLoad			Generalization		
ElectricalLoad			Generalization		
ApplianceUsage			Association		

Entity name	Location			Related views	ENV, SCH
Definition	Defines the location of the building.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
longitude	Position of the house relatively to the Greenwich meridian (GPS figure)	Float	degree	0°0’0”	-180° to 180°
latitude	Position of the house relatively to the Equator (GPS figure)	Float	degree	0°0’0”	-90° to 90°
altitude	Elevation of the house relatively to sea level	Integer	meter	0	-200 to 3000
country	Country where the house is built	String			

Linked entities	Relation type
WeatherForecast	Association
Building	Association

Entity name	Luxometer			Related views	WSN, EPI
Definition	Sensor that measures the light flux.				
Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
MeasurementSensor	Generalization

Entity name	MeasurementSensor			Related views	WSN, EPI
Definition	Sensors that collect data about analog variables.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
minValue	Minimum value that can be read by the sensor	Float			
maxValue	Maximum value that can be read by the sensor	Float			

Linked entities	Relation type
Sensor	Generalization
Thermostat	Generalization
Luxometer	Generalization

<table>
<tr><td>Entity name</td><td colspan="2">Mechanism</td><td colspan="2">Related views</td><td>BIM</td></tr>
<tr><td>Definition</td><td colspan="5">Control mechanisms that are installed in the home to increase its energy efficiency, but don’t generate or consume energy by themselves.</td></tr>
<tr><td>Attribute name</td><td>Short description</td><td>Data type</td><td>Unit</td><td>Default value</td><td>Range of values</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Linked entities</td><td colspan="3">Relation type</td></tr>
<tr><td colspan="3">HomeEquipment</td><td colspan="3">Generalization</td></tr>
<tr><td colspan="3">Blinder (as an example)</td><td colspan="3">Generalization</td></tr>
<tr><td colspan="3">ShadeControl</td><td colspan="3">Association</td></tr>
</table>

<table>
<tr><td>Entity name</td><td colspan="2">ModBUS</td><td colspan="2">Related views</td><td>WSN</td></tr>
<tr><td>Definition</td><td colspan="5">ModBus is a standardized communication protocol in the industry, where it is mainly used to interconnect industrial electronic devices that fulfil the needs of the building community prior to BACnet.</td></tr>
<tr><td>Attribute name</td><td>Short description</td><td>Data type</td><td>Unit</td><td>Default value</td><td>Range of values</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Linked entities</td><td colspan="3">Relation type</td></tr>
<tr><td colspan="3">NetProtocol</td><td colspan="3">Generalization</td></tr>
</table>

<table>
<tr><td>Entity name</td><td colspan="2">NetProtocol</td><td colspan="2">Related views</td><td>WSN</td></tr>
<tr><td>Definition</td><td colspan="5">Identifies all the entities that are related to the networking protocol used for communication purposes.</td></tr>
<tr><td>Attribute name</td><td>Short description</td><td>Data type</td><td>Unit</td><td>Default value</td><td>Range of values</td></tr>
<tr><td>protocolName</td><td>Network protocol supported for different devices</td><td>String</td><td></td><td></td><td>[KNX, ModBUS, 6LowPan, etc.]</td></tr>
<tr><td>version</td><td>Protocol version</td><td>String</td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Linked entities</td><td colspan="3">Relation type</td></tr>
<tr><td colspan="3">CommDevice</td><td colspan="3">Association (One to Many)</td></tr>
<tr><td colspan="3">KNX</td><td colspan="3">Generalization</td></tr>
<tr><td colspan="3">ModBus</td><td colspan="3">Generalization</td></tr>
<tr><td colspan="3">Zigbee</td><td colspan="3">Generalization</td></tr>
</table>

Entity name	Opening		Related views	BIM	
Definition	Identifies the openings in a surface, as windows, doors, etc. The opening can be just a hole.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
idGBxml	Identifier of the Opening object in the GBxml file	String			
openingType	The type of opening	String			[FixedWindow, OperableWindow, FixedSkylight, OperableSkylight, SlidingDoor, NonSlidingDoor, Air]
Linked entities			**Relation type**		
Surface			Aggregation		
ShadeControl			Association		

Entity name	OperationMode		Related views	BIM, USR, SCH	
Definition	Defines the operation modes available for each home equipment.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
name	Name of the operation mode	String			
mode	Sequential number of the different operation modes	Integer			
averagePower	Average power consumption or generation. This value is useful when the HomeEquipment operation is estimated by the operation time. For example, a 100 W lamp is "on" by 1 hour.	Float	W		
averageEnergy	Average energy consumption or generation. This value is useful when the HomeEquipment operation is estimated by	Float	Wh		

	the number of operation. For example, a single shower uses 1.4 kWh.				

Linked entities	Relation type
HomeEquipment	Association
DetailedOperationMode	Association
ApplianceUsage	Association

Entity name	Order			Related views	ADV
Definition	Links the control rule with the advice to be sent to the user and with the control actions that have to be executed if the user accepts the advice.				
Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
ControlRule	Association
Advice	Association
Building	Association
ControlAction	Association

Entity name	Orientation			Related views	ENV, SCH
Definition	Defines the orientation of the building.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
NorthDegrees	Angle between the house front wall and the North	Float	Degree	180°	-180° to 180°
EastDegrees	Angle between the house front wall and the East	Float	Degree	90°	-180° to 180°

Linked entities	Relation type
Building	Association

Entity name	PV			Related views	BIM
Definition	An electricity generator that uses the sun radiation as primary energy source.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
ElectricalGenerator			Generalization		

Entity name	Permission			Related views	RGH
Definition	Represents a single permission to perform a specific operation within a specific functional area.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
permissionName	The name of the permission granted for the users	String			
createdBy	The details of user, who creates the permission	String			
timeOfCreation	The time when the permission was created	Time			
Linked entities			Relation type		
Group			Association		
PermissionType			Association		
FunctionArea			Association		

Entity name	PermissionType		Related views	RGH	
Definition	Contains information about which kind of actions or operations are granted for the users during the interaction within the FIEMSER system.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
nameOfPermissionType	The name of the permission type that could be selected by the FIEMSER user.	String			[PTAdd, PTEdit, PTRemove, PTExecute, PTList]
descriptionOfPersmissionType	The description of the permission type that can be selected by the FIEMSER user.	String			
Linked entities			**Relation type**		
Permission			Association		

Entity name	Presence		Related views	WSN, EPI	
Definition	Sensor that detects motion and changes state.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
Linked entities			**Relation type**		
StateSensor			Generalization		

Entity name	PrimaryEnergySource			Related views	ENV, BIM
Definition	Specifies the energy sources that are used in the system.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
name	Name of the energy source	String			
code	Number that is associated to the energy source	Integer		0	[0→Electricity 1→Diesel 2→Natural Gas 3→Wind 4→Sun]
renewable	Tells if the energy source is renewable or not.	Boolean			[0→No 1→Yes]

Linked entities	Relation type
Generator	Association
EnergyPricesWebResource	Association
ContractedEnergySupply	Association

Entity name	PushButton			Related views	WSN, EPI
Definition	Sensor that changes its state based on the pressure done by a user.				
Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
StateSensor	Generalization

Entity name	Radiator			Related views	BIM
Definition	A thermal load that has a heat exchanging role and is used for heating building spaces.				
Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
ThermalLoad	Generalization

Entity name	ResourceSchedule			Related views	SCH, EPI
Definition	Generalization of the schedules of all resources that described the power use/generation schedule.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
powerValues	The power values corresponding to the schedule	List[Float]	kW		
dataQuality	The quality values corresponding to the schedule	List[String]			[Estimated, Calculated]

Linked entities	Relation type
BuildingProgrammedSchedule	Composition
StateBasedLoadSchedule	Generalization
ThermalBasedLoadSchedule	Generalization
GeneratorSchedule	Generalization
StorageSchedule	Generalization
Device	Association

Entity name	Scene			Related views	USR, SCH
Definition	Defines scenes (specific usages of a building, in terms of comfort and appliances usage).				
Attribute name	Short description	Data type	Unit	Default value	Range of values
type	Name of the scene (e.g. “dinner”)	String			
description	Description of the scene	String			
initTime	Time of the start of the scene	Time			
endTime	Time of the end of the scene	Time			

Linked entities	Relation type
ZoneUsageProfile	Association
ApplianceUsage	Aggregation
ComfortSetting	Association

Entity name	Sensor			Related views	WSN, EPI
Definition	Any sensing hardware installed on the Control Device (e.g. temperature, humidity, light sensors...).				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
sensorType	Definition of sensor type (e.g. Temperature, Humidity, Light...)	String			
sampleRate	Frequency at which the sensor is currently sampling data	Integer	Hz		
accuracy	Accuracy of the sensor				

Linked entities	Relation type
Actuator	Association
HardComponent	Generalization
StateSensor	Generalization
MeasurementSensor	Generalization

Entity name	ShadeControl			Related views	BIM
Definition	Represents a criterion to help determine if the shades will be open or closed.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
idGBxml	Identifier of the ShadeControl object in the GBxml file	String			
type	Define the relation with the opening	String			[InteriorInsulated, InteriorUnInsulated, ExternalInsulated, ExternalUnInsulated]

Linked entities	Relation type
Opening	Association
Mechanism	Association

Entity name	Shadowing		Related views	ENV, SCH	
Definition	Defines the main shading conditions on photovoltaic array.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
shading	Percentage area indicating shadow on the PV array	Float	%		0 - 100
Linked entities			Relation type		
Building			Association		

Entity name	SoftComponent		Related views	WSN	
Definition	Any software component installed on the Control Device to deliver sensing/acting control behaviour.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
version	Version of the software (used to identify API, capabilities, etc.)	String			
Linked entities			Relation type		
ControlComponent			Generalization		

Entity name	SolarHeater		Related views	BIM	
Definition	A thermal generator that uses the sun radiation as primary energy source.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
ThermalGenerator			Generalization		

Entity name	StateBasedLoadSchedule		Related views		SCH
Definition	Describes the schedule of those resources that are represented by digital values, such as their on/off operation, along with the power they consume/generate. For example, for a washing machine it would include the beginning of its operation and the end of it.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
stateValues	The state values corresponding to the schedule	List[Boolean]			[0→Off 1→On]
Linked entities			**Relation type**		
ResourceSchedule			generalization		

Entity name	StateSensor		Related views		WSN, EPI
Definition	Sensors that collect data about status.				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
Linked entities			**Relation type**		
Sensor			Generalization		
PushButton (as an example)			Generalization		
Presence (as an example)			Generalization		

Entity name	Storage		Related views		BIM
Definition	HomeEquipments that store energy (thermal or electrical).				
Attribute name	**Short description**	**Data type**	**Unit**	**Default value**	**Range of values**
averagePowerLosses	Average value of the thermal or electrical losses in the time	Float	kW	0	> 0
Linked entities			**Relation type**		
HomeEquipment			Generalization		
DetailedLosses			Association		
ThermalStorage			Generalization		
ElectricalStorage			Generalization		

Entity name	StorageSchedule			Related views	SCH
Definition	Describes the energy generating/consuming schedule of a storage device.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
ResourceSchedule			Generalization		
ElectricalStorageSchedule			Generalization		
ThermalStorageSchedule			Generalization		

Entity name	Surface			Related views	BIM
Definition	Defines the surfaces that delimit a BuildingSpace or a BuildingZone.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
idGBxml	Identifier of the Surface object in the GBxml file	String			
Linked entities			Relation type		
Opening			Aggregation		
BuildingZone			Aggregation		
AdjacentSpace			Association		

Entity name	Switch			Related views	WSN, EPI
Definition	Actuator that changes state upon the reception of a signal.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
Actuator			Generalization		

Entity name	SwitchingCTRLAct		Related views	ADV	
Definition	Describes a control action associated to a switching operation that only changes the state of the actuator.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
state	Tells the state of the actuator after executing the action	Boolean			
Linked entities			Relation type		
ControlAction			Generalization		

Entity name	TV		Related views	BIM	
Definition	An electrical load used for entertainment.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
ElectricalLoad			Generalization		

Entity name	Tank		Related views	BIM	
Definition	A thermal storage that stores a hot fluid.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
ThermalStorage			Generalization		

Entity name	TemperaturedSchedule		Related views	SCH	
Definition	Describes the schedule of temperatures for each specific BuildingSpace and according to the planned schedule for the building.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
temperatureValues	The temperatures corresponding to the schedule	List[Float]	°C		
Linked entities			Relation type		
BuildingProgramedSchedule			Association		
BuildingSpace			Association		

Entity name	ThermalBasedLoadSchedule		Related views		SCH
Definition	Describes the thermal based loads, like the HVAC, electric heater, that have their consumption in kW and their control is based on the values assigned to the thermostat.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
ResourceSchedule			Generalization		

Entity name	ThermalGenerator		Related views		BIM
Definition	Equipments that generate thermal energy.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
Generator			Generalization		
SolarHeater			Generalization		
Boiler			Generalization		
CHP			Generalization		

Entity name	ThermalGeneratorSchedule		Related views		SCH
Definition	Describes the thermal generation schedule of a device by adding the temperature values.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
temperatureValues	The temperatures corresponding to the schedule	List[Float]	°C		
Linked entities			Relation type		
GeneratorSchedule			Generalization		

Entity name	ThermalLoad			Related views	BIM
Definition	Loads that consume thermal energy.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
Load			Generalization		
Radiator (as an example)			Generalization		

Entity name	ThermalStorage			Related views	BIM
Definition	Equipments that store thermal energy.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
volume	Capacity of the tank	Float	m3		> 0
specificHeat	Thermal capacity of the fluid in the tank	Float	kWh/ ºC		> 0
minTemperature	Minimum operation temperature	Float	ºC		
maxTemperature	Maximum operation temperature	Float	ºC		
Linked entities			Relation type		
Storage			Generalization		
Tank (as an example)			Generalization		

Entity name	ThermalStorageSchedule			Related views	SCH
Definition	Describes the thermal generation/consumption schedule of a storage device by showing the evolution of the temperatures.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
temperatureValues	The temperatures corresponding to the schedule	List[Float]	ºC		
Linked entities			Relation type		
StorageSchedule			generalization		

Entity name	Thermostat			Related views	WSN, EPI
Definition	Sensor that measures temperature values.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
Linked entities			Relation type		
MeasurementSensor			Generalization		

Entity name	User			Related views	RGH
Definition	Gathers users of the FIEMSER system.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
userName	The name of the registered user	String			
password	The password of the registered user	String			
gender	The gender of the user	String			[Male,Female]
dateOfBirth	The date of birth of the registered user	Date			
location	Location where the user uses the FIEMSER system	String			
email	Email address of the registered user	String			
isOnline	Status whether the user is using the system	Boolean			
isAnonymous	Status whether the user is registered or not	Boolean			
isAuthenticated	Status whether the registered user is logged in or not	Boolean			
timeOfReg	The time of registration of the user	Time			
timeOfLastVisit	The time of last visit of the registered user	Time			
Linked entities			Relation type		
Group			Association		
Building			Association		
BuildingPartition			Association		

Entity name	WeatherData		Related views	ENV	
Definition	Stores the hourly evolution of weather.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
weatherDataValues	List of hourly values for the related weather parameter	List[Float]			

Linked entities	Relation type
WeatherForecast	Association
WeatherDataType	Association

Entity name	WeatherDataType		Related views	ENV	
Definition	Stores the possible weather parameters.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
type	Name of the weather parameter	String			

Linked entities	Relation type
WeatherData	Association
WeatherWebResource	Association

Entity name	WeatherForecast		Related views	ENV, SCH	
Definition	Represents the weather forecast.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
date	Day of the forecast	Date			
initTime	Start of the period where weather is forecast	Time			
endTime	End of the period where weather is forecast	Time			
state	Indicates if the weather forecast is valid or obsolete	Boolean			[0→obsolete 1→valid]

Linked entities	Relation type
Location	Association
WeatherWebResource	Association
WeatherData	Association

Entity name	WeatherWebResource		Related views	ENV	
Definition	Defines the characteristics of the web resources providing weather data.				
Attribute name	Short description	Data type	Unit	Default value	Range of values
IpAddress	IP address of the website				

Linked entities	Relation type
Building	Association
WeatherForecast	Association
WeatherDataType	Association

Entity name	WindMill		Related views	BIM	
Definition	An electricity generator that uses the wind as primary energy source.				
Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
ElectricalGenerator	Generalization

Entity name	Zigbee		Related views	WSN	
Definition	Zigbee is a suite of high level communication protocols that are used over IEEE 802.15.4 standard. It is a proprietary networking protocol that supports multiple wireless devices, using features from the underlying IEEE 802.15.4 communication medium.				
Attribute name	Short description	Data type	Unit	Default value	Range of values

Linked entities	Relation type
NetProtocol	Generalization

<table>
<tr><td>Entity name</td><td colspan="2">ZoneUsageProfile</td><td colspan="2">Related views</td><td>USR, SCH</td></tr>
<tr><td>Definition</td><td colspan="5">Define different profiles for the usage of a building zone.</td></tr>
<tr><td>Attribute name</td><td>Short description</td><td>Data type</td><td>Unit</td><td>Default value</td><td>Range of values</td></tr>
<tr><td>Name</td><td>Name of the profile for the zone usage (e.g. usage of bedrooms for working day)</td><td>String</td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Linked entities</td><td colspan="3">Relation type</td></tr>
<tr><td colspan="3">HomeUsageProfile</td><td colspan="3">Aggregation</td></tr>
<tr><td colspan="3">Scene</td><td colspan="3">Association</td></tr>
<tr><td colspan="3">BuildingZone</td><td colspan="3">Association</td></tr>
</table>