PROJECT FINAL REPORT

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1. Final publishable summary report

1.1 Executive Summary

KnoHolEM improves energy efficiency of public buildings (by up to 30%) in Europe by offering a system that monitors energy consuming devices and informs negotiable energy optimization plans, orchestrated by the building energy manager, taking into account a wide range of objectives, including occupants' comfort. This is achieved through progressive cycles of integration of computer models, including the BIM (Building Information Model) and energy simulation models, used to predict and manage energy efficient behaviour. This aims to overcome the high variety, and resulting extant incompatibility, of the different models currently used in the construction and building management industry, while responding to on-going dynamic changes in usage and configuration of individual buildings.

The energy savings that are realised are achieved by the development of a machine learning environment that determines the most appropriate usage (i.e. control set points) of energy consuming devices and electronically operated building components (including windows and blinds) based upon occupant usage patterns that are analysed against the energy building model and the historic energy usage data from the building. From this analysis the KnoholEM system determines the most appropriate action to take in order to minimise consumption. This information is fed by a gaming environment to the Facilities Manager where he/she can let the system run or override if they feel that another course of action is required. For instance this could occur when the Facilities Manager is receiving real time information form the building occupant's via the user in the loop interface.

One of the major challenges that this project is aiming to overcome is the interoperability and usage of data in order to monitor and control the energy consumption within the building. Building information models go some way to alleviating this, especially when using standardised Industry Foundation Classes (IFC) as a meta-model.

KnoHolEM applies a holistic, knowledge based approach that maps disparate models into a single, open ontology format, augmented with dynamic energy saving rules. In this way the relevant elements from different models can be easily captured, filtered, searched, mapped and interlinked. Existing tools and platforms can be leveraged to use this schema to flexibly extend, tune and manage the evolution of the open model schema and to import, share and query over data instances from different sources. A Visualisation capability has been developed to provide stakeholders with visual interfaces to easily create logical relationship between elements derived from different models to define rules that model the dynamic behaviour of different elements. Key here is the ability to put the user in the loop, allowing building occupants to directly visualise and interact with useful projections of the model so that they can provide progressively more accurate details about their typical behaviour in interacting with the building and devices contained therein or about problems they experience with comfort levels or other building automation features. These tools interface with existing energy modelling tools, building control systems and operational log feeds to support the iterative and increasingly accurate modelling of energy efficiency-related behaviour through correlation and analysis of energy modelling predictions, energy system control rules and building performance data. This subsequently allows the buildings Facility Managers to control the energy performance of the building in a real time 'user in the loop' framework in an easy to use 3D model that will therefore provide improved thermal comfort of the occupants and reduced energy consumption by only providing the energy required for the occupants in the building at any given time.

The solution has been implemented and validated in two buildings, i.e. Blue Net (office) in Seville, Spain and the 'Forum' (extra care scheme) in Eersel, Holland.

1.2 Project Context and Objectives

The project is targeting the issues of improved energy management in buildings, based on real time data models that help the Facilities Manager to control the building in an informed holistic manner. This, in turn, will promote energy reduction and reduce the gap between predicted and real energy consumption.

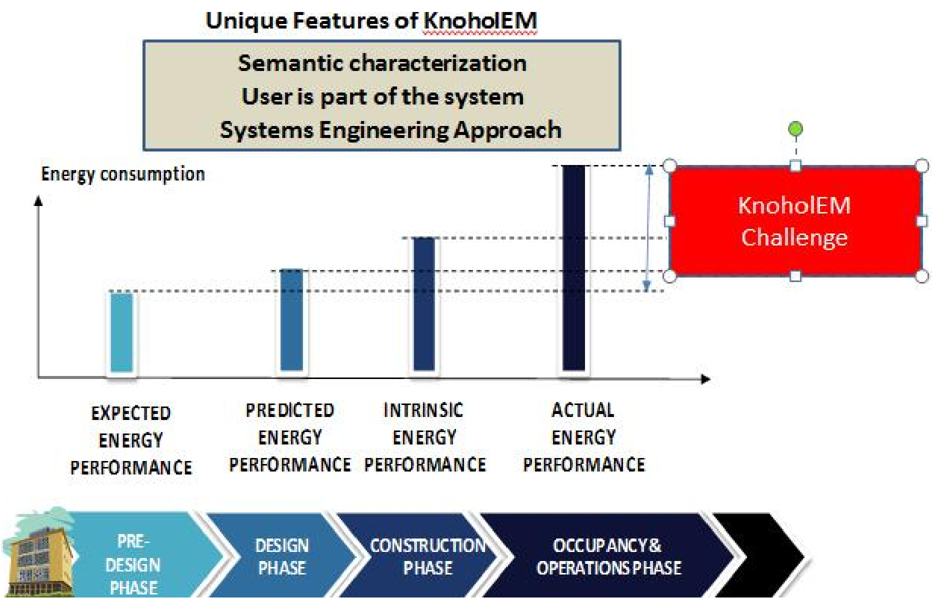


Figure 1 Energy Performance Gaps: The Need for the KnoholEM Solution

The KnoHolEM project aims to develop an intelligent building energy management system for facilities managers, using an underlying knowledge-base, based on a holistic view comprising different aspects of a building. Based on a state-of-the-art prediction and decision making engine, the facilities manager is updated in real time about the performance of their building and how to improve it. The system will constitute an intuitive interface enabling them to interact with their buildings in a more informed and more effective way than ever before.

Utilising artificial intelligence techniques which mimic the way the human brain learns, data from the building continuously trains the decision-making capabilities of the system. This provides a dynamic solution to meeting the requests of the facilities manager, such as reducing energy consumption or carbon dioxide emissions. Coupled with an ontological knowledge base and fuzzy reasoning controllers, the KnoholEM solution provides robust, flexible and expandable system architecture.

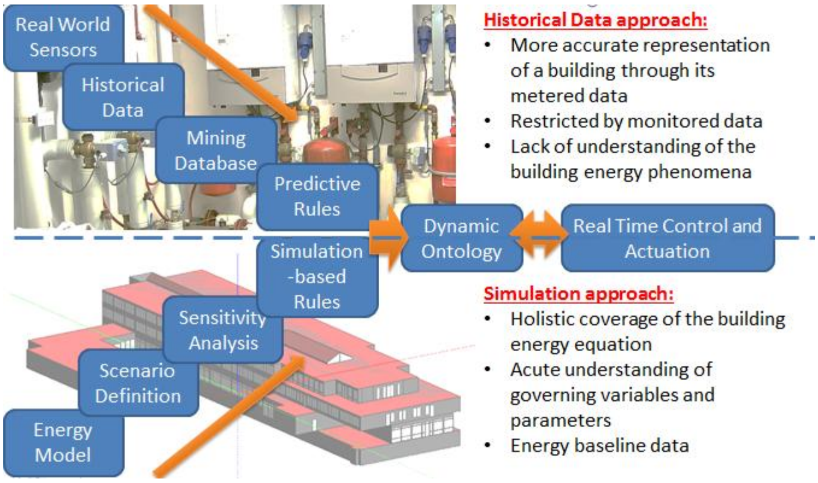


Figure 2 – The usage of real time monitoring data with modelled performance using a dynamic ontology

The system will allow users to establish an integrated view of energy consumption in each specific zone, as well as for the building as a whole. With the help of a building automation system and other metering systems installed on site the energy consumption can be expressed in various ways including: energy consumption per appliance; per group of appliances; per building zone; per user event. It can also be related to variables including occupant activities; building element states; environmental parameters such as humidity, temperature, and light intensity.

Currently, facilities managers utilise building management systems to affect the performance of their building. This relies on their experience and judgment to actuate various separate systems, and to estimate their impact on one another.

The KnoholEM solution acts automatically to reduce uncertainty by allowing a real-time energy profiling of the building. The system then suggests energy saving rules, informed by real-time data, to improve the performance of the building.

The knowledge base is represented in a form of ontology described using the OWL (Ontology Web Language). Basically two types of ontologies have been developed within the project:

- The generic ontology which represents domain knowledge for building holistic energy management. It contains definitions, terminologies (T-box), and taxonomies that are aligned with IFC. The information model contained in the generic ontology is applicable in any building. The development of generic ontology is the main objective of the activities within Work Package 1. The generic ontology covers the information model for both static and dynamic aspects of buildings. The consideration of multi-aspect in information modeling offers an holistic view of the building.
- The generic ontology is populated and extended with building specific information resulting in more building specific ontologies corresponding to the specific buildings. The creation of building specific ontologies is achieved through the activities performed in the Work Package 2. There are different methods to develop the building specific ontologies. The ontology representation of knowledge base equipped with rules and axioms offers reasoning capabilities that address information incompleteness, uncertainty and interoperability issues.

The knowledge base is generated from human knowledge as well as from knowledge extracted from different data representing the building and background environmental conditions such as temperature and weather. This kind of data is collected through sensors and building automation systems. It contains information related to monitored data, building geometry, installed sensors positioning and type, user activity and behavior related data, intelligent learning algorithms that are on a later stage integrated to rules for energy optimization, generated from simulated predicted energy consumption. It represents the main interface between the generated rules trough energy modelling simulation and the real mapped from field sensor values.

Algorithms have been developed to store in near to real time monitored data coming from the measuring devices/sensors in the data mining database. Depending on the particular case (particularities of the BMS installed and existing sensors), data is retrieved on every 10 minutes or 8 minutes. The KnoHolEM **Energy Real Time Controller (EnRTC)** collects the building actual states and map it through fuzzy logic to the optimal energy usage identified by data mining algorithms and the simulated energy optimization rules. The activities represent one of the highest technical complexity in the project and will be further explained in the detailed Work Package 3 description. In order to ensure the applicability of the developed solution in different demonstration objects, it is necessary to establish an understanding of how the demonstration objects work: energy use within the buildings, and the interaction of the building occupants with the building and its services. The tasks related to this are performed in Work Package 5. For each demonstration building, the functional requirements and constraints are defined. It also includes establishing an energy audit for each building, including envelope, fabric, and existing monitoring and management devices. This led to different scenarios for energy analysis and optimisation for each building, and the development of an energy and thermal model derived from the defined scenarios. The energy model is used as the basis to build an information model and to generate rules in the knowledge base in order to execute the energy analysis and optimisation algorithm.

An important part of all software is the user interface. The KnoHolEM project aims to deliver a user-friendly energy visualisation and reporting service that will transmit to the FM the KnoholEM suggestions. The Smart Building simulator or the "**User in the loop**" was developed as a visualisation tool to improve user involvement and increase awareness of energy performance. It represents also the final project outcome, the framework that integrates all KnoholEM tools and has interfaces to the specific ontologies and the data mining database. The suggestions provided by EnRTC are presented in the visualisation tool. Additionally the tool offers the user interaction, so that the users are able to choose type of rule and % of energy savings. In this way the KnoholEM solution enables a user oriented strategy for energy savings. Depending on his personnel preferences the FM or building owner can apply different strategies, for example reduce electricity, heating or cooling etc. The detailed descriptions and achievements of the tasks can be seen in section.

The KnoholEM User in the loop provides to the building owners also access to historical data. He can check what exactly the monitored data on a particular day and hour was and compare it to the current one.

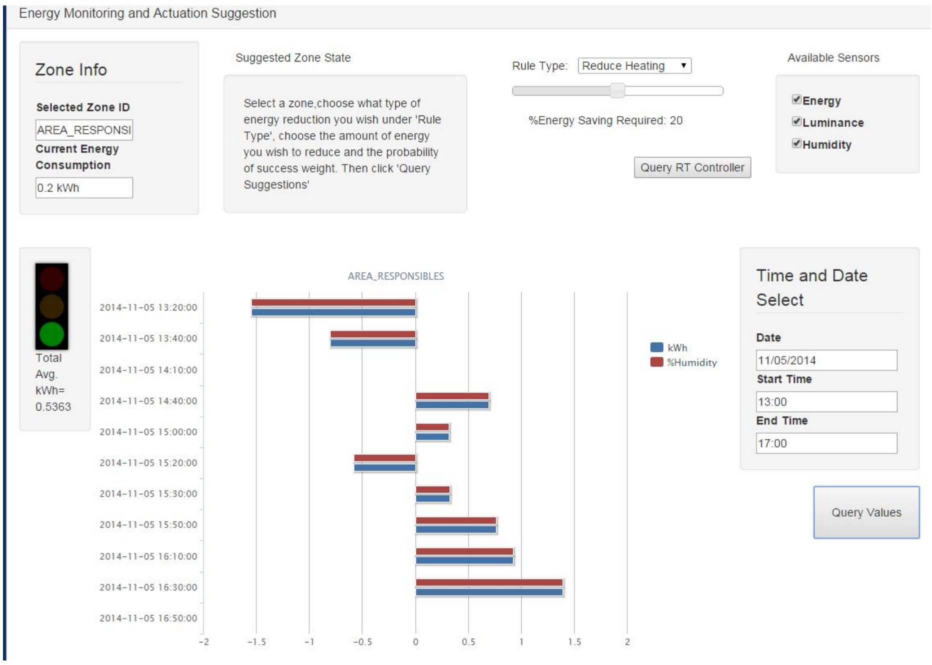


Figure 3 - KnoholEM "User in the loop" (data from the Blunet building

The KnoHolEM development methodology comprises five work packages and is reflected in the KnoHolEM system architecture. The system architecture of the KnoHolEM solution is depicted in Figure 4.

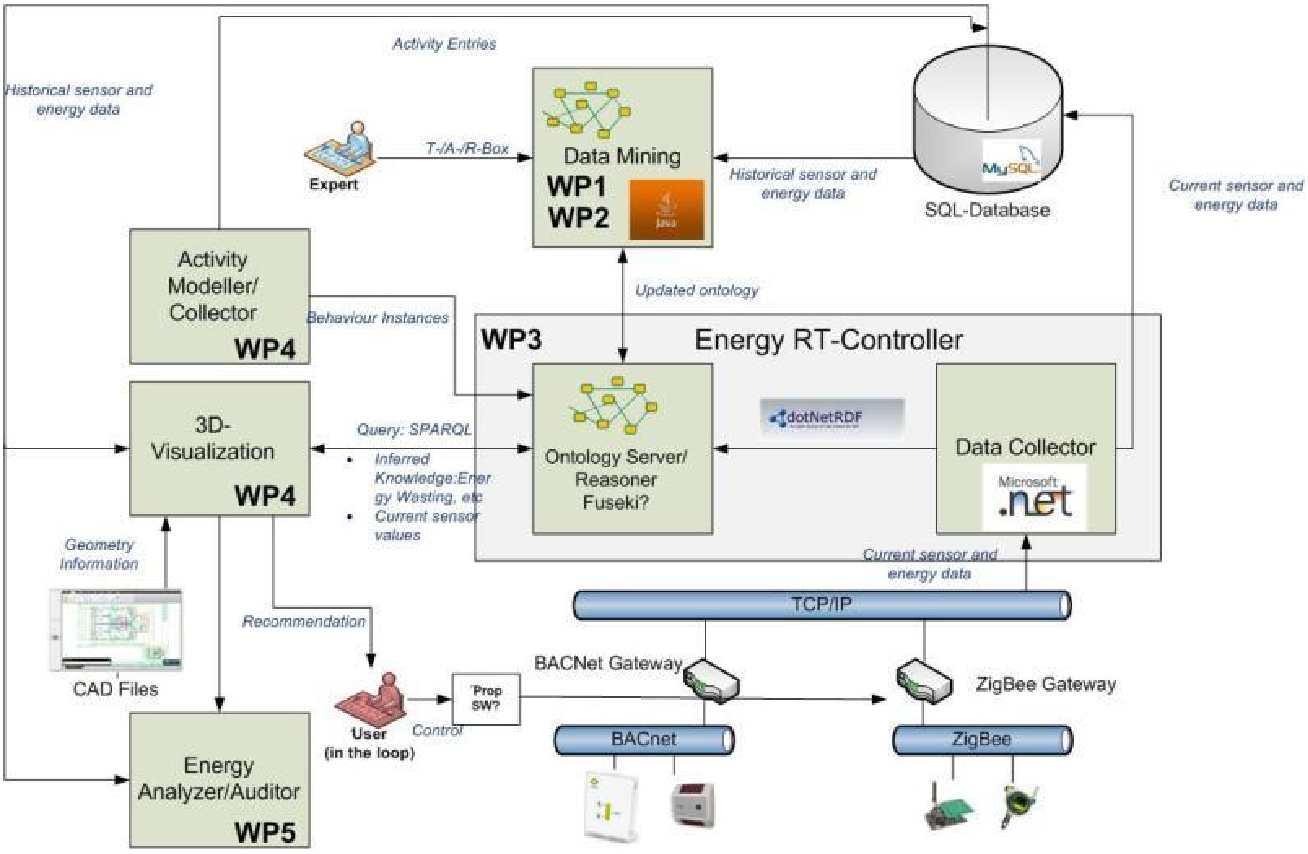


Figure 4 - System Architecture

After the energy audit of the buildings has been performed and most of the required system components identified and conceptualized, the KnoholEM team elaborated a process to deliver the KnoholEM solution that has been applied to all five demo objects. This process is shown on Figure 5. We concentrated to deliver run first the KnoholEM solution on 2 buildings (FORUM and Blunet) and then on the other three. The biggest challenge was to map the simulated energy optimization rules to the real values coming from the sensors in the buildings, so predicted energy consumption could be compared to actual and appropriate suggestions for improvement provided. During the implementation and after that testing phase, several interactions and additional features were implemented in order to find the most optimal way to run the system. For example, an automatic check of the consistency of the rules is currently performed before to store these to the data mining data base, which means before to “send” them for execution by the RT controller.

The development of the rules themselves and their mapping to the actual building state caused a delay from the initial plan set-up after the second project meeting, which resulted to a delay in the project validation phase. However we achieved to run the KnoholEM system with predicted energy consumption at all five buildings and validate the established process. Currently we believe that with small efforts on optimization side, the KnoholEM solution can be run on every building (with a BMS) for less than 6 months.

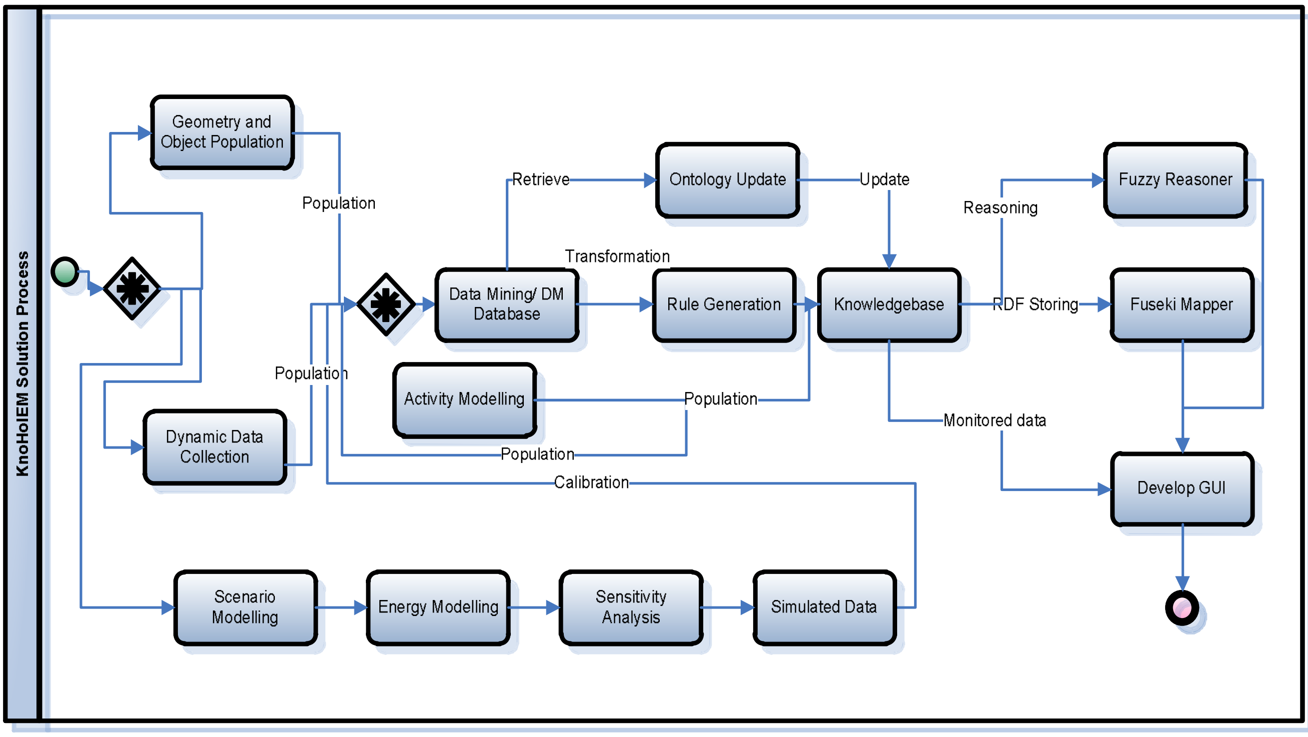


Figure 5: Process to deliver KnoholEM on every building

1.3 Scientific and Technical Objectives and Results

The development methodology that supports the described process for deliver the KnoholEM solution integrates all developments of the project in a framework that could not work without some of its components. The idea behind this concept is that this model can guarantee that in no matter what building with no matter what installed BMS or sensor devices, the KnoholEM solution could be applied and run. Differences could be observed only by the type of suggestions that the system provide to the FM.

An example for that is the MediaTic building where no set points are available. The suggestions provided concern temperature changes and are extracted directly from the simulated rules that could be traced and monitored by installed devices. In other buildings like FORUM and Blunet, where set-points are installed, the system suggests a change in the heating or cooling settings. This approach proved to be a successful one when we needed to deal with very different scenarios from an energy modelling point of view and infrastructure point of view of the buildings and therefore its technical developments and interfaces represent important technical innovation.

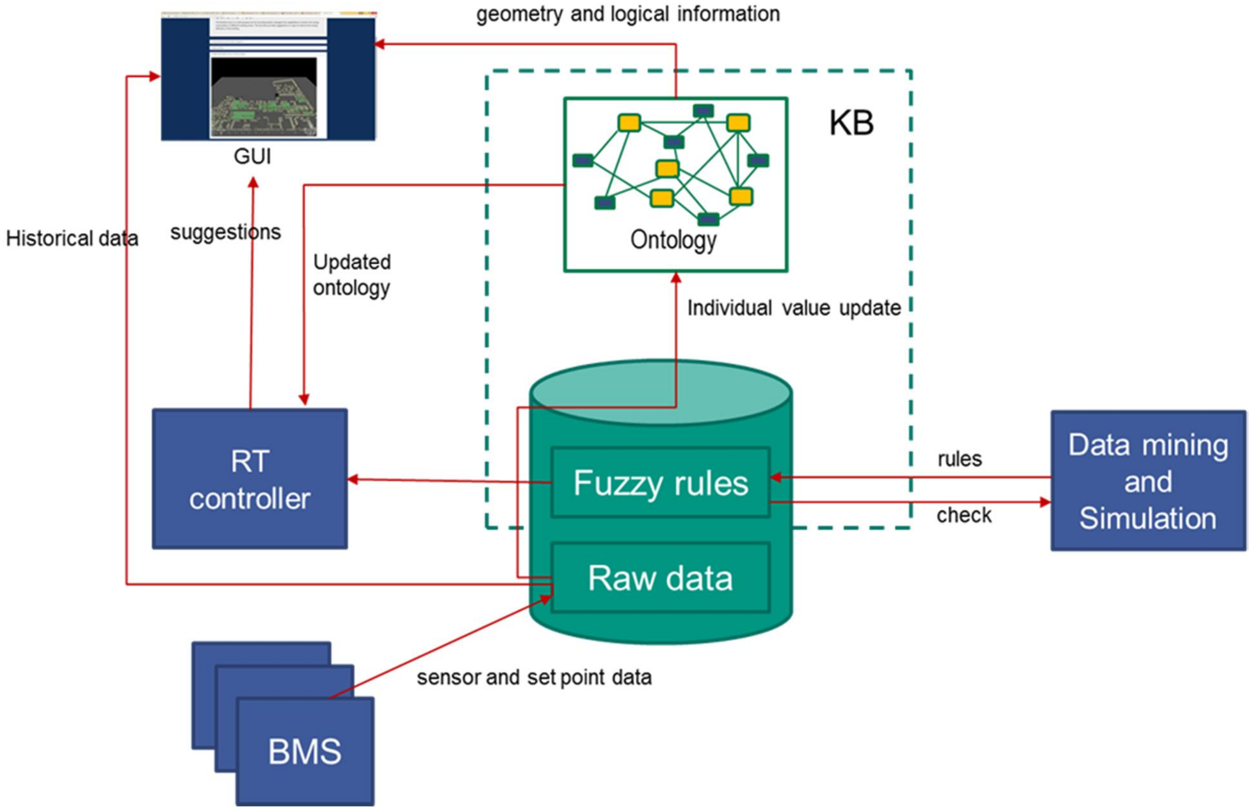


Figure 6 - Implementation of KnoHolEM system

Summary Achievements by Work Packages

Work Package 1

Work package 1 aims to create the generic knowledge base representation of a building including its functionalities. The basic elements are related to:

- constructing a general building taxonomy and a generic building ontology (contains the structure, definitions, and taxonomy of domain knowledge of energy management in building);
- generation of a generic building ontology aligned with IFC entities that will serve as the main input for the creation of a specific ontology for each building in WP2;
- development of a methodology for specific ontology enhancement and population with sensor, building element, placement and SWRL enrichment information . This includes also the development of a concept for enrichment of the ontology with simulated rules that are combined with the SWRL and reinforce a scenario based approach for each building.

The IFC alignment with the Knoholem solution has been ensured by the ontological representation of the building. The OWL-DL language has been used for ontological representation combined with SWRL rules that permit to make explicit knowledge regarding the information gathered from the buildings. To keep the alignment with IFC, we develop an IFC-OWL mapping mechanism implemented using OWL class annotation. The class annotation maps the OWL classes to IFC entities and IFC enumeration elements. The annotation corresponds to IfcEntity maps an OWL class to an IfcEntity, whereas a combination of annotations correspondtoIfcEntity and correspondsToIfcEnumerationElement relates the OWL class to an IFC enumeration type and value.

The creation of the initial generic building ontology has been based on core classes that include:

- Building structures, elements and functions
- Building controls (sensors, actuators etc)
- General user behaviour
- Building geometry (positions etc)

The generic ontology is then deployed with the following steps in order to achieve a specific for each building representation (in WP2) that becomes the main part of the KnoholEM knowledge base.

<u>Step 1</u>: Creation of core OWL classes, properties, axioms and rules by a domain expert. In the project the domain expert is the KnoholEM project consortium.

<u>Step 2</u>: Definition between OWL class and entities in the building information standards, for example IFC. This step is also performed by the domain expert.

Development of the building specific ontology

<u>Step 3</u>: Population of ontology classes related to the static elements of the building (BuildingElement). The population is done by using the OntoCAD tool that is developed in WP2.The population process should be performed by the facility manager or someone who has good knowledge in the architecture and structure of the building.

<u>Step 4</u>: Population of ontology classes related to the user behavior. This is accomplished by using the behavior modelling tool developed in WP4. It is done by the occupants or facility managers.

<u>Step 5</u>: Enrichment of the knowledge base with the rules generated semi-automatically by applying data mining and machine learning algorithms (by developing a knowledge discovery in databases process). We developed a data mining framework as the result of WP2.

<u>Step 6</u>: Manual ontology population and extension based on building specific information, such as the actor, goals, and states.

The established methodology provides a “guideline” to develop the building specific ontology and is implemented in the frame of WP2.

This task was performed mainly in Y2.

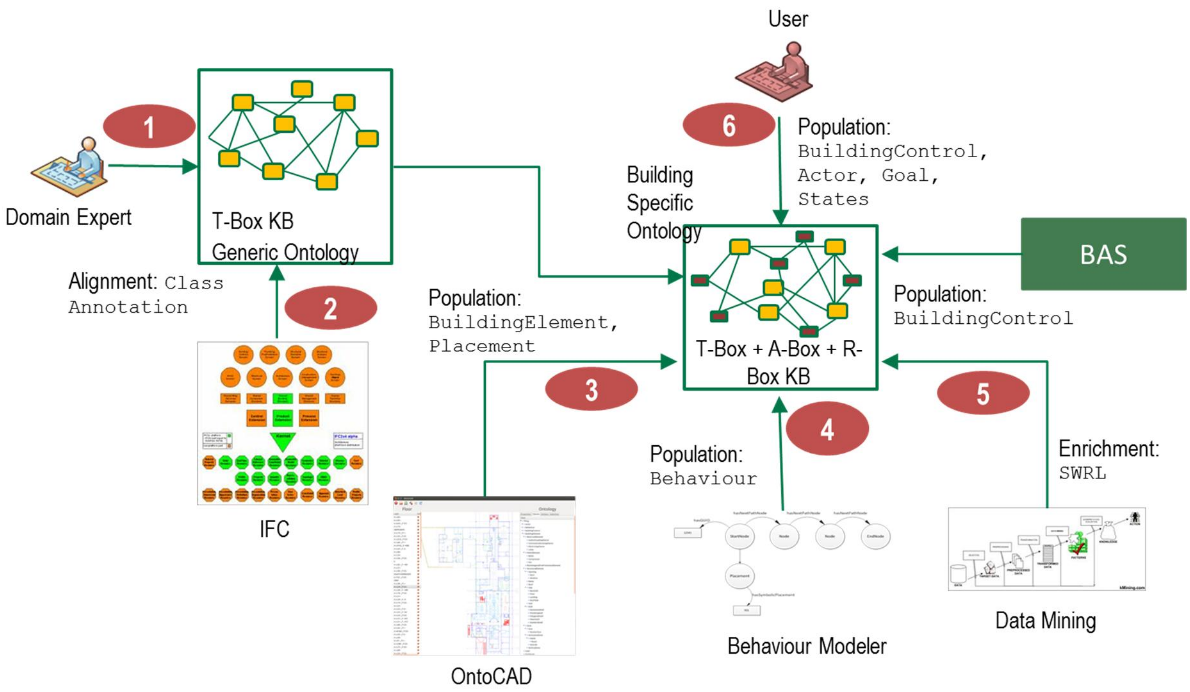


Figure 7 - Knowledge base development methodology

Work Package 2

The main result of WP2 is a building specific ontology for each demonstration object. Since the aim of KnoholEM project is to have a holistic view of energy management during the buildings operational phase, the developed knowledge base should cover different aspects of the building. The knowledge base development methodology that allows collaboration of different stakeholders (WP1) is used as a guideline for WP2 to extend the generic ontology with building specific information.

In the frame of WP2 has been developed a **methodology for behaviour capturing** (T2,2) which resulted in the development of an activity modeller, (part of the work was delivered in WP4). A detailed analysis with a number of projects within the ee-Semantic community has been performed, in respect to the behaviour of occupants and its impact on the energy consumption in the building. Based on the conclusions made and established requirements for the behaviour and occupancy model within KnoholEM, a flexible and extensible behaviour model has been developed to capture user activities.

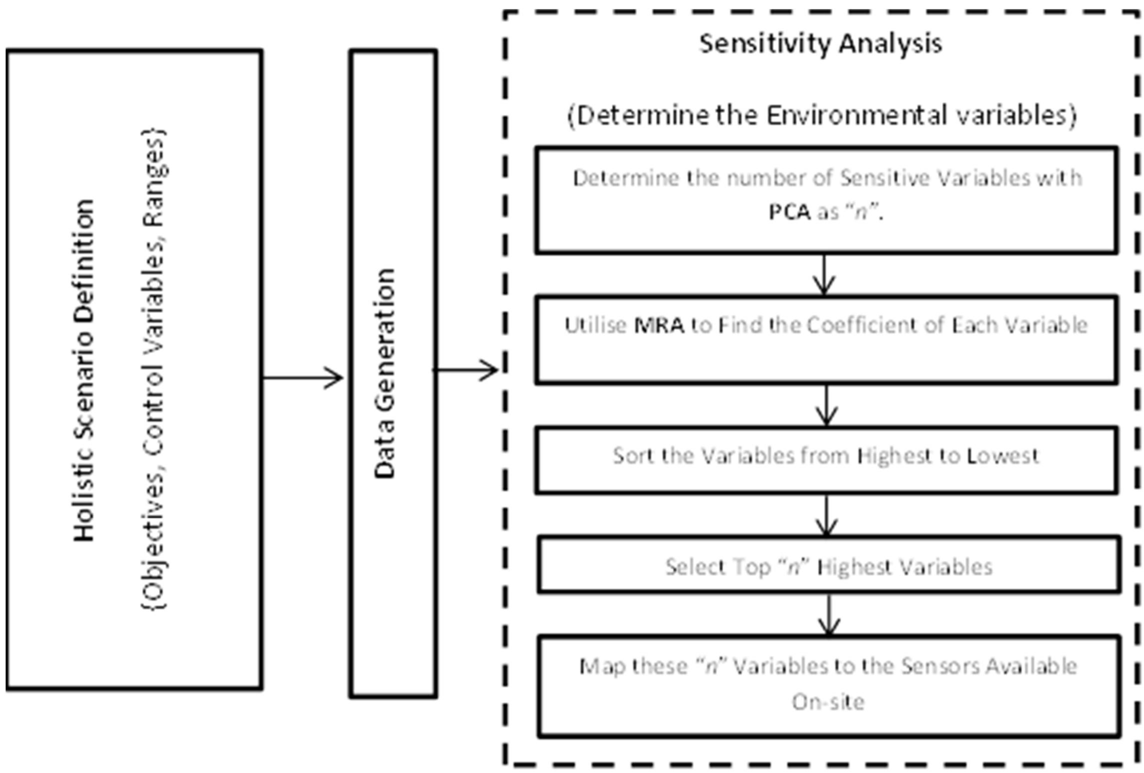
The creation of **building specific ontology** for each building has been supported by the OntoCAD tool, developed by the KIT team. It aims to create individuals for the classes and subclasses of BuildingElement and to enrich them with geometric properties. Drawings are exported from CAD design software using the exchange format DXF and the population process is accelerated trough pattern matching algorithms (to find similar objects). The other advantage of the tool is that it enables the import not only from AutoCad files but also from IFC files. The tool has been optimized to be user friendly and used by non-professionals (non-developers). By the end of the third project year the tool has been published as an open source with a license model that enables other parties to implement changes and make then also public. After the project end the tool will be uploaded on a public repository as an **Open source** result from the project.

- Behavior data population has been delivered by the Activity modeller developed by the TCD team (developed in Wp4).
- Enrichment with SWRL rules and simulated data rules is performed by the data

mining framework

The developed **data mining framework** represents the main interface among simulated rules and ontology and simulated rules and RT controller from another site. It consists of :

- a data mining relational database (MySQL) to store historical dynamic data for each demonstration object. Four tables are created in each database to store actual sensor values, actual set point values, historical sensor values, and historical set point values. An additional table is created with the data mining required schema. The data from the tables storing the historical data are transformed a stored in the data mining table;
- a set of data mining algorithms to discover new knowledge and validate the extracted patterns, and
- output models to store the data mining results;
- stored monitored data from sensor values retrieved on different interval (between 8 and 10 min depending on the BMS settings)
- **The theoretical rule generation** (simulated rules) for each pilot starts with the thermal energy model development using DesignBuilder. The model contains the following properties of the pilot zones such as; geometrical information, material details, occupancy schedules, device energy consumption schedules and weather data information. This generated thermal model will then be converted to an EnergyPlus model for simulation and theoretical data generation. The next step of the rule generation process is to develop a holistic energy management scenario. In the holistic scenario, the reduction of three main objectives are considered, which are thermal energy (cooling and heating energy consumption), electrical energy consumptions, and absolute value of thermal comfort index level measured with Predicted Mean Vote (PMV). The reduction



of each objective is based on a negotiation process which has following six levels of reductions; 5%, 10%, 15%, 20%, 25% and 30%. To achieve a selected level of reduction on any selected objective, available control variables/set points are selected for each proposed scenarios, such as room air temperature, window set points, etc. The overall process illustrated as follows.

The sensitivity analysis rules extracted by the above procedure have the following format:

IF <PREDICATE>1 ^ <PREDICATE>2 ^ … ^ <PREDICATE>N THEN <PREDICATE>

whereby each PREDICATE consist of a left and right operand connected by a operator:

<OPERAND> <OPERATOR> <OPERAND>. The first four predicates in the rule condition are reserved for the following metadata fields:

- The zone ID of area affected by the rule,
- the rule weight,
- the rule type,
- the energy reduction rate targeted by the rule (5%, 10%, 15%, 25% or 30% energy reduction target).

A comprehensive library for the further processing of the rules have been developed which encompasses the following functionalities:

Parsing: forms the core of the library functionality. The parser builds a model for the rule structure and metadata and provides convenience methods for its processing and evaluation. An example of such functionality is the production of a natural language representation of the suggestion contained in the rule consequent. The natural language representation is stored and automatically gathered by the RT controller from the data mining DB.

Writing: converts a rule model to its textual form according to the format outlined above. This functionality allows for the algorithmic production of rules for testing purposes.

Conversion: translates the rule into the Semantic Web Rule Language (SWRL)[2]. This process has been fitted to the requirements of the RT controller (see below) and consists of the following steps:

1. The parsed rule model is translated in terms of OWL API's SWRL interface3. The rule metadata is included as OWL annotations.
2. A copy of the generic building ontology is augmented with the converted rule. This individual approach allows for the conversion of a large number of rules without causing memory overflows.
3. The RDF/XML[4] representation of the rule is extracted and inserted to a special database accessed by the RT controlled.

Alignment and consistency checking: A consistency check has been implemented in order to enable a better match to the energy optimization rules to the ontology and the existing sensors in the building. It consists of a framework for evaluating the rules against a set of criteria. Each rule predicate must fulfil two basic requirements:

1) it must refer to a sensor which is defined in the building ontology and classified correctly according to the sensor taxonomy and
2) the sensor must be present in the building monitoring system which writes the current value in the building database.

[2] http://www.w3.org/Submission/SWRL/
[3] http://owlapi.sourceforge.net/
[4] http://www.w3.org/TR/REC-rdf-syntax/

The consistency check identifies the sensors which haven't been formalised in the building ontology and makes sure that the population process has been done correctly. In addition, it excludes those predicates, which refer to sensors outside the building monitoring and thus prohibit the evaluation of the rule conditions.

Evaluation: preforms the actual evaluation of the rules' conditions against a set of sensor values.

Work Package 3

The activities of the Work Package 3 have been focused on the design of the Energy Real Time Controller (EnRTC) based on automatic reasoning technologies from specific building ontologies in OWL format (A-Box and T-box) with the relative SWRL rules (R-Box) obtained from the activities of Work Package 2, on the implementation and validation of the EnRTC, on the analysis and verification of communication protocols of each building's BMS and on the real time data retrieving by the demonstration buildings.

The Energy RT Controller (EnRTC) a software application developed by CETMA is based on different loosely-coupled components that performs semantic-based reasoning over a set of optimization rules in order to suggest to the end-user a set of optimization actions devoted to the improvement of the energy efficiency performance of the monitored facility.

The Energy RT Controller is a complex system with several components that need to interact among them in order to accomplish their task and satisfy the final objective as above described.

The main components of the controller are the following:

- RT Scheduled Task (RTST) – This component is deployed on the Service Bus and its main task is to activate the Real Time Control Process (RTCP) module (deployed on a different execution environment) by invoking its dedicated WS (Web Service) interface. RTST is based on Quartz technology: on the basis of a given frequency value, the task is scheduled by the Service Bus environment to be executed and then start the main process (managed in all its steps by the RTCP module).
- Real Time Control Process (RTCP) – This module can be considered as the orchestration component of the KnoHolEM system for all that concerns the execution of the basic RT control process (i.e., data acquisition, KB update, inference, rules execution, storage the EE actions). The RTCP module communicates with:
  - the Data Mining database in order to retrieve the last updates of the sensors' readings and set-points of the monitored/controlled building;
  - the Semantic Alignment Service (SAS) to update the ontology's instances stored in the Knowledge Base (OWL file and RDF Store);
  - the JESS Engine (through the related Bridge) in order to execute the SWRL rules.
  - the Fuzzy Rule Engine to retrieve the fuzzified rules from the Rule Base (remote database) and execute the fuzzy process to identify the optimization actions that will be used by the GUI module.
  - Local DB to store the configuration information and the results of the each execution run.

In particular, the phases followed by the reasoning process are the following:

§ Model loading (OWL Axioms) from the SAS module,

§ SWRL Rules from the remote database (Data Mining DB),

§ Creation of a unique OWL file containing both Axioms and Rules,

§ Instantiation of the JESS Rule Engine Bridge,

§ JESS Engine running,

§ Sending of the fired rules to the Fuzzy Rule Engine and the fuzzy rules of the Rule Base,

§ Storing of the fired rules in the local database with related action suggestions

§ Exposing of fired rules on RESTful Web Service interface in order to enable the GUI to retrieve the action suggestions identified by the EnRTC.

Ø Knowledge Base – The KB developed in OWL (Ontology Web Language) format storing the terminological (TBox) and assertive (ABox) knowledge (facts specific of the monitored/controlled building).

Ø Semantic Alignment Service (SAS) – This sub-module is responsible of the provisioning of the semantic information currently stored in the EnRTC. The main objective of SAS is to align the instances stored in the KB and in the RDF Store w.r.t. the update requests coming from the field (new values read from the Data Mining DB related to the sensors' readings and set-points). In addition, the SAS sub-module exhibits WS interfaces in order to:

ü submit SPARQL queries to the RDF Store and retrieve results in RDF/XML format,

ü retrieve the content of the KB (OWL),

ü retrieve the facts (ABox) stored in the KB.

Ø KB-RB Access – This component is integrated in the SAS module and represents the API (Jena API and OWLAPI) enabling the interaction between the EnRTC and the OWL KB.

Ø RDF Triple Store – This element is the physical repository (Jena TDB) of the RDF Graph representing the same semantic information (in <s, p, o> triples) stored in the KB and managed by the Mapper component.

Ø Mapper – The Mapper is the SPARQL endpoint (in the specific case, Jena Fuseki) used by the EnRTC. Fuseki is a SPARQL server that provides REST-style SPARQL HTTP Update, SPARQL Query, and SPARQL Update using the SPARQL protocol over HTTP.

Ø JESS Rule Engine Bridge – This element is an extension of the JESS Bridge library having as main objective the creation of a communication interface between the JESS Engine and the rest of the EnRTC.

Ø JESS Engine – This module is a third-party component that provide the possibility to "reason" using the available knowledge supplied (KB facts and SWRL rules) in the form of declarative rules. The communication with this component is enabled by the JESS Rule Engine Bridge.

Ø Fuzzy Rule Engine – This component uses the fuzzy version of the SWRL rules fired at the end of the reasoning process (provided by the JESS Rule Engine Bridge) in order to implement a fuzzy reasoning process to identify the optimization actions that are used by the GUI application.

Other components of the KnoHolEM system that are external respect to the EnRTC are:

- Data Mining Access and Data Mining DB – The database (with or without an access layer) storing the data acquired from the field (building) related to the sensors' readings and set-points. This information is used to update the instances of the KB. In addition, this database contains the RuleBase that stores the SWRL Rules used in the reasoning process.
- Data Mining Engine – The component devoted to the identification of the new rules that will be validated by the knowledge expert before to be added to the Rule Base.
- GUI – The Web application that will show the optimization actions identified by the EnRTC at the end of each scheduled control process.

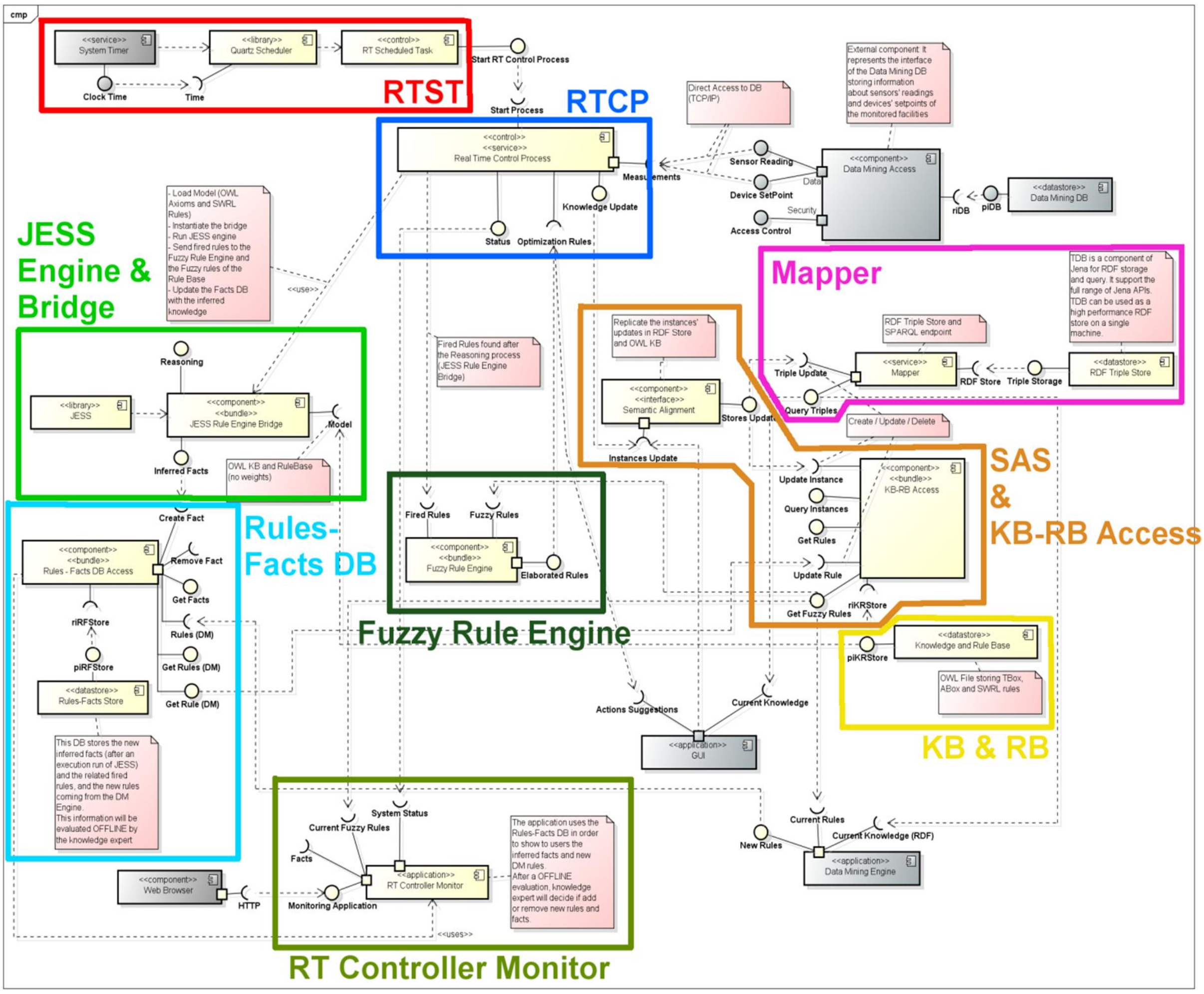


Figure 8 - EnRTC Component diagram

The EnRTC is deployed on four different execution environments, namely:

- WSO2 Application Server (AS).
- WSO2 Enterprise Service Bus (ESB).
- Apache Fuseki.
- Oracle MySQL DBMS.

The internal components of the Controller have been reported in the following table:

#	Component Name	Artefact Nature	Deployment Env.
1	RTControlProcessService	WAR	WSO2 AS
2	SemanticAlignmentService	WAR	WSO2 AS

3	ReasoningService	WAR	WSO2 AS
4	FuzzyReasoningService	WAR	WSO2 AS
5	RTControllerConfiguration	JAR	Imported by WARs
6	RTScheduledTask	JAR	WSO2 ESB
7	RTController_DS	XML file	WSO2 AS
8	RTMapperServer (Fuseki)	Folder	O.S. Directory
9	rtcontroller_db	SQL schema	MySQL DBMS
10	OWL ontology(-ies)	OWL file	O.S. Directory

In the production environment, the operating system is Ubuntu Server 12.04 LTS. The structure of the folders where the different elements of the Controller are deployed is the following:

/knoholem

- **/environment**
  - **/wso2as** (WSO2 AS main folder)
  - **/wso2esb** (WSO2 ESB main folder)
  - **/rt_mapper** (Fuseki)
- **/kb**
  - **/owl_kb**
    - *Ontologies files*
    - **/mapper_kb**
      - **/forum** (Fuseki RDF Store Files of Forum)

The schema of rtcontroller_db is the following:

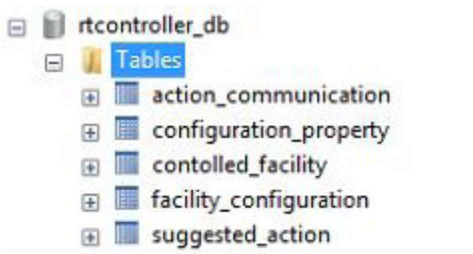


Figure 9 - rtcontroller_ds tables

controlled_facility table contains the information about the facilities;

facility_configuration table contains the information about the connection to the remote mining database for retrieving the real time data from the field and the rules, the OWL file location and the RDF store base URL;

action_communciation table storing the communications associated to the actions suggested from the reasoning process;

suggested_action table storing the suggestions inferred from the reasoning process.

The access to this internal database and to the external mining database are configured by XML file of RTController_DS service used for provide WSDL for stub generation to be insert in the code of EnRTC.

The WAR applications of the services generated by the code of the EnRTC are installed by loading on administration console of WSO2 AS in the Application lists section:

	Context	Display Name	State	Type	Sessions	File	Last Modified	Actions
☐	/FuzzyReasoningService-1.0.0	Fuzzy Reasoning Service	Started	JAX-WS/RS Webapp		FuzzyReasoningService-1.0.0.war	2014-10-28 16:42:35	Find
☐	/ReasoningService-1.0.0	Reasoning Service	Started	JAX-WS/RS Webapp		ReasoningService-1.0.0.war	2014-10-28 16:47:31	Find
☐	/RTControlProcessService-1.0.0	RT Control Process Service	Started	JAX-WS/RS Webapp		RTControlProcessService-1.0.0.war	2014-10-28 16:47:59	Find
☐	/SemanticAlignmentService-1.0.0	Semantic Alignment Service	Started	JAX-WS/RS Webapp		SemanticAlignmentService-1.0.0.war	2014-10-28 16:48:39	Find

Figure 10 - Application Services

For each building the Task are deployed on the Enterprise Service Bus:

Figure 11 Enterprise Service Bus

The results of each fuzzy reasoning cycle of EnRTC are exposed for the GUI by use of RESTful Web Service interface.

As shown, the integration architecture of the EnRTC is service oriented: it exploits the full potential of the interfaces based on Web Service (WS) technology. The developed application is hardware, programming language, and operating system independent; this means that applications written in different programming languages and running on different platforms can exchange data over Intranets or the Internet using Web services.

In this way, all the internal and external components are able to communicate with EnRTC components through the Service Bus, ensuring at the same time the flexibility and the accomplishment of all the requirements related to information security, privacy, and data integrity.

As regard the functionalities of EnRTC, Although there are cases in the literature in which extension of fuzzy logic mechanisms is used for energy efficiency of buildings, currently, has not been identified another implementation of a controller which provides for the application process of such features in real time. So, we can say that Knoholem Fuzzy RT reasoning represent something unique in the particular field of the application of artificial intelligence systems and knowledge-based energy management applied to building automation.

An advantage respect the original Knoholem project is given by the fact that EnRTC can support its functionality without the need of a dedicated hardware box, becoming suitable facing with the modern concept of the Internet of things: indeed it can allow the expert knowledge to manage and supervise the solution in different buildings in a centralized manner in addition to the activities of facility manager in the field.

As regard the functionalities of data retrieving actuated in Work Package 3, before starting in implementation of the communication solution with different BMSs in each building, Tera was responsible about analysis and check of each BMS's communication protocols, to find available communication solutions and suggest solution more useful in Knoholem purposes. BMSs installed in each building were analyzed and results are reported in table below.

Building	BMS	Main Protocol	Database	Rest - Web Service
Forum	Priva	BACnet/IP	---	XML
BlueNet	Eugene	Modbus/TCP	SQL Server	JSON
Pica	Eugene	Modbus/TCP	SQL Server	JSON
HHS	Octalis	Confidential	SQL Server	---
HHS	Priva	BACnet/IP(*)	SQL Server	XML(*)
Media TIC	Controlli	BACnet/IP	SQL Server	--
Media TIC	nAssistant Server	Modbus/TCP	SQL Server	XML

(*) Option no developed

As shown in table, there are different protocols implemented in each building. Furthermore there are different services exposed but not for each BMS. However, except in Forum building, in each building the BMS use a SQL Server as data repository.

After this analysis the conclusion is that the more useful solution is to connect directly to BMS's databases and query about sensors state.

As regard the real time data retrieving by the demonstration buildings, Matrix has had the opportunity to know directly the technological reality inherent Building Automation; this aspect is very important because the company has among its objectives to become a technological reference within the market of Home Automation.

As part of the design process Matrix could develop and test innovative technologies for home automation systems, their integration and, at the same time, to use the company previous know-how to improve the Knoholem solution.

In particular, the company has had the opportunity to deepen their knowledge of communication protocols and techniques of information storage. In this regard has therefore developed a set of procedures that have set up the software layer required to retrieve information from various BMS present in the demonstration object, their formatting in the unique pattern of data established for the Knoholem solution and sending the processed data to the mining database to be used by the ontology.

Work package 4: Smart Building simulator and building in the loop

The activities of the Work Package 4 have been focused on the design, implementation and evaluation of the web-based visualisation tool 'BuildVis' developed by TCD. This tool makes use of the building specific ontologies, in OWL format (A-Box and T-box), obtained from the activities of Work Package 2. Here we list the main features of the BuildVis tool, how these interact with the other aspects of the KnoHolEM solution, some of the more relevant findings, and finally the evaluation of the BuildVis tool with different users: the demo object Facility Managers (FMs), and also the demo object occupants. The main objective of the BuildVis tool is to provide a usable interface to the KnoHolEM solution so that the FM can interact with the Real Time controller developed in WP3. It also provides additional features to the FM and building occupants, which will also be presented below.

In addition to this, the validation of the analysis and the verification of the communication protocols of each building's BMS and on the real time data retrieving by the demonstration buildings is also presented, as well as the development of an Information Delivery Manual to facilitate the standardisation of the KnoHolEM ontology in Industry Foundation Classes (IFC).

The BuildVis Interface consists of both a front and back end. The main components of these are presented and discussed here. For more information, consult Deliverable 4.2:

BuildVis Back-End:

1. **Fuseki Server installation:** Fuseki is an RDF (Resource Description Framework) server with a simple to use web-based client for uploading an OWL ontology. TCD have five server instances, one for each demo object, hosted on its own internal Virtual Machines (VMs) in TCD. Each of these has the latest building specific ontology loaded. These can be queried using SPARQL over HTTP through an endpoint (URL) provided by each Fuseki server instance.
2. **Bi-directional Communication Interface with Fuseki RDF Server:** The client-side communication interface makes use of the REST-style interaction provided by Fuseki. An AJAX (Asynchronous JavaScript and XML) call is made client side to the Fuseki endpoint. SPARQL queries are all hardcoded client side. New SPARQL queries must be hardcoded to support new requests to the ontology. The BuildVis interface makes uses of these queries to query the ontology for a) the position, zone_id and perimeters of all zones b) the sensor_id, type (inferred by class), and zone_id for each zone that contains it for all sensors and c) the activity_id, activity_type, occupant_id, zone_id, start_time, duration, date of all occupant defined activities. In addition to this, a SPARQL update and delete allow for activities and zones to be added/deleted in the ontology. How these are post-processed is discussed in more detail in the front-end section.
3. **Bi-directional Communication Interface with MySQL Database:** The MySQL databases are hosted on KIT servers. PHP code has been written to handle querying of the MySQL databases for sensor data. The PHP queries each of the five MySQL servers for the building objects. The queries query by sensor_id and timestamp (or between two timestamps), and return each value for its respective timestamp(s). How these are post-processed is discussed in more detail in the front-end section. An additional piece of PHP code was developed to update the MySQL database with activity data, to help support the WP2 data mining activity.
4. **One-directional Communication Interface with RT Controller:** An AJAX call is also written to connect with the RT controller. The RT controller provides a URL which returns a JSON object. Due to cross domain issues, this JSON object is wrapped in a call back function and we use a 'jsonp' call to handle this. The JSON message returns a list of suggestions which includes the rule_id, rule_type, efficiency_target, textual_suggestion, zone_id, sensor_id and sensor_type. How these are post-processed is discussed in more detail in the front-end section.

BuildVis Front-End:

1. **Web-interface Overview Screen:** The overview screen which is presented to any user of the BuildVis tool has been developed using HTML5 and the BootStrap libraries. BootStrap supports the creation of features which control the way HTML elements are presented to users and is ideal for front-ends which are required to work on both desktop monitors and handheld devices.
2. **3D Building Geometry:** Extensive work has been done to ensure that the building

visualisation can be presented to the tool users in an aesthetically pleasing manner, while also being optimised so as to room as smoothly as possible on older PC's and laptops, or handheld devices like tablets and smart phones. The primary focus was investigating and rendering Industry Foundation Class (IFC) architectural models in 3d, in an interactive web-browser view. Our sample buildings had an inconsistent range of 2d and 3d architectural model formats to consider, all of which we were able to render. Our most consistent available format was traditional 2d CAD (computer-aided design) proprietary formats. To bring these into a 3d representation we developed an algorithm to extrude these line-based plans into 3d triangle-based geometry, which lends itself to rendering on modern commodity GPU (graphics processing unit) hardware. Typical challenges for rendering 3d models of the various CAD plans are listed here:

- converting a range of very complex CAD file formats into the simple 3d
- triangle-based geometry required for rendering.
- identifying simple line segments from plans, suitable for extrusion into 3d
- applying realistic lighting and shading to improve 3d scene perception
- identifying corners and edges of geometry for outline rendering, to improve
- symbolic spatial perception
- developing a 3d coordinate space such that 3d coordinates of other systems
- (sensors, arbitrary zones, etc.) can be represented in the same 3d render
- spatially subdividing the geometry into sensible-sized blocks such that it renders efficiently given the multi-processor nature of modern GPUs

The following WebGL features were implemented client-side to enable the building geometry visualisation:

- dual sided 3d extrusion and tessellation of 2d CAD models
- 3d positional and 2d dynamic text rendering algorithm
- 3d and 4d (quaternion) geometric linear algebra maths library for JavaScript
- interactive 3d scene camera with visual touch-screen controls
- ray-casting mouse selection of 3d elements
- Blinn-Phong and CAD-style surface normal-based illumination shaders
- post-processing and compositor shader framework
- batched rendering algorithm for efficient parallel asynchronous processing of vertices and primitive generation
- custom file format geometry conversion pipeline to handle 3d and 2d source CAD models uniformly

The resulting 3d geometry is presented to the user in a window on the web browser, and provides functionality to rotate, move and zoom in and out of the building model.

3. **Zone Visualisation and Interaction:** The zone visualisation is done using the WebGL implementation. On opening the browser, all zones are queried from the ontology and displayed. Some transformation work is required to align the zone position given in the ontology to the building geometry visualisation and this must be done manually (once). The transformation data is stored client side. Client side, the zones are stored in a list, so that zones can be removed and added if required. On creation/deletion of a zone, the ontology is also updated server side. Zones can be selected using the webGL implemented ray-casting mouse selection, at which point all sensors (also queried on loading the browser) which are related to that zone are added to a second sensor list. These are used for querying the MySQL database, described next.
4. **Building Energy Monitoring Visualisation:** Once a zone is selected, the user is

presented with a list of sensor types available in that zone (e.g. energy, temperature, humidity, etc.). The user can then query the historical values for that zone by selecting a sensor_ type from a checklist, from the MySQL database. This is presented using an open source library called HightCharts which supports visualisation of data as different types of charts (bar, pie, etc.). A bar chart is used to display data by value and timestamp. Currently, the interface post processes the values, so in the case of energy metering, were more than one energy sensor exists, these values are added together and the total energy consumption is displayed. Also displayed in the interface is the total average energy consumption of the zone (currently only for the most recent week), and the current energy consumption of the zone (where this data is available). A simple traffic light system is used to indicate when the current energy consumption is higher than the total weekly average.

5. **Suggestion Query Visualisation:** The suggestion query interface displays suggestions for a selected zone. Using the connection to the RT controller, all suggestion for that zone are loaded client-side and processed. The interface supports selection of the efficiency_target (e.g. 10%, 20% or 30% reduction in energy consumption) through a HTML5 slider, and rule_type from a drop down menu (e.g. Reduce Heating/Electricity/Cooling or Thermal Comfort). This then filters the suggestions and presents the suggestion text to the user.
6. **Activity Modeller:** The activity modeller was developed to support the development of activity models for building occupants. It provides a means for building occupants to enter in their weekly activities, e.g. where they were, start and end times, where they lunch, meetings etc. It makes use of an opensource library called handsontables which provides an excel like interface to enter in tabular data. Through this, occupants can select the start and end time of an activity, the zone it takes place. Activities are also stored to the ontology and an additional piece of code was implemented to update the MySQL database with activity instances.
7. **Logging Interface:** The logging interface is for logging when rules are enacted. It provides a simple input window so that the user can log when they enact a suggestion. This is saved to the ontology.

Interface Implementation Findings

HTML5 has proven itself to be flexible (meets current requirements of energy management interfaces), extensible (meets new and novel requirements, like those of KnoHolEM) and scalable (can be deployed on devices that have browser support for HTML5) method for meeting the demands of KnoHolEM interface. The approach to the underlying data model has also proven itself to be flexible, as the ontology can be mapped to existing standards like IFC, and extensible as new ontological concepts can be quickly modelled in tools like Protégé, and the resulting ontology uploaded to the Fuseki server, where new data instance can be created, queried and deleted. Nonetheless, there are issues around the visualisation of large building geometry files which were discovered during the course of the development of BuildVis.

The major disadvantage to web-distributed rendering of building geometry is the download time for large architectural models. The 3d models extruded from our 2d CAD plans were small enough in our sample buildings to present no obvious delay, but larger building models, especially IFC models, can be in the order of several hundred mega-bytes, which even when compressed by a web-server, introduce a considerable undesirable delay to user experience and therefore also product utility value.

The major commercial offering that has emerged during the span of this project, Autodesk 360, is also based on WebGL, and benefits from most of the same advantages as our project, as listed above. A considerable advantage offered by 360, over our project, is the ability to construct a custom, highly-optimised scene-based file format, instead of using unsorted data, IFC files, or extant 3d file formats. This provides a much more efficient download time and therefore better user experience. Compared to our project, 360 is limited in terms of the freedom of 3d views, and less comprehensive integration with building management systems. It is very difficult to suggest a better method for future projects, as most architects are using proprietary, commercial software to save and export 3d CAD files, which we are then constrained to working with. A new, simplified open standard of 3d file format suitable for rendering buildings on modern computer graphics hardware would make a significant impact on this area, but this then relies on export support from the major commercial software tools.

BuildVis Usability Evaluation

The evaluation of the visualisation and "user-in-the-loop" was conducted in **two phases** and consisted of both summative and formative evaluations. These evaluations can be found in greater detail in Deliverable 4.3. Here we describe them in brief.

The evaluations were to assess the level of usability of the interface, as the usability is seen as a key factor for the success of the KnoHolEM solution. The evaluation methodology is based upon state of the art principles in usability evaluation. All the evaluations tool place over the web. The interface was sent to each participant who was required to answers pre and post questionnaires, as well as completing several tasks involving typical KnoHolEM tasks.

The **first phase** of testing was conducted on the Activity Modelling tool and consisted of both formative and summative evaluations. The formative evaluations are discussed in the previous section and formed part of the rapid prototyping of the initial tool. The summative evaluation was conducted on 13 participants in the b-digital offices in the media-tic building. They assessed metrics such as the Standard Usability Scale (SUS) score, and specific questionnaires about the interface.

The **second phase** of testing consisted of a summative evaluation of the FM tool, first with technical users and second with each of the five FMs for the five building objects. The technical users were each tested with the Forum building. The FM's were tested each on their respective building, with the same set of tasks. They assessed metrics such as time to complete tasks, the Standard Usability Scale (SUS) score, and specific questionnaires about the interface.

Usability Evaluate Findings

The evaluations gave important indications about the levels of usability associated with the BuildVis tools. The evaluation of the FM BuildVis tool is the culmination of the development life cycle of the BuildVis tool as part of the KnoHolEM project. It brings together all the main features of the KnoHolEM solution and presents them through a web–based interface. The evaluation demonstrated that there are still issues related to the usability of the tool for its target users, Facility Managers. Although the number of evaluation participants for the final evaluation was small (5), their background means that their results are of particular relevance to the system. The SUS score of 59.5 is something that requires improvement. The final summative evaluation of the BuildVis Activity modeller also indicates that changes are still required to improve its usability. A number of good suggestions have been made on how to improve the interface, and these will be implemented and tested in future versions.

IFC Standardisation

Each of the WP leaders has contributed towards the development of the Information Delivery Manual which describes the KnoHolEM business use case, and captures this use case in a formal manner, through the use of Business Process Modelling Notation (BPMN) models and tabular data. The IDM has been presented to the BuildingSmart community for evaluation. We believe this will go some way towards the process of certification of the new and novel models developed in the KnoHolEM project.

Building Gateway Validation

As mentioned in the first part of this document, in this work package a validation activity has been performed on the protocols and data retrieving for each demonstration building. The validation activity has been necessary to check the connections and communication with the BMS on one side, and connections and communication with DB mining to the other side. Dedicated procedures have been created to open connection with DBMS and read/write data and, at the same time, third party tools (see Squirrel) to perform additional tests on this task have been used.

Once the communication was been verified, attention moved to the information retrieved from the BMS that has been converted into the unique data model defined for Knoholem solution. This has been a crucial aspect in the validation phase because, in this way, the ontology uses only a data model for all buildings. The positive feedback related to the correct conversion into Knoholem data model is obtained matching the data input and the data output of the Converter module.

Finally, the validation examined the entire software layer: in this case the tests performed have had the objective of monitoring the data transfer from each building to the correspondent DB mining; data have been checked for several months and appropriate tools have also been created to allow the check of the presence of a single sensor in an established time gap in the DB mining, or to check the total number of expected sensors in an established time gap.

As output these tests, many graphs have been produced that show the results of the test themselves; they also have highlighted that, even if the connection with the BMS or DB mining fails for some reason (ex. network error), the system continues to run showing the occurred errors. In addition to the software layer validation, it has also been performed the validation of EnRTC: in particular there have been verified the correct functioning of every unit of code and the correct fulfilment of the functional requirements of the services.

Work Package 5

Demonstration Object Energy Audits/Validation

Data Gathering Months 1-9: An early number of problems were encountered in performing Task 5.1, in particular gathering enough detailed information to perform calculations for use as a base line. It was expected from the DoW description that the demonstration objects would be able to provide detailed information about their own specific buildings which would then be centrally collated and analysed, ideally via the installed Building Management Systems and any installed automatic Monitoring and Targeting (aM&T) software. Attempts at data gathering were initially carried out in three ‘waves’. The initial attempt was to provide a spread sheet with all the types of data that are required but was considered to be pitched at a “too technical level”. The further attempt was to produce a text based document that tried to convey similar information to the first attempt, but in an easier to understand form. This produced a limited response. The third attempt used a graphic representation of the data required and the reasoning behind it. This produced a better response, but the actual data provided was still at a very limited level not suitable for intended purpose.

This limited supply of information required a change of strategy with the introduction of a building “Data gathering Table” pro-forma being introduced for completion at month 10. This generic table covered all possible variances within the 5 case study buildings (e.g. no gas supply, with or without renewable technologies etc) and a detailed description of its requirements being provided per Demonstration Object Partner via video conference. This table was then to inform a generic “energy profile” sheet per building, a short form précis of the information required for Task 5.1.

Data Gathering Months 10-12: Whilst not building specific, the “Data gathering Table” pro-forma provided a good starting point to collate the data required for Task 5.1, the pro forma “energy profile table” précis could then be altered to be building specific, discarding inapplicable subdivisions such as for non-existent energy supplies and technologies.

The success or failure of the KnoHolEM solution is demonstrated by showing improvements in the building functioning. At a simple level this is done by looking at energy use before and after deployment of the solution after correction factors are applied for variables such as external climate and building occupancy. External weather data was also meant to be collected from the building specific weather stations located on each Case Study building, however no such has been forthcoming and in reality this has meant that has been sourced directly by BRE via alternative means - External weather data concurrent with the project and energy consumption data periods has been instead collected/downloaded from the USA’s National Climatic Data Center’s web-portal and download site which allows the download of meteorological data from weather stations around the World. Meteorological data was collected from the following weather stations, for the cities in question:

Barcelona Airport (Weather Station Ref: 81810) – for the MediaTic (BDigital) building; Seville/San Pablo (Weather Station Ref: 83910) – for the PICA & BlueNet (Isotrol) building; Eindhoven Airport (Weather Station Ref: 63700) – for the Forum (Smarthomes) building and Rotterdam/The Hague (Weather Station Ref 63440) – For the HHS building.

Data Gathering Months 13-24: Data gathering was performed over the entire year however it suffered from the same variable granularity as the original document, in particular gathering enough detailed information to perform calculations for use as a base line, due to the very different extent of metering, sub-metering and automated trend-logging available in each building. However, in the instance of the Forum building an improved level of monitoring was available in the 2nd year due to the addition of “Plugwise” energy monitoring equipment. Following on from the initial three ‘waves’ of data gathering as described in D5.1, this provided a set pro forma to be completed for each building, This process greatly helped the collection of data in the 2nd year as the tables merely needed updating for an additional 12 months in most instances. From the pro forma “energy profile table” précis the building specific energy consumption tables were collated.

Data Gathering Months 25-36: Data gathering was again performed over the entire year for the energy consumption levels of each case study building. Data collection in Year 3 was completed in the same manner as Year 2 as a set methodology had been established in the first year of the project.

From the energy consumption data received for the Demonstration Objects, a series of energy profile tables were collated for the buildings and reported in Deliverable Report 5.1. Given the range and quality of energy consumption data received the energy profile tables were not able to be completed in full for each building. Deliverable Report 5.1 illustrates that the 5 Demonstration Objects chosen for use in the KnoHol-EM project all vary greatly from one another in form, size, methods of servicing and end use, ranging from large university buildings to smaller buildings comprised predominantly of residential units. Further, the actual extent of the building's area used within the project also ranges, with building portions of approximately 600m^2 (Forum) to 1,000m^2 (Bluenet and Mediatic) being assessed. These variations made it a difficult exercise to collate a view of energy use which is consistently applicable to all buildings.

In Deliverable Report 5.1, delivered in year 1 it suggested that due to limited historic energy consumption data for some buildings and/or a lack of sub-metering to discern use for individual end uses (e.g. lighting) or distinct floor-areas, that the data collection process be on-going for the duration of the project and the Deliverable Report updated. Moreover, one of the intended Demonstration Objects, the IDEAS building in Seville has been replaced with another building, the PICA building, in October 2012 which has meant that this building could not be included in the work progressed towards work task 5.1 and data for this building can only be gained from its October 2012 inclusion onwards. Therefore, as the key to D5.1 is the collection of historic energy consumption data the document was conceived as a living document and annual updates created for each year of the project. The first annual update was collated to draw together the energy consumption data for each building for 2012/2013 and presented as annual update to the original document in October 2013. The results collected for the period to September 2014 created the 2nd updated Deliverable Report 5.1 and were presented as an annual update to the original document in October 2014.

Evaluation Procedure for Energy Savings and Investment Amortisation

Task 5.2, as described, was not feasible at the original delivery date in the project development. The Task's deadline for month 9 did not tally with the works meant to inform its creation. Building specific ontology rule sets were not yet formulated; these were created and developed over the length of the project (finalisation of their extension being in month 35) whilst WP2 task 2.4's creation of a data mining algorithm that the evaluation procedure will be "strongly linked to" was due for completion in month 30.

As works towards Task 5.2 were not feasible until practical deployment of the project no work could be completed in year 1. However, for Year following the first Review Task 5.2's methodology was completed and delivered as Deliverable 5.2, although the analysis that makes up this report's detail would still need to be completed at the end of the project, once cross comparison of the "before" and "after" effects of the Knoholem solution on energy consumption is possible to gauge its financial marketability. In year 3 this analysis of Investment amortisation could not begin as there has been no works progressed towards the introduction of the sensor and control works for the KnoHolEM solution in any Demonstration Object – this was due to occur in the latter, extended stages of the project pushing this task for completion to months 40-42. As the works intended for the extension period were not completed it was not possible to perform the task and deliver this Deliverable Report by month 36 in the originally planned work schedule.

Demonstration Objects Energy Profiling and Energy management System Initial Definition.

In Year 1 Task 5.3 used the Forum building as a test case for the Building Energy Model.

The Forum was chosen as a test case for the model as it is the most simplified building HVAC/services-wise and the only building with complete enough details to create both a realistic 3d geometry of the building from existing CAD drawings and to inform the thermal model with details of the building's fabric definition, occupation schedule and HVAC/services system and set-points. Without this large dataset of information gathered from the project partner's (SmartHomes and WSZ), a detailed enough BEM could not be created to analyse later simulations of energy savings within the building due to the KnoHolEM approach. The BEM was initially constructed in the code TAS in year 1 of the project with a full 3d geometry of the building created, however the project concentrates on only certain Ground Floor areas within the Forum building.

In year 2, a large change in the Knoholem methodology meant that as well as these simulations used as a validation test against which the actual consumption data can be assessed they were now also used to inform the ANN model – providing the first step in the system diagram of the Knoholem methodology. For this reason, the Forum model was re-simulated in the open source EnergyPlus simulation software (via Design Builder) and a series of simulations created to allow for optimisation strategies. Following successful simulation of the Forum building, EnergyPlus simulations of the Mediatic building were begun. However, it is noted that this additional work sits outside the scope of the purely "validation" Work Package 5, despite this work taking up the majority of BRE's manpower for several months.

The altered methodology devised for the project as a whole continued to add additional time demands during year 3 of the project that are not within WP5 alone, necessitating minor delays in Deliverable 5.4. To collect enough information to perform the simulation a large amount of data still needed to be gathered regarding both the fabric and services within the buildings, due to buildings being replaced within the Project and late arrival of data (PICA and HHS respectively) this made an initial definition of all buildings an unrealistic option in year 2. However, this new methodology allowed for a split of Tasks 5.3 and 5.4 from an initial definition and enhancement to a completion of each building in series. Deliverable 5.3 was also completed in Year 2. This deliverable is the initial profiling and simulation of the Demonstration Objects. With two buildings completed in sequence, Forum then Mediatic in year 2, the remaining Demonstration Objects were modelled in the Design Builder system for use within the validation Work Package during year 3 for WT5.5 and Deliverable 5.4.

<u>Demonstration Objects Energy Management Systems Enhancement</u>

As described above Deliverable 5.4 was completed in year 3, its work task (5.5) concentrated on the full definition of the remaining buildings to produce the relevant Building Energy Model and was a continuation of the prior work tasks rather than an initial then enhanced system as found in the DoW. The BEM for PICA, Bluenet and HHS were constructed in Design Builder/EnergyPlus in year 3, unlike the Forum building they had no previous works to inform them from the prior Work Tasks (5.3/5.4). The re-working of the entire project methodology meant additional works in Task 5.5, as per 5.3/5.4 that were not directly linked to Work package 5's Validation process per se, however the works to create Deliverable 5.4 finalised Tasks 5.3 through to 5.5. Whilst Year 3 effort was expended to create Energyplus outputs for the thermal models i.e. not Validation work (required as Cardiff University required simulation outputs in a text based format for their elements of the project) the completed BEM from Task 5.5 also allowed further test simulation work of the optimisation scenarios at the end of year 3. These test scenarios giving a simulated corollary to the expected energy consumption results from Task 5.6.

Demonstration Objects Energy Management Systems Validation and Benchmarking

Demonstration Objects Energy Management Systems Validation and Benchmarking aimed "to deploy, fine-tune and conduct final testing of the demonstration objects energy management systems and establish lifecycle costs". The task due to start "as soon as the real-time hardware boxes as well as their software are functional and installed in the demonstration objects". However, as the above description reveals this work task can only be completed once the working Knoholem solution was installed and working in Demonstration Object buildings and providing data to analyse. The planned project extension would have therefore moved these works for Year 3 from months 34-36 to months 40-42. However, the hardware and software of the KnoHolEM approach was not installed by the original end date and thus there is no monitored data from within the Demonstration Objects to allow Work Task 5.6 to begin, save for data to compare to test scenarios simulated in WT5.5.

Naturally due to the lack of installed systems or their "fine tuning"(as described in the DoW) there was no practical finalisation of the project and the works could not be delivered as Deliverable D5.5 at the end of the project (whether month 36 or 42). Validation could only begin where works have progressed towards the introduction of the sensor and control works for the KnoHolEM solution in any Demonstration Object and a suitable period of operation was allowed for analysis. The works intended to be in operation for the extension period requested in the 2nd Review were to have allowed for a period of operation of a cooling season in the Spanish buildings (Summer 2014) and the heating season in the Dutch buildings (Winter 2014/14). However, as these operating periods were not completed it was not possible to perform the task and deliver this Deliverable Report as planned.

2 Project Impact, Dissemination and Exploitation

2.1 Dissemination Activity

The consortium attended many events and presented the project to over 3000 thousand people. A selection of key activities is given below, with all dissemination activities of all partners found in the table at the end of this chapter.

Some of the main dissemination achievements could be summarized as follows:

- The consortium disseminated results to more than **50 research conferences** and seminars with a total number of participants extending 3000 people;
- After the nomination for Best paper during the second project year (Nomination for scientific publication resuming the KnoholEM ontology development and population concept) , **13 scientific publications** have been submitted and **1 Best Paper award** was granted to the KIT team. 3 **Joint publications** (TCD, KIT, BRE and Bdigital teams) has been presented to conferences in 2014 and 2 are expected to be more published in 2015. The publications are primarily focused on the web-based vizualization dedicated to energy management and teaching methodology for virtual engineering practical courses for students based on KnoholEM ontology results and know-how gathered for energy management in buildings;
- BRE as lead partner delivered many seminars to industry groups; these include the ICE BIM conference 2013, BRE Trust research conference The Siemens Future Cities Lab, London April 2014 to 200 people, China BIM conference June 2014 to 400 people;
- VoCamp workshop participation: Partners P2, P4 and P5 attended the VoCamo workshop on Building Information Modeling (BIM) in Brussels
- 1 Best paper nomination for the KIT team at the KEOD Conference in Portugal Paper accepted at ICAE conference in Pretoria, 1-4th July. Paper accepted for Special Issue Journal publication.
- Nick Tune from BRE is on the board of BuildingSMART the body that develops openBIM standards it was requested that the work done by the project expands the IFC and IDM BuildingSMART standards (Task 4.5). Therefore all the findings from the projects and the work done on BuildingSMART standards have been shared with the technical committee of BuildingSMART international;

The following tables give selection of some of the dissemination and publication activities of KnoholEM for a more detailed list refer to years 1-3 reports.

Dissemination activities of all partners

No.	Title	Partner involved	Role of the partner	Name of the Event	Date	Number of participants	Place	Links
1	Smart Homes & Smart Living event	SMH/WSZ	Booth	Beurs Domotica & Slim wonen	October 2012	120	Eindhoven	http://www.beursdomoticaenslimwonen.nl/beursdomotica/Exposanten/English.aspx
3	VoCamp workshop participation	KIT	Presentation	VoCamp Conference	February 2013	N/A	Brussels, BE	http://www.adapt4ee.eu/adapt4ee/news/show.html?id=52
4	EEB ICT Workshop	TCD	Presentation	EEB ICT	March 2013	N/A	Dublin	
6	Second Workshop on Energy-Efficiency in Buildings participation	TCD	Presentation	Second Workshop on Energy-Efficiency in Buildings	March 2013	N/A	Dublin, Ireland	http://www.csi.ucd.ie/files/agenda_2013_02_13_3.pdf
10	Innovation Festival in Bari	MATRIX	Exhibitor, stand n.4	"Festival dell'Innovazione di Bari"	May 2013	60	BARI	http://www.festivalinnovazione.puglia.it/contenuti/#.UfeE16z4mE8
12	VoCAmp workshop participation	KIT	Participation	VoCamp Conference	June 2013	15	Kaiserslautern, DE	http://www.adapt4ee.eu/adapt4ee/news/show.html?id=60

13	Intelligent knowledge generation for energy management in buildings	KIT	Poster presentation	KIT Annual Energy Forum	June 2013	60	Karlsruhe, DE	http://www.energie.kit.edu/Jahrestagung.php
14	Presentation at Amtech BIM event	BRE	Presentation	BIM a focus on reality	June 2013	100	Siemens crystal	Presentation at Amtech BIM event
16	Introduction of KnoHolEM Project	KIT	Presentation	KIT-Stadtforschung	July 2013	40	Karlsruhe, DE	
17	International Conference on Applied Energy	TCD	Presentation	International Conference on Applied Energy	July 2013	N/A	Pretoria, South Africa	http://www.applied-energy.org/accepted%20paper.html
18	Instituted of Structural Engineers BIM event	BRE	Presentation	IstructE BIM event	September 2013	200	Institute of structural engineers	
20	Joint Workshop KnoHolEM-Adapt4EE on Behavior Modelling	KIT/TCD/BRE	Organization	Joint workshop KnoholEM-Adap4EE on Behavior Modelling	September 2013	30	Karlsruhe, DE	http://www.adapt4ee.eu/adapt4ee/news/show.html?id=64
21	KnoholEM results disseminated and discussed	CU/BRE	Main organizer	The 21st International Workshop: Intelligent Computing in Engineering	16th -18th July 2014	150	Cardiff	http://egice2014.engineering.cf.ac.uk/
22	Disseminated KnoholEM results	BRE		International Conference on Sustainable Design and Manufacturing	28th-30rd April 2014	100	Cardiff	http://sdm-14.kesinternational.org/
23	Presentation at Institute Civil Engineers BIM conference	BRE		Making BIM work for you	16 October 2013	500	London	http://www.ice-conferences.com/ice-bim-2013/

24	Presentation at BRE Trust Research Conference	BRE	Main Organizer	BRE Trust Research Conference	25 Feb 2014	200	London	http://www.bre.co.uk/trc/page.jsp?id=3240
27	"Intelligent, energy-efficient buildings and cities"; knowledge base concept of KnoholEM	KIT	Presenter	Women for Energy	12.12.2013	~50	Stuttgar, Germany	https://www.steinbeis-europa.de/event.W4E-2013.html
30	Energy efficient Public buildings workshop: Presentation of the KnoholEM final outcome	KIT	Organizer	LESC Open Day	23th July 2014	~120	Karlsruhe, Germany	http://www.imi.kit.edu/2292.php
31	Opening the Industry 4.0 Lab at LESC in cooperation with Bechtle	KIT	Co-organizer	Opening the Industry 4.0 Lab at LESC	24. Sept. 2014	85	Karlsruhe, Germany	http://www.imi.kit.edu/2484_2334.php
32	Annual assembly of all professors in Mechanical Engineering from Germany and Holland	KIT	Organizer	WiGeP Herbsttagung 2014	25-26 Sept.2014	50	Karlsruhe. Germany	http://www.imi.kit.edu/2484_2386.php
33	Poster and Demo presentation of the KnoholEM project	KIT	Co-organizer	TechViZ Open Day at LESC	14.Oct. 2014	60	Karlsruhe, Germany	http://www.imi.kit.edu/2485.php
35	ConnectIdea2Business	KIT	Exhibitor + Presenter	ConnectIdeas2Business 2014	26.05.2014	~200	Karlsruhe, Germany	http://www.connectideas2business.org/english/programme/
36	Concerteo Premium Conference	SEZ	Organizer + Echibitor	Concerteo Premium Conference	22.-23.10.2013	300	Bruessels	http://www.amiando.com/concerto_conference.html

Scientific Publications

No	Title	Main author	Title of the periodical or the series	Publisher	Place of publication	Year of publication	Link
1	A Virtual Reality-based Context Simulator for Evaluating the Effect of Uncertainty on Smart Building Applications	TCD	Thesis	Trinity College Dublin, School of Computer Science and Statistics	Trinity College Dublin	2013	http://www.krismcglinn.com/thesis-kmcglinn.pdf
2	Ontology Development towards Expressive and Reasoning-Enabled Building Information Model for an Intelligent Energy Management System, KEOD Conference, 19-22.Sept.2013	KIT **Best Paper nomination**	KEOD Conference 2013	International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management.	Portugal	2013	http://www.keod.ic3k.org/DoctoralConsortium.aspx?y=2013
3	Semi-automated Ontology Population from Building Construction Drawings,	KIT	KEOD Conference 2013	International Joint Conference on Knowledge Discovery,	Portugal	2013	http://www.keod.ic3k.org/DoctoralConsortium.aspx?y=2013
4	A Context Simulator for Supporting Evaluation of Smart Building Applications when Faced with Uncertainty	TCD	Pervasive and Mobile Computing	Elsevier	Online	2013	http://www.sciencedirect.com/science/article/pii/S1574119213000394

5	Interactive Visualization for Energy Efficiency Concepts using Virtual Reality.	Häfner, P., Seeßle, J., Dücker, J., Zientek, M., Szeliga, F.	20th Eurographics Symposium on Virtual Environments (EGVE)		8-10. December, Bremen, Germany	2014	
6	Virtual Reality Aided Energy Efficiency Optimization in Operational Phase of Public Buildings. (under review)	Häfner, P., Wicaksono, H., Häfner, V., Seeßle, J., Dücker, J.	IEEE Virtual Reality 2015		Arles, France	March 2015	
7	Teaching Methodology for Virtual Reality Practical Course in Engineering Education BEST Paper AWARD	Häfner, Polina; Häfner, Victor; Ovtcharova, Jivka	Procedia Computer Science Volume 25	International Conference on Virtual and Augmented Reality in Education 2013	Teneriffe, Spain	Nov. 2013	
8	A flexible and extensible web-based visualisation and configuration interface for holistic energy management of buildings	Kris McGinn	International Conference Applied Energy	ICAE	ICAE Conference Paper	2013	

2.2 Exploitation

Overview of exploitable results

List of future exploitation measures per exploitable result

No	**Exploitable knowledge, product(s) and service(s) incl. consultancy**	**Partner Interested in Exploitation**	**Target group and sector**	**Type of Exploitation** Research, Product Improvement, new product	**Patents or IPR protection**	**IPR owner**	**other partners involved**	**Time to commercial use (after project end)**
1	Method for ontology development	**KIT**, TCD, CETMA	Ontology experts; knowledge management experts	Research, Education	no	KIT		No commercial use is foreseen
2	OWL based BIM model	**KIT**, TCD, CU, HHS, BD	Architects, knowledge management experts	Research, Education	no	KIT	TCD	No commercial use is foreseen
3	IFC-OWL Mapping method	**KIT**, TCD, HHS	Ontology experts, energy modelling experts, energy consultants	Research, Education	no	KIT	TCD	No commercial use is foreseen
4	Sensitivity Analysis method	**CU**, CETMA, KIT, TCD, ISOTROL,HHS, TE	Ontology experts, energy modelling experts, energy consultants	Research, Education	no	CU	KIT	No commercial use is foreseen
5	Fuzzy Reasoning	**CETMA**, BRE, ISOTROL,HHS, BD,TE	Knowledge management experts, engineering company (data acquisition), energy management companies, big data companies	Service	Yes	CETMA		Immediatley
6	Data Mining Framework	**KIT**,	Knowledge management experts,	Research, Education,	no	KIT		Immediately

		TCD,CETMA, ISOTROL, HHS,BD	engineering company (data acquisition), energy management companies, big data companies	Service,				
7	Scalable method for gathering data on activities	TCD, KIT, **BRE**, ME	Knowledge management experts, engineering company (data acquisition), energy management companies, big data companies	Research, Education, Service,	no	BRE		Immediately
8	OntoCad Tool	**KIT**, BRE, ,TCD, HHS	Architects, ontology experts, energy management experts	Research, Service	Yes	KIT		2 months
9	Energy Real Time Controller	**CETMA**, ISOTROL, HHS, KIT	Knowledge management experts, engineering company (data acquisition), energy management companies, big data companies	Research, Service	Yes	CETMA, Tera, Matrix		6 months
10	Interactive visualisation tool	**TCD**, KIT,BRE,CU, SH, WSZ, HHS, ME,TE	Architects, engineering companies, Software companies, contractors, facilities management,	Research Service	Yes	TCD		6 months
11	Case study building analyses	**CU**, HHS	Architects, engineering companies, Software companies, contractors, facilities management,	Research	No	CU		Immediately
13	Building Energy model (BEM)	**BRE**, TCD, CETMA, CU, HHS, ME	Architects, engineering companies, Software companies, contractors, facilities management,	Research	No	BRE		Immediately
14	KnoholEM integrated solution	KIT, TCD, CETMA, CU, ISOTROL, SH, WSZ, HHS, ME, TE	Building managers/owners	Service	Yes	TCS, CU KIT CETMA TCD TERA		2 years

						MATRIX BRE		
15	Energy Audit	**BRE**, ISOTROL, SH, WSZ, HHS, BD, ME, TE	Architects, engineering companies, Software companies, contractors, facilities management,	Research	No	BRE		Immediately

Exploitation strategy

Most of the partners wish to utilise the learning and IPR from the project to offer new products or services, or to improve the way they operate as a business, or to further their research. There is however very few organisations from within the consortium that have the technical skills, capital or market reach that could commercialise the solution independently. The consortium did not feel externalisation would be the most appropriate methodology, as the project was highly complicated and there was not an obvious company that the consortium would approach to partner with. Also a joint spin-off company was dismissed as this was thought to be too time consuming and costly to develop due to IPR agreements and shareholding percentage ownership agreements. The Open Society approach was being partially implemented as some of the organisations (especially the Universities) were planning to write papers on the project, sharing learning and using the knowledge to further develop the knowledge in ICT in construction such a extending the IFC schema to allow energy management of buildings. Also R&D would be implemented as many partners wished to further the increase the knowledge and IPR that had been created by developing new research projects.

Therefore, for the reasons sated above a mix of strategies will be used: open/research by the Universities and internal/externalisation by industry.

Most of the partners will use elements of the knowledge/IP generated to improve their current business offering or to sell new ones. As noted previously some partners wish to go into partnerships/deals with others so that they can use/exploit the IP that has been generated by another partner in order to sell a product or service they believe has commercial opportunity.

In regard to the exploitation of the 'whole' KnoholEM solution to the market place as a 'for sale' product, It appears that very few partners would have the commercial or technical size to take the product to market (most will take to market an element of the solution). However BRE plan to take the KnohelEM solution to market but in a staged manner via a spin out business in partnership with Cardiff University. The reason for this is that BRE believe the market is not ready for the product yet (within the next two years) as more buildings require Building Information Models and improved monitoring systems in order for the solutions to be affordably implemented. However, the market for improved energy management in buildings via machine learning is a large market that BRE would like to exploit for public and commercial buildings.

In order for BRE or any other partner to commercialise the tool it will require the organisation that has created the IPR (as noted above) to enter into an agreement with the organisation wishing to exploit the solution. Therefore the most vital IP required to develop and sell the overarching solution is;

- Methodology for Ontology creation (including the use of OntoCAD) – Developed and owned by KIT
- Fuzzy reasoning and real time energy controller – Developed by CETMA
- Visualisation tool – Developed for TCD

In order for BRE or any other partner to commercialise the KnoholEM solution they will have to negotiate the use of the aforementioned IPR. However, the use of the IPR/Knowledge will not be enough to take the product to market in the short time as further work is required. When investigating the cost of developing a market ready version of the KnoholEM solution, it is important to consider the cost associated to deploy it. For buildings without BIMs the cost of creating a BIM/ontology and energy model as well as supplying/installing monitoring equipment into an existing building may be prohibitive, in relation to a cost value proposition. The KnoholEM solution will therefore be more applicable to newly constructed buildings that have an associated Building Information Model, Energy Model and BMS.

Staged commercialisation of the KnoholEM solution

Stage 1 – energySight

The BRE/Cardiff University will develop a spin out business that will firstly take to market their energySight product. This is a service where the company will provide an energy performance audit of the building via existing or installed monitoring devices (additional monitoring devices will only be installed during a set period of time to provide real performance data, for buildings where the current monitoring systems does not provide the level of granularity that is required). The real data will be compared with modelled performance data for the building. This will therefore show the difference between the buildings actual performance compared to the designed projected performance. Via the knowledge we have gained via the KnoholEM project we will run scenario models of the real performance against the simulated so that we can determine how the building should be operated in the most optimum manner based on its current usage so that energy use can be minimised. In effect this is the KnoholEM solution without the ontology. As noted the reason for using this methodology to begin with means we do not need the BIM/Ontology which means a lower cost of delivery. However we realise that the level of energy saving will be slightly less because of this. Additionally BRE does not need to develop a new tool/product to get to market as this will be a service based on the knowledge we have gained from the project.

The service will obviously be aimed at existing buildings; predominately that that have been constructed within the last 5 years and that are not performing as well as the design models indicates it should. It is worth noting that once ANN/Machine learning tools from companies like Schneider become widely adopted then this service will not be as relevant as the buildings should perform closer to how they were designed. However we do not believe that this will take from our market share within the first 5 years.

Stage 2 – KnoholEM

In approximatley 2 years when the esight product has significant market penetration. The BRE/CU spin out company will launch the KnoholEM solution. The reason for this is that more buildings will have BIMs and comprehensive energy models and new buildings will have sufficent monitorng/BMS systems. The complete solution requires a user interface and monitoring/actuation hardware. It is not proposed that the BRE/CU spin out business develops the hardware. Instead the proposal is that we partner with an organisation such as Schneider to utilise their hardware and actuation equipment. We will develop the user interface and will embedd our algorythms into our partners equipment so that the solution can be delivered cost effectively.

The development of the commercial ready solution will therefore require

- Development of the user interface, ideally in partnership with TCD.
- Creation of the final solution in collaboration with partners who's IP is required
- Creation of partnering contract with a major hardware control company
- Further live testing
- Commercial/market plan

Further developments required to commercialise KnoholEM

In order to commercialise KnoholEM the Integration of the BMS and the bespoke sensors that are added to report in a real time bases needs to be addressed. During the project we have been able to take the data from the building but this has been a protracted process that has involved many visit to the buildings, the problem is that there is little standardisation in relation to energy monitoring devices. Therefore further work is needed to develop an approach to take the data from BMSs in an easy to use format.

Further work is also required to allow the solution to integrate with standard BIMs. Currently, for the system to work with BIMs it requires an extension to the IFC so that monitoring/energy consuming devise information/data is added to the IFC schema.

Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when* ***Grant Agreement number*** *is entered.*	
Grant Agreement Number:	285229
Title of Project:	KnoholEM
Name and Title of Coordinator:	Nick Tune

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***No***
2. Please indicate whether your project involved any of the following issues (tick box) :	***YES***
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	

RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	0 Yes 0 No
• Research having the potential for terrorist abuse	

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	1	
Work package leaders	3	4
Experienced researchers (i.e. PhD holders)	2	6
PhD Students		2
Other		

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**3**
Of which, indicate the number of men:	3

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?

- ¡ Yes
- l No

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective				Very effective
q Design and implement an equal opportunity policy	¡	¡	¡	¡	¡
q Set targets to achieve a gender balance in the workforce	¡	¡	¡	¡	¡
q Organise conferences and workshops on gender	¡	¡	¡	¡	¡
q Actions to improve work-life balance	¡	¡	¡	¡	¡

¡ Other:

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

- ¡ Yes- please specify
- l No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

- l Yes- please specify: KIT shared the project utcomers with students at the university
- ¡ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

- ¡ Yes- please specify
- l No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

- Main discipline[5]:
- Associated discipline[5]: | Associated discipline[5]:

G Engaging with Civil society and policy makers

11a	**Did your project engage with societal actors beyond the research community?** *(if 'No', go to Question 14)*	¡ ❙	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ¡ No
- ¡ Yes- in determining what research should be performed
- ¡ Yes - in implementing the research
- ¡ Yes, in communicating /disseminating / using the results of the project

11c	**In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?**	¡ ¡	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ¡ No
- ¡ Yes- in framing the research agenda
- ¡ Yes - in implementing the research agenda
- ¡ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ¡ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ¡ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ¡ No

13b If Yes, in which fields?

[5] Insert number from list below (Frascati Manual).

Agriculture		Energy		Human rights	
Audiovisual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		Environment		Internal Market	
Consumers		External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	
Customs		Fisheries and Maritime Affairs		Regional Policy	
Development Economic and Monetary Affairs		Food Safety		Research and Innovation	
Education, Training, Youth		Foreign and Security Policy		Space	
Employment and Social Affairs		Fraud		Taxation	
		Humanitarian aid		Transport	

13c If Yes, at which level? ¡ Local / regional levels ¡ National level ¡ European level ¡ International level	
H Use and dissemination	
14. How many Articles were published/accepted for publication in peer-reviewed journals?	**8**
To how many of these is open access[6] provided?	**8**
How many of these are published in open access journals?	**8**
How many of these are published in open repositories?	**8**
To how many of these is open access not provided?	**0**
Please check all applicable reasons for not providing open access:	
q publisher's licensing agreement would not permit publishing in a repository q no suitable repository available q no suitable open access journal available q no funds available to publish in an open access journal q lack of time and resources q lack of information on open access q other[7]: ……………	**0**

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		**0**
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	**0**
17. How many spin-off companies were created / are planned as a direct result of the project?		**1**
Indicate the approximate number of additional jobs in these companies:		**3**

[6] Open Access is defined as free of charge access for anyone via Internet.
[7] For instance: classification for security project.

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

l	Increase in employment, or	q	In small & medium-sized enterprises
q	Safeguard employment, or	q	In large companies
q	Decrease in employment,	q	None of the above / not relevant to the project
q	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:* *5*
Difficult to estimate / not possible to quantify	q

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

l	Yes	¡	No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

¡	Yes	l	No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

l	Press Release	l	Coverage in specialist press
q	Media briefing	l	Coverage in general (non-specialist) press
q	TV coverage / report	q	Coverage in national press
q	Radio coverage / report	q	Coverage in international press
l	Brochures /posters / flyers	l	Website for the general public / internet
l	DVD /Film /Multimedia	l	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

q	Language of the coordinator	l	English
q	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]