	EUROPEAN COMMISSION DG CONNECT	Final Report
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Project No.: 285150

Project Acronym: SEEDS

Project Full Name: Self learning Energy Efficient buildDings and open Spaces

FINAL REPORT



Period covered: from 01/09/2011 to 28/02/2015

Funding Scheme: Collaborative Project

Start date of project: 01/09/2011

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1 Final publishable summary report

1.1 Executive summary

SEEDS is an FP7 project in the field of ICT technologies for Energy efficient Buildings. It started in September 2011 and ended in February 2015. It focuses on the development of a Building Energy Management System (BEMS) to optimize buildings' performance in terms of energy, comfort and life cycle cost. It can be applied to single buildings or group of buildings and surrounding open spaces.

SEEDS performs detailed modelling of the HVAC equipment which is by far the largest energy consumer in buildings. The modelling of the energy equipment in the building is based on IFC – an Open BIM data exchange format.

SEEDS implements an innovative model predictive control strategy based on sensor measurements and self-learning techniques. This methodology allows taking into account the properties of a building and its energy behaviour without the need of having explicitly the architecture model (usually in BIM) of the building. If available, SEEDS uses BIM data about the building floorplan/layout and the building services structure. If BIM format is not available, then a tailored SEEDS' methodology is used for gathering the information about the spaces, energy equipment, supplies and storages and user conditions. This methodology is based on a MS Access schema and allows designing a BEMS for a building starting using only the information available on the building facilities and the appropriate set of measurements that are captured by wireless sensor nodes. This Access database represent an own ontology of a building information model (BIM). Its structure is based on Industry Foundation Classes with enhancements to cope with SEEDS requirements. The SEEDS architecture includes access to several self-learning methods, such as neural networks, decision tree learners and Bayesian networks that can be used to learn models for predicting variables such as temperature, air quality as well as presence in rooms. These predictive models are used by a Particle Swarm Optimisation algorithm that has been specifically tailored for optimising settings to minimise energy consumption whilst maintain comfort, leading to an energy efficient control strategy. Thus, unlike previous approaches, there is no need to have detailed architecture information (such as material parameters, thermal capacities etc.) and hence, SEEDS can be easily applied to the energy-aware upgrading/optimization of existing building services systems and to the retrofitting of old buildings which may lack constructional specification details necessary for traditional systems. Moreover, the use of wireless technologies, coupled with a capability for self-learning and optimisation provides a BEM model that evolves with time.

SEEDS allows improving the energy behaviour of buildings reducing the energy costs and the CO₂ emissions while taking care of comfort & health conditions (indoor temperature, humidity, air quality and lighting level). On the other hand, the commissioning and maintenance of HVAC and lighting systems is simplified with respect to traditional ones and so is the cost. Moreover, one of the paramount characteristics of SEEDS is its ease with which it can be applied to any building which will facilitate market penetration of customized ICT solutions for building operation.

SEEDS includes two validation pilots in two different climatic areas and of different uses: an office building in Madrid (Spain) and a building into University of Stavanger Campus in Stavanger

(Norway). According to recent surveys¹, offices buildings and educational buildings 40% of non-residential building stock in Europe.

1.2 Summary description of project context and objectives

SEEDS develops an ICT tool for the optimal management of the energy behaviour of a building (or group of buildings) and surrounding open spaces: a Building Energy Management System (BEMS). SEEDS is able to make predictions about future conditions/behaviour of the building environment and its inhabitants in order to decide on the best control settings that will minimize energy consumption while meeting comfort and health conditions. SEEDS relies in a wireless network of sensors and actuators deployed in the building. It is very appropriate for upgrading of existing buildings.

SEEDS' BEMS relies on the following objectives (O):

- O1. Development of innovative methodologies for the monitoring and control of energy consumption parameters inside buildings and surroundings or districts based on self-learning and optimization techniques. This objective has been fully met.
- O2. Optimization of the building's (including surrounding space and district) performance in terms of comfort, functionality, energy efficiency, resource efficiency, economic return and lifecycle value.

SEEDS BEMS includes several components and systems whose joint performance allows optimizing the energy behaviour of the buildings. These components includes: the Controller, the Facility Model² and the Energy Calculator, the Self-Learning, the Optimizer, the WISAN and GUI. These components were tested in a simulated prototype before their implementation for the two pilot buildings. After that, the joint performance and the communication of/among the different components were also tested for the original UiS scope and it worked well. However, during the very last stage of the project during the implementation in the Ferrovial pilot, some errors were found in the Optimizer code. These errors haven't been solved yet at the moment of submitting this report. The solution of these errors is being a difficult task because the researcher who developed the code in UiS (partner # 6) left the organization and the person to substitute him hasn't been able to solve the problem yet. Therefore, this objective has been partly met because of the miss-functioning of the Optimizer code. However, the rest of the components properly perform their tasks and communicate well among themselves.

- O3. Development, demonstration and validation of a methodology suitable for retrofitting and new construction including open spaces.

¹ "Europe's Buildings Under the Microscope", Buildings Performance Institute Europe (BPIE), October 20¹1.

² The *Facility Model* component was initially called *Building Model*. The term *Building Model* may be confusing because it seems to be related with the physical model of the building including architecture issues such as wall and window models and balancing the thermal flows. However, SEEDS' focus is the modeling of the technical building equipment and its thermal balancing. The term *Facility Model* is used since D2.8 onwards.

A methodology has been developed and validated for the SEEDS concept. A commissioning flow suitable for the application of SEEDS in any building has also been developed. Because of the errors in the Optimizer code references above, it hasn't been possible up to accomplish all the steps in the commissioning flow for the two pilots. Therefore the full demonstration (all components managing the building) in the two pilots hasn't been possible yet but the only inconvenience is the Optimizer. However, the developments were tested in a small size testbench and the integration of all software components was also tested for one of the pilots (UiS pilot) using WISAN mock up, prior to the commissioning of the nodes.

O4. Integration with existing control systems (like safety, security, fire alarm or lifts).

SEEDS' BEMS has been conceived so that it can easily be integrated with other control systems in the building. As SEEDS is only a prototype, the demonstration of SEEDS hasn't considered the integration with other control systems existing in the two pilots.

O5. Exploitation and dissemination of the technologies developed and best practises learned.

SEEDS concept and project was presented in a number of dissemination events: conferences and workshops, wikis and newsletter. An initial exploitation plan has also been developed but most of project partners.

O6. Contribution to the reduction of greenhouse gas (GHG) emissions and, by hence, contribution to the fulfilment of the SET-Plan on energy efficiency.

SEEDS methodology, modelling and concept is oriented towards the minimization of energy consumption and by hence CO2 emissions.

To achieve the above list of goals, the following scientific/technical objectives (STO) are pursued:

STO	Objective Description	Related to WP	State
STO1	Development of a modelling methodology for a wide spectrum of building types and energy systems and subsystems.	WP1, WP2	Finished
STO2	Research and development of scalable implementations of global optimization algorithms.	WP5	Finished
STO3	Development of self learning and optimization behavioural models for energy systems and subsystems in buildings.	WP1, WP2, WP5	Finished
STO4	Development and adaptation of a network of Wireless Intelligent Sensors and Actuators (WISA) and design and implementation of communication middleware and configuration tools for the WISA.	WP3, WP4	Finished
STO5	Development and refinement of anytime self-learning and optimization algorithms able to cope with the requirements of energy management systems.	WP5	Mostly finished (1)
STO6	Validation and implementation in two pilot demonstrators.	WP1, WP7, WP8	Partially finished(2)

Table 1. Scientific/technical objectives (STOs)

(1): At the moment of the submission of this report some problems in the Optimizer code remains (2): Because of the problems with the Optimizer the full validation in the pilots hasn't been possible yet.

The above STO are linked to the following technical achievements (TA)

TA#	Technical achievement description	Related to WP	State
TA1	Processes, systems and tools for the development of a BEMS based on self-learning and optimization techniques.	WP1, WP2, WP3, WP4, WP5, WP6	Mostly finished (1)
TA2	Holistic classification of building types and energy systems and subsystem and methodology for energy control systems modelling.	WP1, WP2	Finished
TA3	Design of energy systems and subsystem behavioural models and implementation into a library.	WP1, WP2	Finished
TA4	Design, development and implementation of a network of WISA and communication middleware and configuration tools.	WP3, WP4	Finished
TA5	Development of anytime self-learning and optimization algorithms tuned specifically for BEMS.	WP5	Finished
TA6	Implementation of scalable global optimization algorithms with relevant computational infrastructure.	WP5	Mostly finished (1)
TA7	Validation and implementation of the technologies developed. Drafting of 'Best ICT practises for energy efficient buildings and surrounding spaces'.	WP1, WP7, WP8	Partially finished(2)

Table 2. Technical achievements (TAs)

1): At the moment of the submission of this report some problems in the Optimizer remains (2): Because of the problems with the Optimizer the full validation in the pilots hasn't been possible yet. Best practises has been draft and included in the corresponding deliverable (D8.6)[1]

Table 1 and Table 2 above include the status of STO and TA at the end of the project. As a summary, most of the tasks were fully accomplished and reached quality standards except for those related to the Optimizer and the demonstration.

In relation to the tasks related to the optimization, the Particle Swarm Optimization methodology was applied and worked well together the rest of the components as it was reported in D5.5 [7] (submitted in September 2014). However, there were some mistakes in the code encountered in February 2015 which hasn't been solved yet. Unfortunately, the researcher in charge of the Optimizer code in UiS left the organization after the completion of D5.5 [7] (which showed a good performance of the Optimizer and Self-learning codes integrated in the SEEDS architecture). The replacement hasn't been able to solve the problems in spite of the strong disposition and help provided by Fraunhofer (partner #2, developer of Controller, FM and SEEDS Cache) and USAL (partner #5, developer of SL and leader of WP5 on Optimization and Self-Learning). As a consequence, some errors in the optimizer code which were discovered at the very last stage of the

project during the validation in Ferrovia (February 2014) hasn't been solved yet and, for that reason, the full implementation of SEEDS in the pilots haven't been possible.

In relation to the demonstration, it was delayed partly due to the complexity of the project and the challenges, not originally considered, that were assumed in order to increase the interoperability and the replicability of SEEDS but mostly due to the difficulties caused a poor and obsolete AS-BUILD documentation of the pilots and the limitations for the installation and commissioning in real occupied buildings. Because of the delay in the demonstration and in order to have some time of SEEDS running in the pilots in order to perform a proper energy validation, the Consortium requested in May 2014 an extension of project duration of 6 months. At that time, the major delay was in the validation in the pilot in UiS. The Commission approved the extension and the end of the project was set in February 2015. Unfortunately, due to the problems mentioned above in relation to the Optimizer the full implementation and validation hasn't been possible in spite of the effort and commitment of the project partners.

Therefore, STO5, TA1 and TA6 are mostly finished and STA6 and TA7 are only partly finished because the full validation of the SEEDS system in the two pilots hasn't been possible.

In spite of not achieving all the planned objectives, the SEEDS project has delivered very positive results: The high level of commitment from most of the partners has made possible to tackle and overtake successfully some scientific and technological challenges that weren't originally considered. As a consequence, the scientific results have been very promising and have overcome the expectations. In fact, the SEEDS project was presented as one of the 5 success stories identified among all the projects funded by the EU under the PPP on Energy efficient Buildings in April 2014.

The following list emphasizes some of the most relevant SEEDS scientific and technical features:

- SEEDS is based on an open and flexible architecture
- SEEDS software is automatically generated for any building based on the creation of a SEEDS MS ACCESS data base which is partly based on IFC structured but enhanced to gather all SEEDS requirements. The integration or update of new building facilities only required the actualization of the MS ACCESS data base and the new execution of the configuration process.
- A Facility Model Library has been developed based on IFC structure and including more than 100 facility components and types with special emphasis on HVAC&R equipment.
- There is no need to have detailed architecture information of the building. Besides, the information on the energy equipment doesn't either to have very exhaustive. Self-learning techniques will continuously learn building and user behavior.
- A wide range of SL methods that can be tuned for particular building types have been investigated. On the other hand, SL is scalable and allows parallelization and distributed processing.
- Hardware and software SEEDS wireless technologies developed will facilitate the deployment, commissioning and maintenance.
- SEEDS' WISAN platform (including configuration tools and data storage) is low cost, scalable and building independent.

- SEEDS has made use of two standards: i) IFC for the generation of MS ACCESS and for the coverage analysis tool developed within the WISAN and ii) OSGI for the controller
- Because of the above reasons the replicability potential of SEEDS is high, in particular in buildings in the commercial field where the energy demand is large and, as a consequence, the energy savings too.

Section 2.1 explains the goals and tasks accomplished during the finished period of the project (M25-M42).

1.3 Description of the main S&T results/foreground

1.3.1 The SEEDS approach and main results

SEEDS develops a BEMS for optimizing building's performance in terms of energy, comfort, and life cycle costs. It is based on an innovative modelling methodology based on measurements, self-learning, optimization techniques and wireless technologies. It performs detailed modelling of the HVAC and lighting equipment, energy sources and energy storages. This methodology allows taking into account the properties of a building and its energy behaviour without the need of having explicitly the architecture model (usually in BIM) of the building or very comprehensive information of the energy equipment (energy sources, storages and demands). SEEDS' relies on the appropriate set of measurements that are captured by the wireless sensors nodes which are also required to implement the most energy efficient control strategy.

Figure 1 illustrates the architecture of SEEDS BEMS which is organized in 3 layers [1] and includes 5 active components (ellipses in the figure) and one passive component which is the SEEDS Cache. .

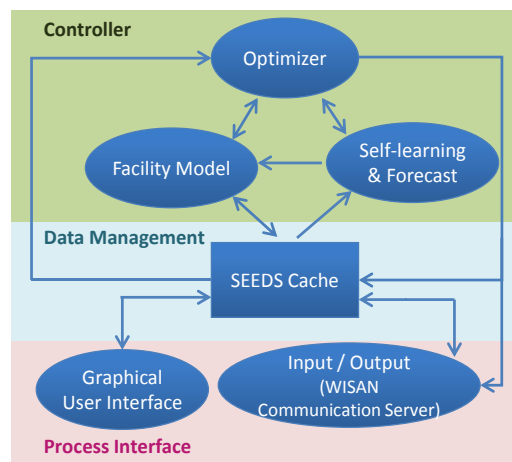


Figure 1. Basic SEEDS Architecture

The Control Layer includes the core components of the BEMS. It receives data from sensors deployed in the building, computes and optimizes new control settings for the facilities in the building and sends these new control settings to actuators in the building. The core components are: i) the Facility Model (FM) which computes the energy consumption/production of all devices or facilities in the building; ii) the Self-Learning (SL) module which forecasts the values of comfort

conditions (such as air temperature, humidity or CO₂ content) and the energy consumption/production of the building for a time horizon ahead and iii) The Optimizing (OPT) module which computes the control settings which will minimize energy consumption keeping comfort conditions for a time horizon ahead.

The Data Management Layer stores historical, present and predicted information on the system. Historical and present data are sensors data, control settings, comfort settings, occupancy, weather conditions and energy consumption while predicted data are the estimated values for comfort settings, occupancy and weather forecast.

The Process Interface Layer includes two components: i) The field devices or Wireless Intelligent Sensors and Actuator Network (WISAN) and its communication server to allow interaction with building equipment and ii) The Graphical User Interface (GUI) to facilitate communication with the user.

1.3.2 The Main Components

1.3.2.1 The SEEDS Controller and the Control Loop

The actual SEEDS Controller consists of the Energy Calculator, the optimization and the self-learning. These three components are part of the control layer of BEMS. In order to organise all variables within SEEDS performance, five groups of variables have been defined. Each of them has a specific meaning in SEEDS BEMS. Table 3 shows these different variable groups and provides some examples. For more information see Deliverable 2.8 [2].

Variable group	Types of variables	Symbol	Examples
Reference variables	Comfort settings, set points of comfort and devices settings	w	Thermal comfort boundaries in rooms
Process variables	Sensor data of comfort and sensor data of equipment	x	Temperature and humidity in rooms
Disturbance variables	Environment variables and use of rooms	z	Outdoor conditions, room use (occupied or no-occupied)
Control variables	Control settings	u	Turn on/off electric radiators, opening percentage of volumetric flow controllers
Load variables	Energy consumption (required) and energy provided	e	Electrical energy consumption of air handling units, thermal energy provided by volumetric flow controllers

Table 3. Variables groups in SEEDS BEMS

Figure 2 shows a block diagram which results from the layer architecture and data flow of the variables above.

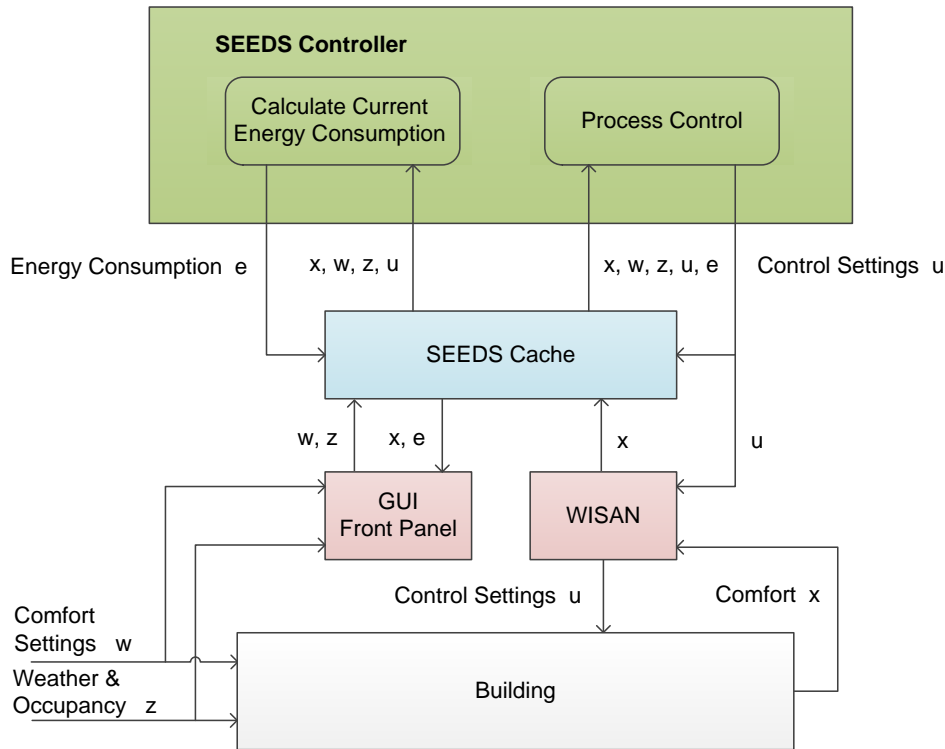


Figure 2 Architecture of SEEDS BEMS in logical view

Figure 3 illustrates the controller's loop to calculate the energy consumption of the building by using the energy calculator and the present values of the process variables, environment variables, and control variables. This task is carried out at determined time points which are set by a sample period.

In the loop of the energy calculation, the process for controlling optimization is inserted. An optimization period is defined as a multiple of the sample period. If SEEDS BEMS is enabled by the facility manager and an optimization time point is reached, a time event is triggered that starts the optimization. The optimization runs in a parallel process. Figure 4 gives an overview about the actives of optimization in relation to self-learning.

The optimization comprises two activities: optimizing itself and the forecast of dedicated comfort variables and energy consumption by self-learning. Optimizing varies the control variables according a given strategy, checks the limitations of the predicted comfort variables and evaluates the objective function for the forecast. If no further reduction of energy consumption can be found or a pre-set number of trials is reached, then the optimization is terminated. The control variable vector related to the best trail is written into SEEDS Cache and sent to WISAN.

The controller is implemented and is used in both demonstrator systems. The controller loop is running with the Energy Calculator and Optimization and generates reasonable values.

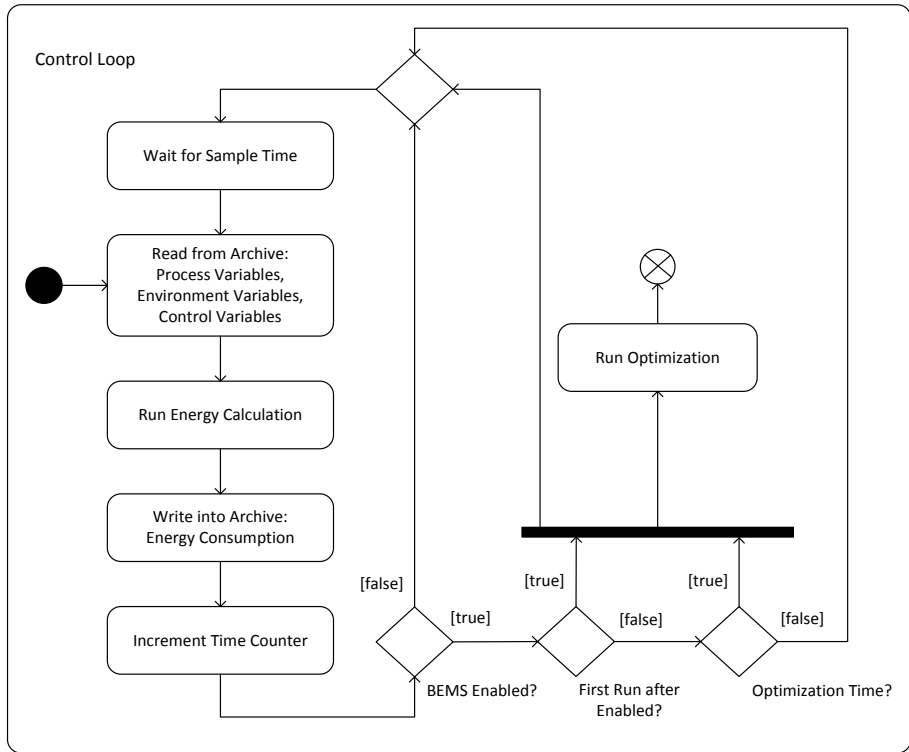


Figure 3. Control loop of energy calculation and starting optimization

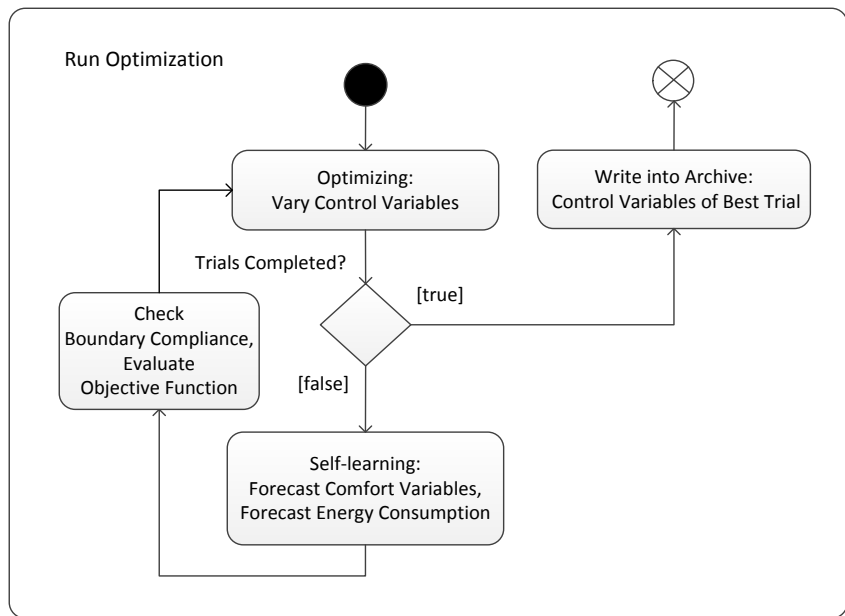


Figure 4 Optimization with forecasting by self-learning

1.3.2.2 The Facility Model and Energy Calculator

The Facility Model models the energy elements in the demonstrators including energy sources, demands and storages. A Facility Model works as a virtual energy meter calculating the energy

consumption of a certain device or group of devices for given device setpoints in a given time period. It is composed of components of a model library of all devices which are available in a building energy system. It provides the single power consumption of each device. In the demonstrators it is distinguished into thermal, electrical and fuel power. Table 4 shows the implemented components for the two demonstrators and where the components are used.

Model	UiS	Ferrovial
Air Handling Unit	X	X
Fuel Boiler		X
Volumetric Flow Control	X	X
Heat Pump		X
Chiller		X
Electric Radiator	X	
Diffusion Element	X	

Table 4. Facility Models for Demonstrators

For the calculation of the energy consumption there are for each power kind a method implemented. These calculations are carried out by means of measurements or data sheets and may be omitted if one of them is missing. The first ones are expression statements, the latter ones are table-lookup algorithms. Additional to power calculations the library implements a method to model local control algorithms, if the control settings are not available in the system.

The Energy Calculator uses an instance of the Facility Model, see Figure 5, and provides the total energy consumption of the whole building. For this step the present values of the process variables, environment variables, and control variables are used. This task is carried out periodically within the sample period Δt . In the demonstrator UiS and Ferrovial the sample period is two minutes. In the control loop the evaluator calls the power calculation methods of all involved devices and computes the present thermal, electrical and fuel powers. These values are multiplied by the Δt to obtain the consumed energy. Summation over all devices results the total energy consumption of the building within Δt .

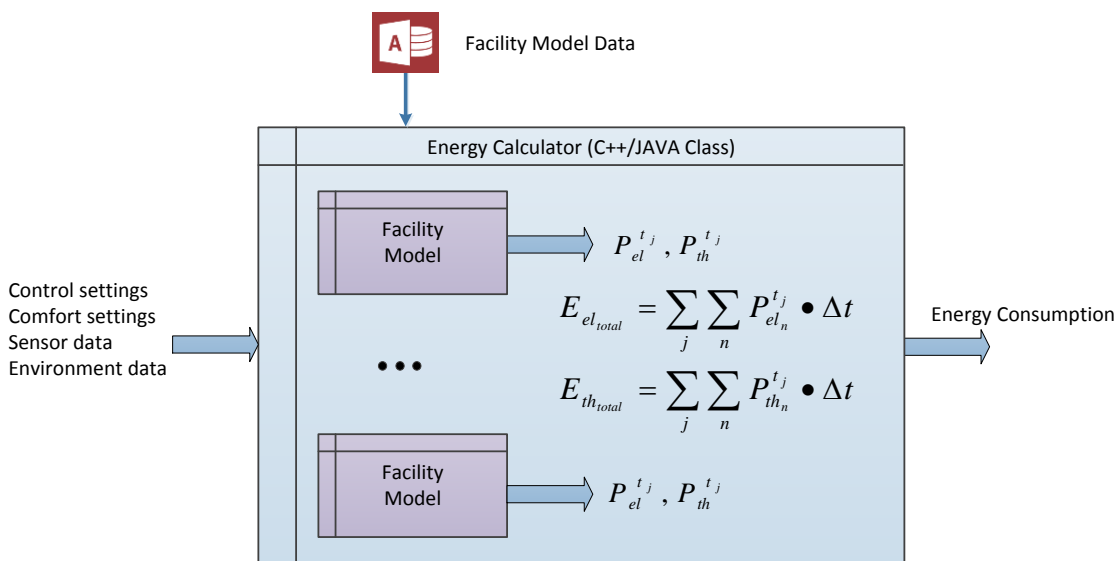


Figure 5 Energy Calculator with instantiated Facility Model

The Energy Calculator is configured and validated for UiS and Ferrovia demonstrator and calculates reproducible values.

1.3.2.3 Optimization by means of self-learning

As summarised in Figure 1, the SEEDS architecture includes a component that aims to optimise energy consumption whilst maintaining user comfort. Achieving this balance implies developing an optimization scheme that is able to look ahead in the near future and provide suitable settings, which in turn implies the need for a component able to predict future environmental variables given certain settings. Hence, SEEDS has developed a novel optimization component that is described in Section 1.3.2.3.1 and a flexible, reusable self-learning component that is described in Section 1.3.2.3.2 below.

1.3.2.3.1 Optimization

Figure 6 illustrates the task for optimization, namely to consider alternative settings u_i , obtain estimates of the comfort variables and energy consumption, and select the most appropriate settings. So, in this illustration, although the settings u_4 demands the least energy, it would lead to uncomfortable conditions (above a certain threshold T_{max}), settings u_1 produces acceptable conditions but u_2 , which also produces acceptable conditions, is less expensive in terms of energy consumption.

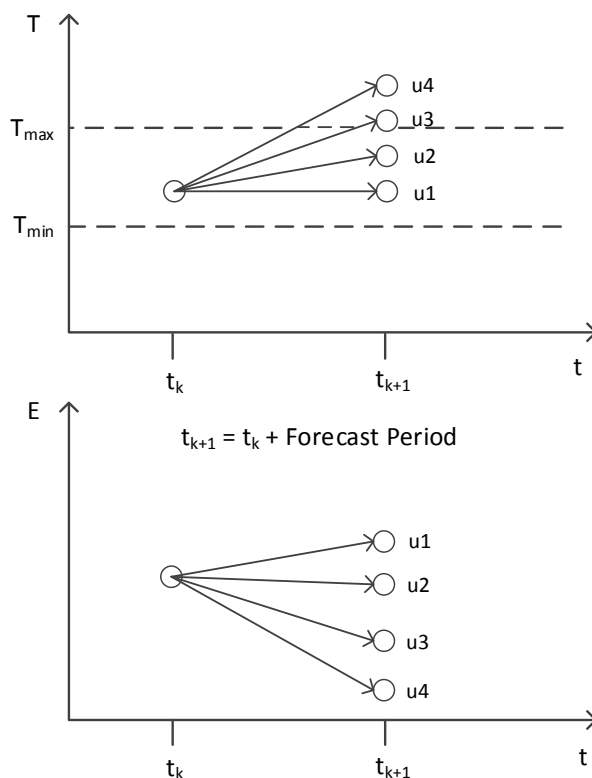


Figure 6. Task for OPT the moment t_k : find the minimum u that satisfies $T_{min} < Tu < T_{max}$.

$$u_1=500 \text{ kWh}; u_2=400 \text{ kWh}; u_3=200 \text{ kWh and } u_4=100 \text{ kWh}$$

As well as looking one step ahead, SEEDS explored whether looking multiple time points ahead would make a difference to managing energy utilisation.

As with most optimization problems, the challenge, of course, is the exponential search space:

$$c = z^{\beta+n-1} \quad (\text{eq. 1})$$

where:

z is the number of different control settings for each device

β is the number of devices to control

n is the number of forecast intervals to analyse

SEEDS explored the use of two AI optimization methods, namely Genetic Algorithms (GAs) and Particle Swarm Optimization (PSO). An evaluation, based on a range of scenarios, including the Helicopter example, revealed that:

- The use of multi-level look ahead can result in additional savings in energy over a single level look ahead.
- Irrespective of which optimisation method adopted, there were additional scalability issues in adopting multi-level look ahead.
- Given the same execution times, PSO produced better results in comparison to GAs and was a simpler optimization.

Given these findings, SEEDS adopted the PSO which was also considered suitable for parallel implementation. To address issues of scalability, several alternative heuristics were considered and attempted, varying from use of expert rules to limiting the search space. Following experimentation, the solutions adopted in SEEDS are:

- To carefully select the initial starting population for the PSO based on pre-optimization overnight,
- Provide an anytime capability where the algorithm is given a fixed period to look ahead and return the best answer within the period, and
- To utilise a cache to make self-learning as efficient as possible.

Tests on a scenario in April 2014 (based on the original scope of UiS pilot: 79 rooms, 2 air handling units, 26 volumetric flow controllers, 72 diffusion elements, 77 electric radiators, 18 lighting systems) on a standard platform consisting of an 8GB with a 2.8 GHZ i7-2640M CPU showed that this solution was effective; so for example a 3 step look ahead forecast could be completed within 1.5 minutes, enabling re-optimisation cycles of 10 minutes.

At the time of writing this report the optimizer was being re-configured (see Section 1.2 in relation to the errors found in the Optimizer code) for the pilots so results are not available.

1.3.2.3.2 Self-learning

The innovative heart of SEEDS is a self-learning component that predicts parameters such as temperature, air quality, humidity, and energy that can be used by optimisation to optimise energy

consumption and maintain comfort. **Figure 7** presents a schematic diagram of the self-learning component that has been developed as part of the SEEDS project. The model is built around the WEKA libraries to enable access to a very wide range of machine learning methods including neural networks, Bayesian networks, decision tree learning, rule induction, etc. , together with pre-processing methods such as feature selection, as well as bagging and boosting. The Train/Re-Train sub-component is able to take data from the archive, produce the model(s) and then store them, ready for use by forecasting, which interfaces to the Optimizer.

The major features of the SEEDS self-learning component are:

1. It provides a self-learning component that can use a wide range of self-learning methods in a form specifically tailored for building energy management.
2. It has been developed to facilitate multi-level look ahead forecasting, allowing optimization methods to minimise energy over a longer time horizon which has the potential of greater energy savings.
3. The implementation of the component has been optimised to improve performance so the impact of the exponential search space of solutions that needs to be overcome by the optimizer is minimised.

The self-learning component was initially tested by applying a range of machine learning methods including neural networks, Bayesian networks, and decision tree learning on a number of scenarios including a building with Thermal Zones simulated using EnergyPlus, a Helicopter Garage Example, and data collected from a commercial building in Madrid. The results, presented at an International Conference on Energy Systems and Technologies in 2012 show the relative merits of the different self-learning methods together with their optimal parameter settings.

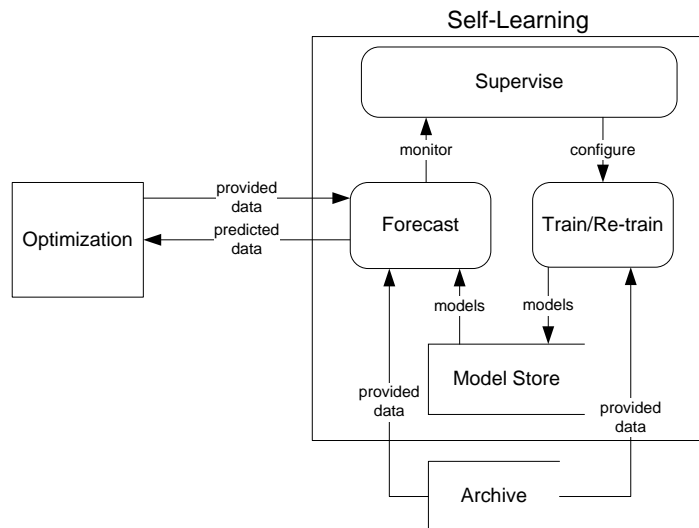


Figure 7. Schematic diagram of the self-learning component

The self-learning component was utilised on the pilots with good results. As an example, for the Ferrovial Building, self-learning was used to develop models to estimate the following parameters:

- Room temperature for each room
- Indoor air quality for each room
- Set points as per room command module
- Movement per room
- Electrical Energy
- Fuel Energy
- Thermal Energy

Neural networks were applied with these settings based on the empirical trials mentioned above, and the results of accuracy and error rates evaluated using a methodology known as 10 cross-validation. The results obtained for both pilots are summarised below.

For the Ferrovial site. Prediction of room temperatures is excellent for all rooms, with the average relative absolute error being 4.22% over the rooms and a standard deviation of 1.22%. The results for indoor quality were less accurate, though still usable when assessing air quality as part of comfort during optimisation. The average relative absolute error for indoor air quality was 18.11% with a standard deviation of 8.79%. Movement in rooms is a Boolean variable, so once again we attempted both neural networks and decision trees. The results for neural networks varied depending on the room, and decision tree learning was more accurate achieving 94.98% accuracy on average over the rooms and standard deviation of 4.06%. Prediction of energy values needed some additional considerations, since in SEEDS a look forward strategy is adopted that extends beyond several time points. This implies that variables used as input features will themselves be predictions from previous states. If prediction of these input features is itself not good, then its effect on predicting energy is likely to deviate more significantly further down the time line. Our experiments showed that prediction of device variables has the potential for being problematic when used in multi-level look ahead mode. Hence, when predicting energy consumption, we experimented with several combinations of input features, leading to a result that the presence of the device variables as input features did not make a significant difference to accuracy, with the relative absolute error still being below 10% for energy prediction. The following figure shows the variation in error when predicting room temperature across for different rooms.

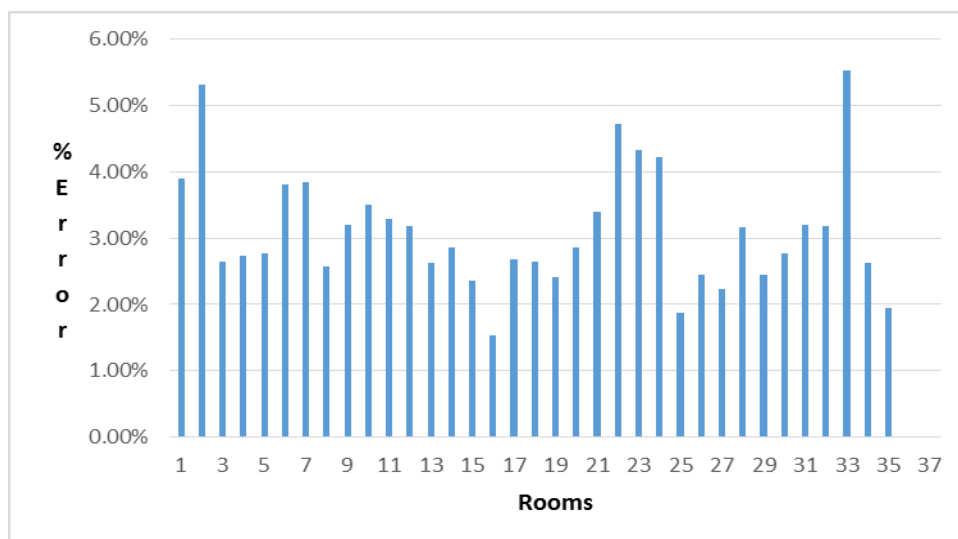


Figure 8. Variation in error when predicting room temperature for the Ferrovial Building.

For the Stavanger pilot, the predictions for temperature are also good, with an average relative absolute error of 7.5% and a standard deviation of 3.5%. Prediction of air quality has a relative absolute error of 18.5% and energy which has relative absolute error of 25%, though this can be expected to improve as more data is available for training. Prediction of set points, using decision trees, is again excellent with 99% accuracy.

In summary, the self-learning and optimization component has achieved the following goals stated at the start of the project:

- A survey of the self-learning and optimization methods for energy management has been completed and will be useful to the industrial and academic communities focusing on energy optimization.
- Designed an architecture that enables the use of state-of-the-art self-learning methods that are capable of dynamically learning the relationships between key variables (such as internal temperatures, external temperature, energy utilisation, energy technology, season, energy utilisation, Co₂, air quality and comfort levels.) that can be used to predict the behaviour of a range of building types under different conditions.
- Implemented methods that can utilise the learned relationships and models to accurately predict the thermodynamics of buildings under various configurations and conditions.
- The use of PSO has led to scalable effective methods for optimising the energy supply that has the potential for wide applicability.
- A novel multi-step look ahead optimisation procedure has been developed, and implemented.
- The self-learning and optimization method have been integrated as part of an open architecture that can be configured for a wide range of building types to facilitate continuous improvements in energy management.

1.3.2.4 Field interaction: the WISAN

The WISAN component represents the Wireless Intelligent Sensor and Actuator Network deployed in the SEEDS component. This component is divided in three elements:

- WISAN Server
- WISAN Nodes
- WISAN Gateways

The WISAN Server is the entry point of the WISAN for the rest of the components of SEEDS. This server allow to:

- Data reception of the different WISAN nodes
- Configuration of the nodes parameters (acquisition sensor rate, actuator state ...)
- Monitor nodes state and store data in the SEEDS Cache

A WISAN node represents the minimum element of the WISAN. This element could be configured with different sensors or actuators as the user defined in the network design process.

The WISAN gateways are the bridge between the WISAN nodes and the WISAN Server. These elements control important features such as network disconnection and the temporal storage if the connection with the server is lost.

To ease the installation of the WISAN, the WISAN Tool Support application has been developed to access directly to the WISAN in an independent way.

The following images show the described architecture:

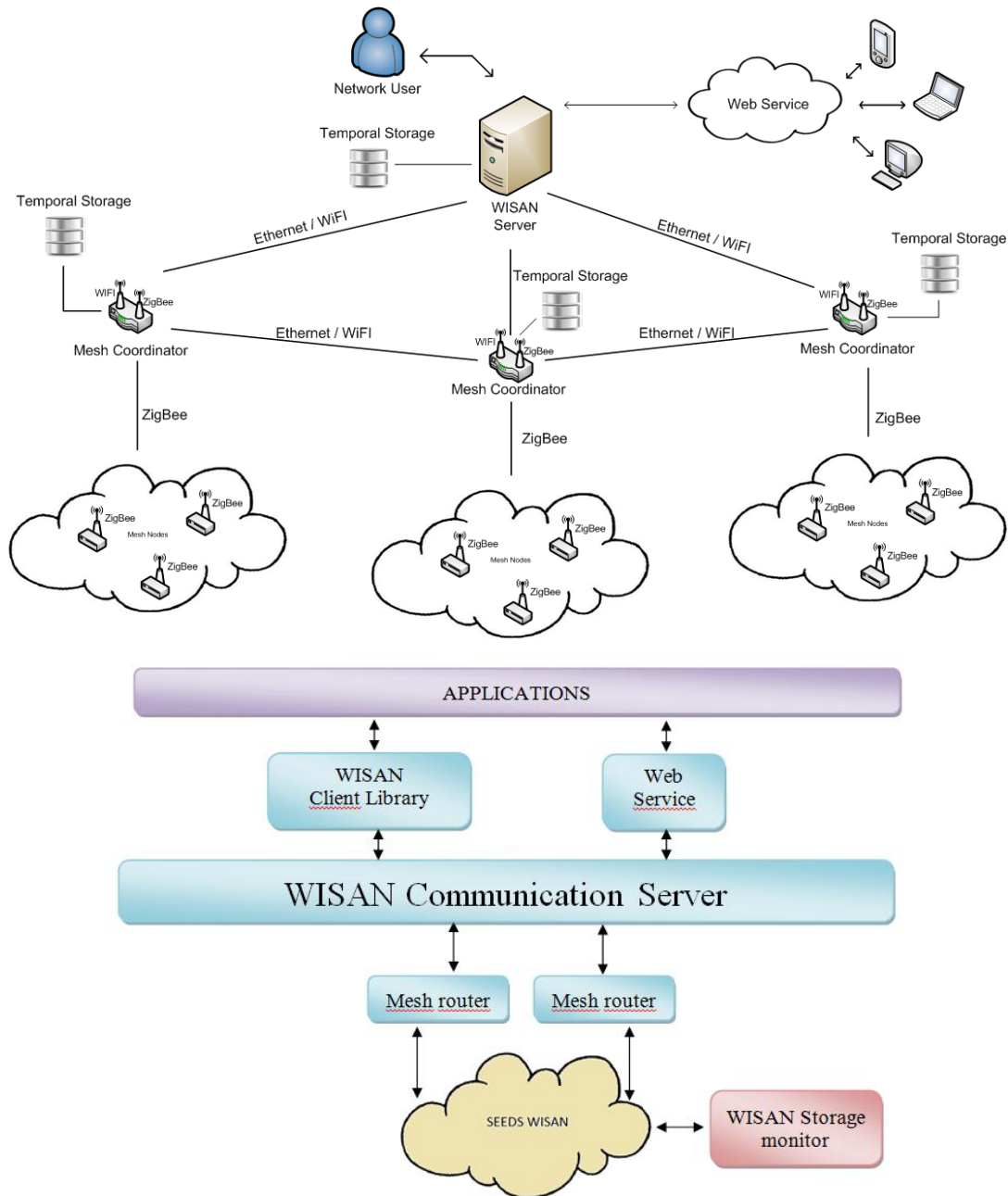


Figure 9. WISAN Architecture

1.3.2.5 User interaction: the GUI

The GUI provides the interface between the user and the SEEDS system. The main objective of the GUI is to give the user the ability to interact with the SEEDS system. Figure 10 below illustrates the individual SEEDS components and the interaction of the GUI with the user and the remaining SEEDS components.

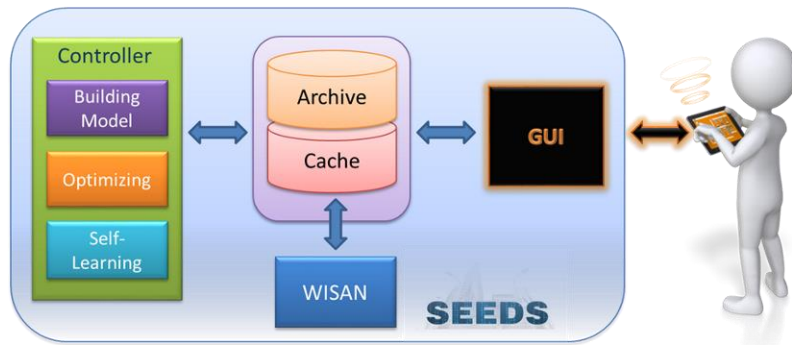


Figure 10. GUI interfaces

The GUI is implemented as platform independent web application and provides the following features and abilities:

- show the building model like reference image (in terms of structure or architecture).
- show the locations/positions of sensors and actuators.
- display their actual sensor values.
- display actuator operating states or output commands to equipment and systems (after self-learning).
- recover the values of the variables from the data base and to show them to the user.
- input user set-points and operating scenarios.
- influence the control strategy and control parameters in a limited way.
- display the calculated prediction of the system behaviour.
- display the curves representing subsystems behaviour (to be updated in real-time).
- report performance statistics that can be used in the validation of SEEDS concepts.

1.3.2.5.1 Main performance indicators of the GUI

- It's possible to display a few thousand of information and interactive controls.
- Separation of Content (Sensor and Actuator information) from the graphical representation.
- This SCADA solution integrates applications and devices from all leading manufacturers.
- It reduces the implementation effort by a generic approach based on the GUI component description.
- Configuration changes only need to change the GUI system configuration (no work on design, imaging or representation are necessary).
- Integration of different kinds of user groups by ability of role based view and interaction.
- Platform independence HTML5 visualization integrates the ability of mobile interaction (usage with almost every graphic-enabled internet device possible including PC, Smartphones, Tablets)

1.3.2.5.2 GUI Structure and Design

The GUIs for the UiS and Ferrovia Demo was build and implemented using the same approach and procedure model (see section 1.3.3.7). For this reason both GUIs exhibit the same structure and design. This section visualizes exemplary the GUI for the UiS Demo (Demonstrator at the University of Stavanger).

The main menu consists of the following elements:

- Weather
- Building
- Production
- TSD

The first main menu item includes the current and predicted weather conditions. The building of the demonstrator is represented by the Building main menu item. The facilities and equipment are summarized in the main menu item Production. The TSD main menu item allows access to the web interface of the Open TSDB that stores the historical data of the BEMS.

Figure 11 shows the common GUI structure:

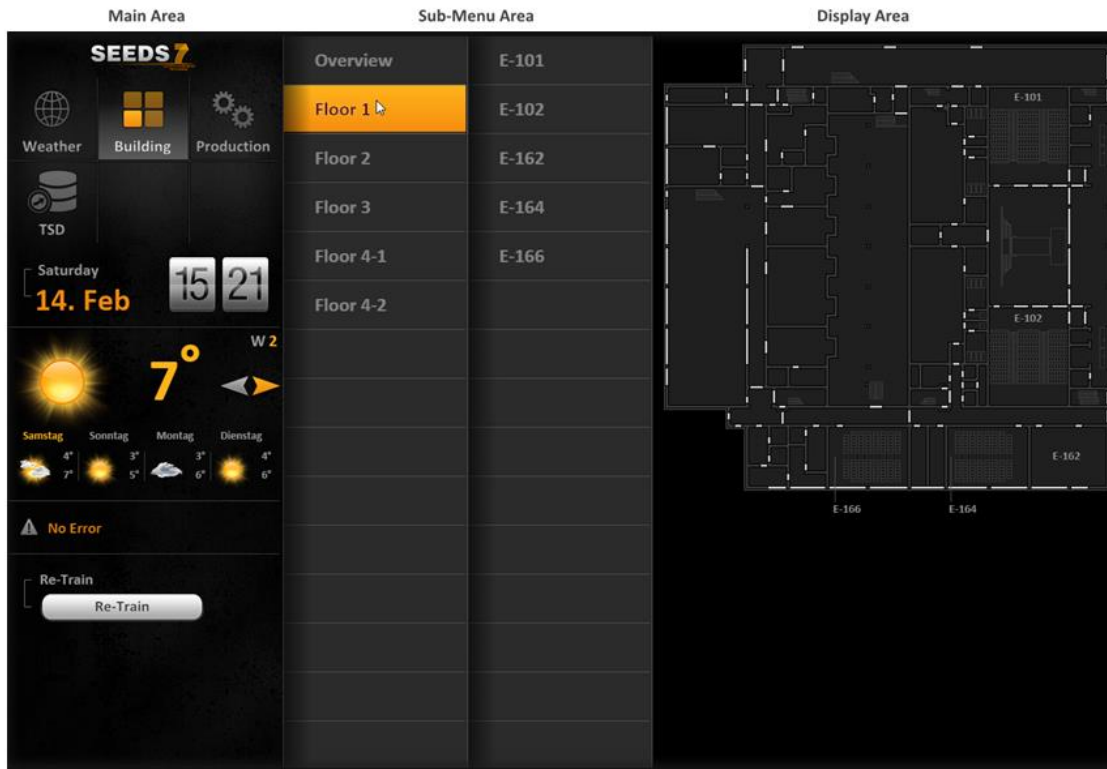


Figure 11. GUI structure

The following pages present some screenshots of the GUI as example of the whole GUI frontend.



Figure 12: Weather display area



Figure 13: Room display area 1

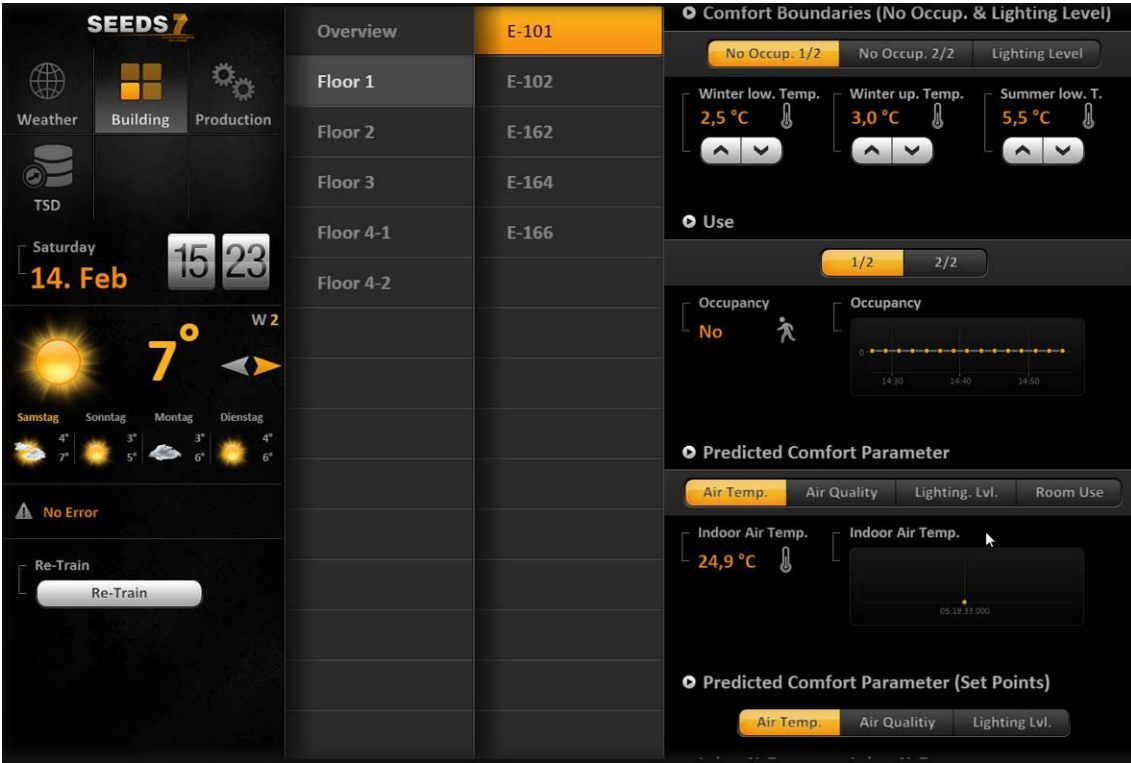


Figure 14: Room display area 2

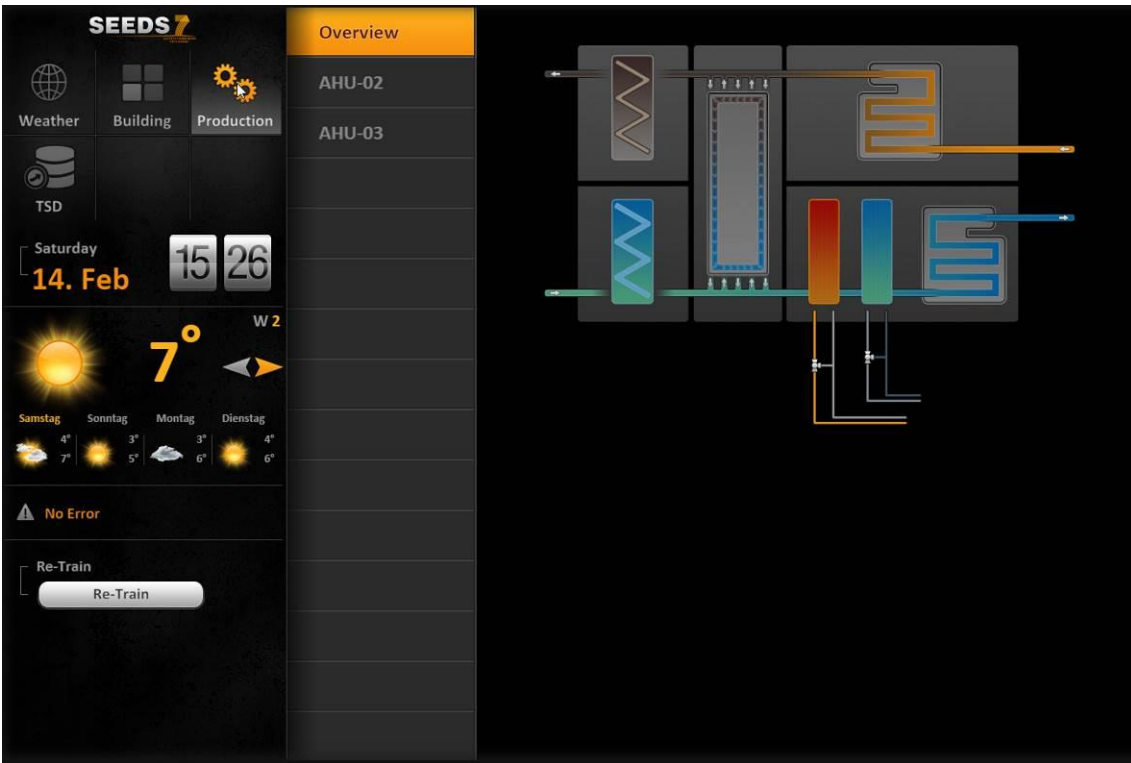


Figure 15: Production systems overview



Figure 16: AHU display area



Figure 17: Air pump display area



Figure 18: OpenTSDB overview

1.3.2.6 SEEDS Cache

The Data Management layer includes the SEEDS Cache³ which stores historical, present and future data.

Historical and present data are:

- Sensor data, control settings (commands sent to actuators or actuators data), comfort settings, use (occupied or non-occupied room), weather conditions, energy consumption and provided energy.

Future data are:

- Predicted use per room (occupied or non-occupied room), future comfort settings, future indoor comfort, future energy consumption and weather forecasts.

As is shown in Figure 1, Figure 2 and Figure 19, all SEEDS components communicate with SEEDS Cache.

The SEEDS Cache is the central element in the SEEDS system. All components write their data to the cache and read the desired data from the cache.

³ In the first deliverables, the term *Archive* was used instead of *SEEDS Cache*. It was planned to use a MySQL data based for relational data and an OpenTSDB data based for temporal data. The temporal data was referred as *Archive*. However, the temporal data base hasn't been integrated in SEEDS. There is only one relational data base (MySQL) which stores both relational and temporal data. It is called SEEDS Cache.

For SEEDS the relational database management system **MySQL** was evaluated and used. MySQL is available as open source software as well as a commercial enterprise version for different operating systems and is used worldwide.

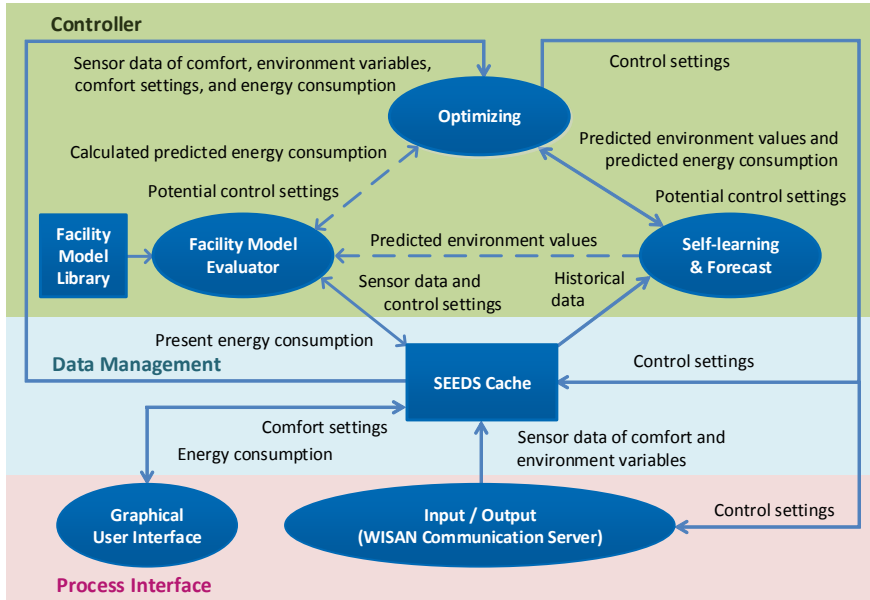


Figure 19: Layers architecture of SEEDS BEMS

All Controller core components need access to the Data Management layer to read or write values from or to the SEEDS Cache. To unify the transfer for the core components, an interface is defined that includes all necessary access methods to the database. This interface was defined to create a database abstraction. This leaves the underlying database used from SEEDS Cache hidden for the other components and allows a database-independent communication and manipulation of the underlying database.

The SEEDS Cache has been successfully populated for the Madrid and Stavanger pilots. In populating these databases for the pilots, some further refinements were made to naming conventions and tables. The few changes confirmed the robustness of the design and its suitability for different buildings and energy management systems.

	Madrid	Stavanger
Time period of logging:	16.10.2014 – 23.02.2015	03.04.2014 - 23.02.2015
Number data points:	619	341
Number of SQL tables:	120	81
Number of all records:	40 370 057	45 240 855
Database size total:	1300 MB	1800 MB
Data growth per day:	~ 10 MB	~ 8 MB

Table 5. SEEDS Cache statistics

1.3.3 SEEDS configuration: general issues and customization for each pilot

1.3.3.1 Overview

One objective of the SEEDS project was to develop a methodology for the modelling of any building for SEEDS BEMS. This methodology consisted on 6 steps (see Deliverable D2.3 [3]) that were required to establish all the relationships among spaces, energy systems and user's comfort and health conditions. The results of these 6 steps were several templates, one per component, showing the variables, and the relationships among them, that each component had to consider. To avoid the error prone procedure of generating all the templates and to allow for a semi automatic configuration of SEEDS component, a MS ACCESS schema to gather the results of the 6 steps was generated.

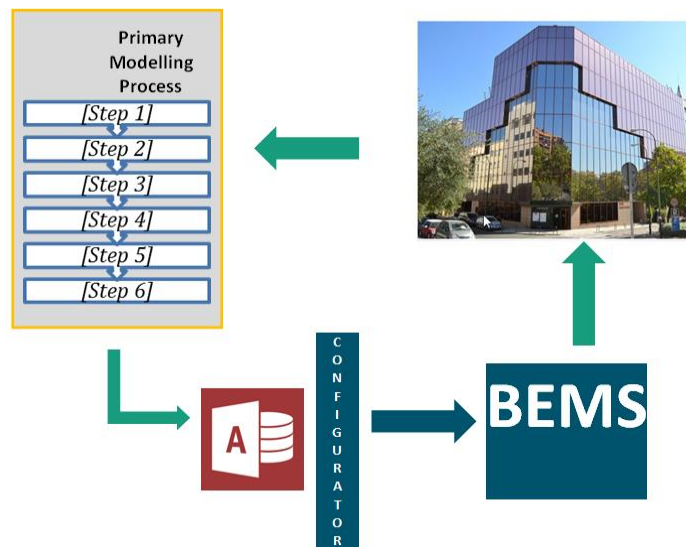


Figure 20: Seeds configuration overview

The starting point for the configuration of SEEDS is the MS ACCESS data base which contains all the relationships among spaces, energies and user comfort conditions that are necessary for SEEDS components. The structure of the database and the contained information's are designed within the project. Parts of the structure are taken from the Industry Foundation Classes with enhancements cope with SEEDS requirements. This is the starting point for the semi-automatic configuration and generation of all building specific components of the SEEDS Controller.

The information stored in the ACCESS database is used to configure the four SEEDS components: Controller, SEEDS Cache, WISAN and GUI. The Controller Builder generates all identifiers for all building data nodes, the necessary code for the Facility Model and Self Learning and creates the interfaces of the Controller to the GUI and the WISAN. The SEEDS Cache Builder generates the layout and function for the MySQL database. The GUI- and WISAN Builder generate the mapping to the SEEDS Cache for their respectively component.

The automation of the software creation process increases the efficiency of configuration updates considerably. The integration of new building facility components or their update only requires the modification of the MS ACCESS data base and the new execution of the configuration stage. This way, SEEDS controller updates and SEEDS software maintenance is simplified. Besides, SEEDS controller software version can be easily installed without major system changes because the

building specific data are kept separate, independent of the SEEDS control algorithm. There are not error-prone manual processes and, as a consequence, the robustness of the SEEDS control software is improved. In summary, the efforts for adaption of the SEEDS controller to a certain building and the software maintenance are significantly reduced.

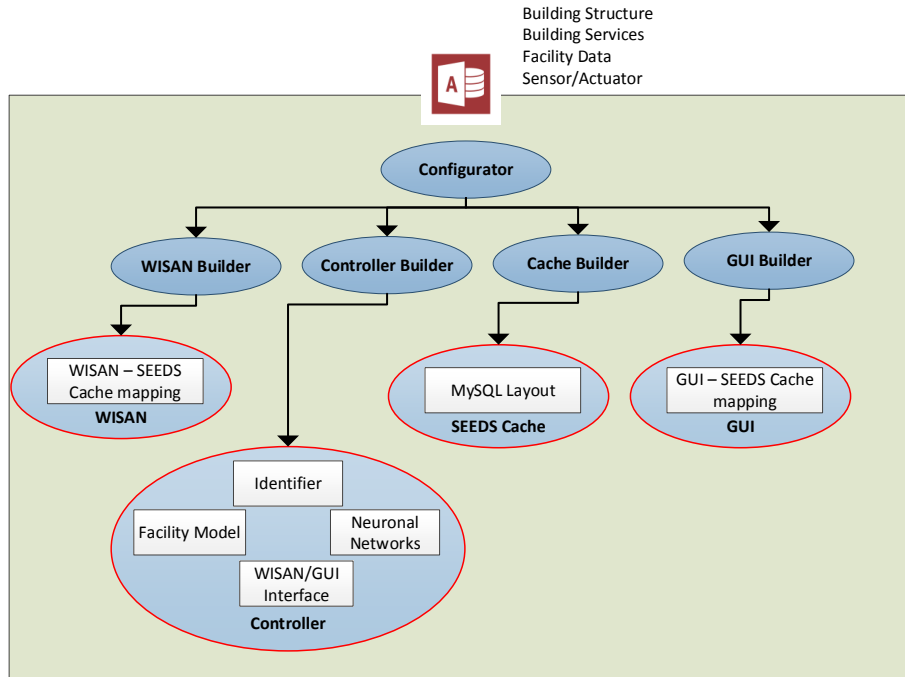


Figure 21: Configuration of SEEDS Components

1.3.3.2 Methodology for SEEDS components configuration based on MS Access data base

As explained above, the MS Access schema was developed to facilitate the introduction of data required to establish all the relationships among spaces, energy systems and user’s comfort and health conditions and the configuration of each SEEDS component. It is the result of SEEDS modelling methodology (Deliverable D2.3 [3]). The automatic configuration of SEEDS components base on the MS Access schema is explained in D2.7 [4], D2.8 [5] and D2.9 [6] of WP2.

SEEDS’ MS ACCESS database represents an own ontology of a building information model (BIM). Parts of the structure are taken from the Industry Foundation Classes with enhancements to cope with SEEDS requirements.

The main groups of tables in MS Access are shown in Figure 22. Each of these groups has a specific purpose within SEEDS: there is a group of tables that defines the data for WISAN, another one defines the Controller variables, another one is for GUI data and so on. Others tables like “Sensor types”, “Actuators type”, etc.; have been omitted in the figure for clarity.

There are mainly nine groups of tables in the MS Access layout for SEEDS project Each one of them has an specific function within SEEDS configuration.. They are listed below:

1. General information of Building and/or Open Space.

2. Systems, Sub-systems and Devices.
3. Variables necessary for SEEDS (metrics).
4. WISAN data (sensors, actuators and node error notifications).
5. Comfort boundaries in conditioned spaces.
6. Technical data of devices entered by user (power, air flow rates, etc.).
7. Predicted parameters by Self-Learning (comfort variables).
8. Energy calculated by Building Model (Facility model) in devices, building and/or open space.
9. GUI data (parameters shown in the graphical user interface).

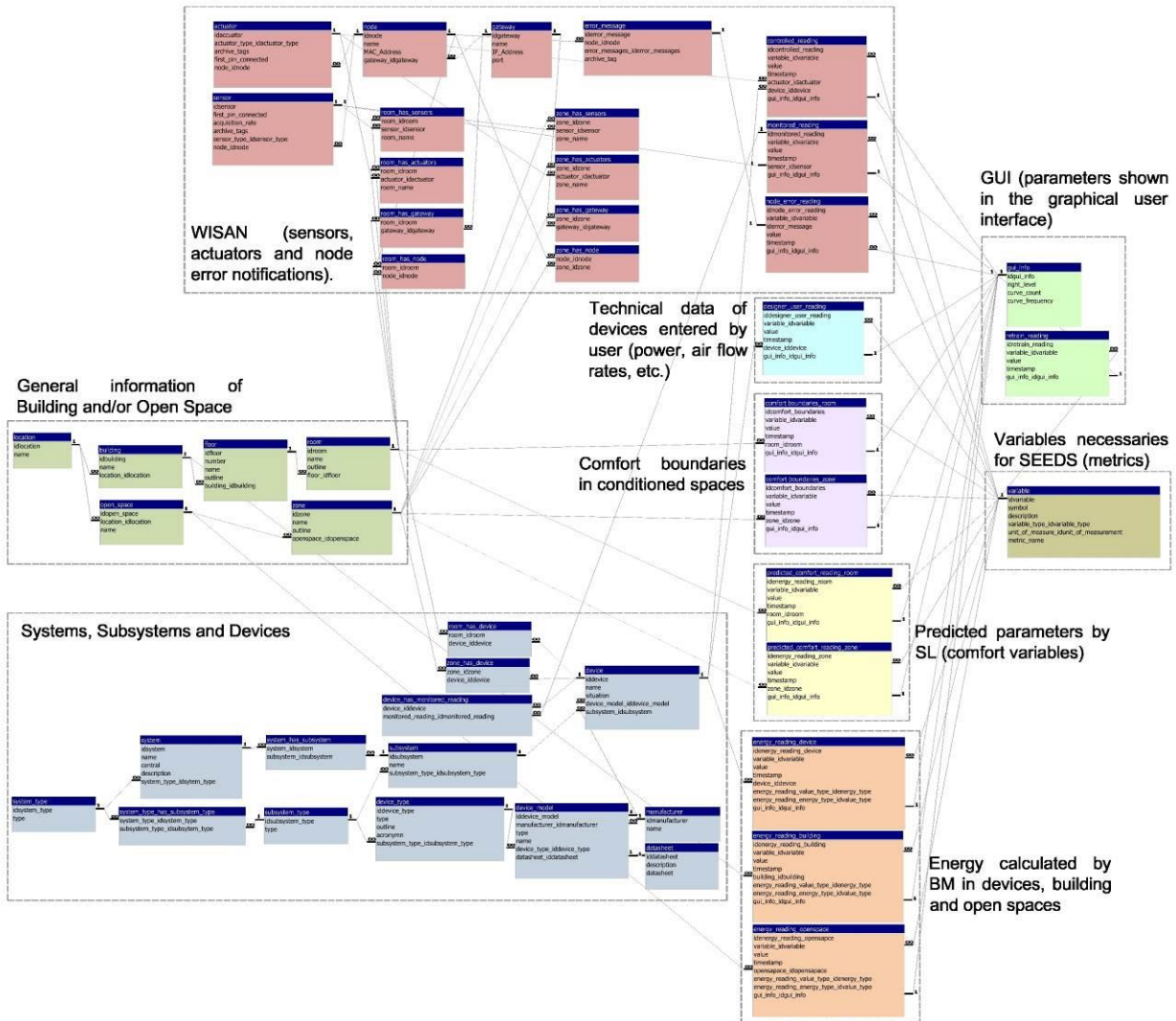


Figure 22. General MS Access layout

1.3.3.3 Controller Configuration

In the Controller the components Building Model, Self-learning, and Optimizing are instantiated and their interactions are managed. In addition, a port is defined in Controller, through which the whole data traffic is handled with SEEDS Cache. All components are implemented in Java and executed in the same Java virtual machine (JVM).

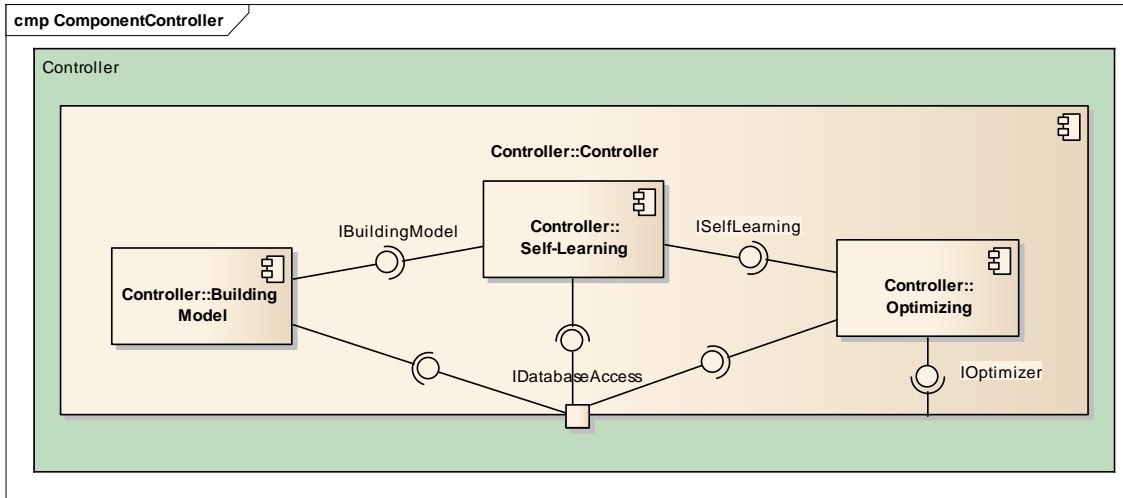


Figure 23: Component Diagram of the Controller

The controller and its components uses time related variables or data classes, respectively. They are declared as tuple [time, value]. Summaries of several time points under an identifier are used to compose, store and transfer time series. To unify the transfer, an interface is defined that includes all access methods to the database to create a database abstraction. The database abstraction hides the underlying database used from SEEDS Cache for the other components and allows a database-independent communication and manipulation of the underlying database.

Depending on the building the SEEDS controller components are able to query the SEEDS Cache for different data points (identifiers). Each identifier represents a (virtual-) sensor or actuator of the building. The database access interface implementation translates the identifiers to a storage location in the SEEDS Cache. Depending of the SEEDS Cache MySQL layout, the Controller Configurator generates the necessary code to query the SEEDS Cache data by an identifier.

Each identifier is represented as a member variable of a JAVA class. Similar data points are summarized in a JAVA class. For an improved overview, the JAVA classes are grouped in different packages.

Example:

```
/**
 * SHT15_Temperature (node=00:13:A2:00:40:BA:23:49 room=P3-Meeting-Room floor=3
 * locationtype=Office)
 */
public static final String P3_MEETING_ROOM = "cipsi_seeds_ferrovial_in_temp
```

`identity=267 idgui=420";`

The java class `In_temp.java` represents indoor air temperatures and contains member variables for all room temperatures. The member variable `"in_temp.P3_MEETING_ROOM"` represents the sensor value of the indoor air temperature for the Meeting Room P3.

The value of an identifier member variable holds a string that is necessary to translate the identifier to a storage location in the SEEDS Cache. The first value represents the MySQL table name (`cipsi_seeds_ferrovia_in_temp`) the second one is the unique id of the identifier in the table. The last one (`idgui`) is used to visualize the data in the graphical user interface.

Starting point for the generation of the SEEDS Controller are the information's that are stored in the ACCESS database. The Controller Configurator queries all the relationships among spaces, energies and user comfort conditions that are necessary for SEEDS Controller and generates the associated identifiers as JAVA code.

	Madrid	Stavanger
Number of identifiers:	619	341
Number of generated JAVA classes:	120	81
Number of generated JAVA packages:	6	6

Table 6. Controller Configurator statistic

1.3.3.4 The Energy Calculator Configuration

The instantiation of the energy calculator is part of the configuration of SEEDS' BEMS which includes the automatic instantiation of all building specific components of the SEEDS controller. For this purpose, all the necessary information is stored in an ACCESS database. This ACCESS database represents an own ontology of a Building Information Model (BIM). Parts of the structure are taken from the Industry Foundation Classes (IFC).

The configuration is performed by Model Builder, see Figure 24. The Model Builder uses a simple Application programming interface (API) that the Facility Model Library provides. It instantiates all required facility models and their corresponding interfaces. For this the Facility Model Library is used, including all models of sensors, actuators, controllers, and HVAC devices and their interconnections. Then, the coupling between the overall facility model and the energy calculator is generated. For the configuration it is advantageous that the Facility Model Library class structure is similar to the IFC-structure. The mapping between the different objects is easy to produce.

During the configuration process the HVAC devices are configured with static performance data that can be found in the ACCESS database. Alternately if there is no static data available, a mode is configured that uses all the sensor information to calculate the power consumption.

By means of automated configuration, the integration of models of new building facility components or their update only requires the modification of the ACCESS data base and the new execution of the configurator.

By means of automated configuration, the integration of models of new building facility components or their update only requires the modification of the ACCESS data base and the new execution of the configurator.

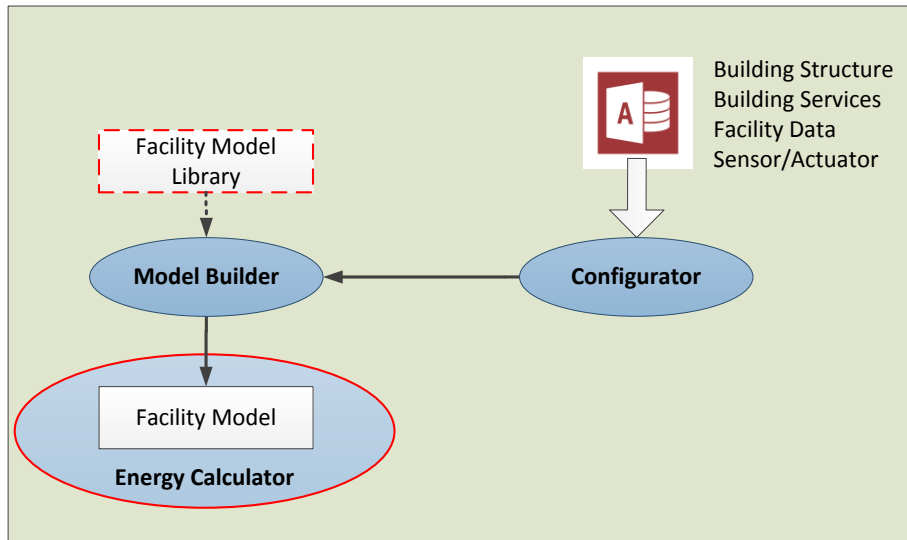


Figure 24. Configuration of SEEDS components

1.3.3.5 Optimizer Configuration

The use of a multi-level optimisation over consecutive time periods is a new concept in the field and so the specification, design and coding was a non-trivial challenge. To improve performance, the following strategies were adopted

- Smart initialization of the PSO particles
- Dynamic OPT call
- Dynamic restrictions of the search space
- Caching
- Concurrency

The SEEDS methodology included steps that require definition of the equipment and variables of a building that is to be managed by SEEDS. To enable a generic implementation for the SEEDS architecture, the project developed an Access database that would provide a source of information to facilitate configuration of self-learning and optimisation models and generation of a user interface. Producing reference energy data for training proved to be more challenging with some unexpected issues around missing data and how different types of energy could be unified. This issue was addressed during the configuration phase.

The global optimization problem was defined as:

$$u_t \rightarrow \text{MIN}[\alpha(\hat{e}, w)_{\Delta t}]$$

Where:

u_t is the optimal control settings for a certain forecast period

α is the cost function

\hat{e} is the predicted energy consumption for a candidate control settings

W is the comfort level

Since the optimization was designed to be generic, only minor adjustments are required for each pilot. The main difference is in the definition of the cost function, which differs between the pilots. Adjustments have to be made to sensor and controller identifiers, but they do not change the mode of operation of the optimization module.

In Ferrovial pilot the cost function was defined as:

$$\text{cost function} = Ee_building_prd.java * \alpha + Fuele_building_prd.java * \beta$$

where $\beta = 1$ and

α changes with the time of the day, according to this table:

18:00 - 22:00	$\alpha = 3.89$
00:00 - 08:00	$\alpha = 1.77$
Rest of the day	$\alpha = 3.04$

The cost function in Stavanger was defined as:

$$\text{cost function} = Ee_building_prd.java * \alpha$$

where $\alpha = 1$.

1.3.3.6 Self-Learning Configuration

The Self-learning component is configurable, allowing its use for different building types and equipment. Self-learning has been developed in a modular manner whereby its configuration is modularized into a single bundle. This enables easy adaptation and configuration. For example, one only needs to change the variables used in self-learning in a single place: the configuration bundle.

In order to configure the self-learning bundle for each pilot building, the input and output variables, in a form that links to the class names used in the controller, was specified in a configuration file (a .vm file). These are dependent on factors such as the number of rooms and the type of equipment in use. As an example, the output variables that are forecast by self-learning for the Madrid demonstrator include the following:

- Set point of indoor air temperature
- Indoor air temperature
- Indoor air quality level
- Lighting level
- Room use (occupied or unoccupied)
- Electrical energy required
- Thermal energy provided

Self-learning is also generic in that a range of self-learning methods can be used. The configuration file specifies the self-learning method used together with their parameters. For example, in the UiS and Madrid demonstrators, feed-forward neural networks and decision trees were used. The parameters used and which work well for neural networks for the two pilots are:

- Learning Rate: 0.2

- Momentum: 0.25
- Nominal To Binary Filter: False
- Training Time: 500 Epochs

Once the configuration files were specified, the files needed by the self-learning methods (namely the ARFF file) were generated per room by using the Velocity engine. The generated files can then be used to train the models and the models used for forecasting, as described in Section 1.3.2.3.

Prior to training, the data was examined and data cleaning was necessary before training the models. In general, the results for most variables, such as indoor temperature were very good (average relative absolute error being 4.22% for the Ferrovial site and 7.5% for Stavanger).

Prediction of energy values for the two pilots needed some additional considerations, since in SEEDS a look forward strategy is adopted that extends beyond several time points. This implies that variables used as input features will themselves be predictions from previous states. If prediction of these input features is itself not good, then its effect on predicting energy is likely to deviate more significantly further down the time line. Our experiments showed that prediction of device variables was not stable for the data from the pilots. Hence, when predicting energy consumption, we experimented with several combinations of input features:

- With all the device variables
- With part of the device variables
- With no device variables

The results showed that not including the device variables makes a minimal difference to accuracy in most cases, and hence given these variables are difficult to predict, and the negative consequences outlined above in terms of their use for multi-step predictions, they were not utilized.

1.3.3.7 WISAN Configuration

The WISAN component is configurable across SEEDS database (MS Access file) using the WISAN positioning tool. This tool is able to connect with the SEEDS database and read the information related with the sensors and actuators. This information, combined if it is available with an IFC model of the building, is the input of the positioning algorithm to study the network coverage of all the WISAN elements.

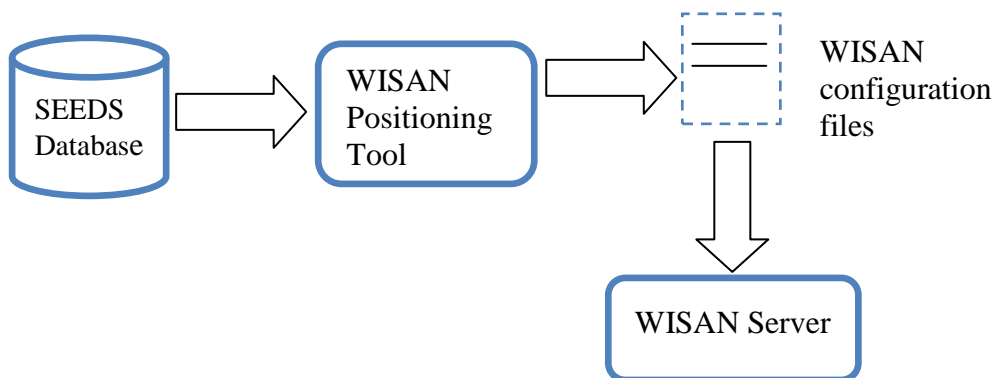


Figure 25: WISAN configuration process

Independently of the coverage study, this tool allows to generate the WISAN configuration files for the WISAN server. The server uses this file to know the configuration of the network and is in charge of distributing the configuration to each gateway and the gateways to the sensors.

1.3.3.8 GUI Configuration

This section describes the common architecture, the particular components and the configuration of the GUI for both demonstrators.

Figure 26 illustrates the common architecture, the individual components of the GUI and the interaction between the components.

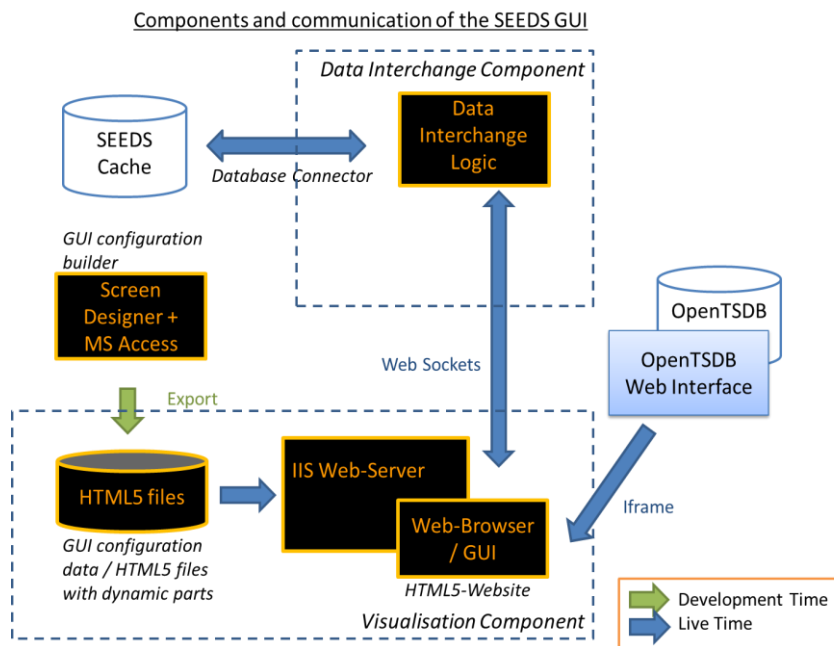


Figure 26: Common architecture and individual components of the SEEDS GUI

The GUI is divided into two main component: Data Interchange Component and Visualisation component.

The Data Interchange Component software is the server software with the following goals and services:

- Periodically reading of the system parameters from the SEEDS Cache
- Send the changed system parameters to the client software (visualisation component)
- Receive changed system parameters from the client software (visualisation component)
- Save the system parameters changed by the user in the SEEDS cache

The data interchange component software for both demonstrators is developed as a windows service. The software is be developed with MS Visual Studio in C #.

The Visualization Component software is the client software, and has the following goals:

- to receive changed system parameters from the data interchange component and display them

- to allow the user to change system parameters
- to send the system parameters changed by the user to the data interchange component using Web Sockets
- to show the GUI elements and system parameter values on the GUI screens
- to allow the user the navigation through the GUI screens
- Display the calculated prediction of the system behaviour
- Display the curves representing systems behaviour (updated in real-time)
- Show the historical system data of the variables from the data base using OpenTSDB Web Interface and iframe.
- to perform user access right management

The visualization software component consists of two major parts. The first part is responsible for the graphical representation and structure of the graphical surface. The second part implements the interface to the data interchange component (server). This part is responsible for the communication and data exchange with the data interchange component.

To achieve the platform independence of the client software the visualization component software is browser-enabled. The client software consist of HTML pages. The HTML pages implement on the one hand the graphical user interface and on the other hand the interaction with the user and the data exchange with the data interchange component. Thus the HTML pages include a static and a dynamic part. The static part is responsible for the graphical representation of the screens and the navigation through the screens. The dynamic part implements the interaction with the user, the communication and data exchange with the data interchange component. This implies the existence of a programming logic on the client. To make this possible Rich Internet Application (RIA) technology is used. This technology offers a lot of possibilities for interaction. HTML5 is the latest development in the RIA technologies. It combines HTML4, Java Script, Java Script Libraries, Flash and FMS in one specification around the API model. The client software will be developed in HTML5.

The communication between the data interchange and visualization component is bidirectional. The Data Interchange Component sends data that has been changed in SEEDS Cache to the Visualization Component. The Visualization Component in turn sends data to the Data Interchange Component when the user changes data in the GUI. The communication between both components is implemented through WebSockets. The WebSockets is the new HTML5 technology to enable bidirectional communication between a Web application and a Web server.

Another important component of the GUI is the GUI Configuration Software (Builder). The aim of the GUI Configuration Software is the creation of GUI configuration file and GUI screens from the static database (MS Access, see section 1.3.3.2).

The GUI Configuration Software works in two steps:

1. Parsing the static database and creating a GUI configuration file.
2. Reading the configuration file and creating all GUI screens using the GUI Screen Templates. The GUI Screen Templates are created using the Vici One Screen Designer.

Figure 27 illustrates the creation of the GUI configuration file and GUI screens using the static database and GUI screen templates.

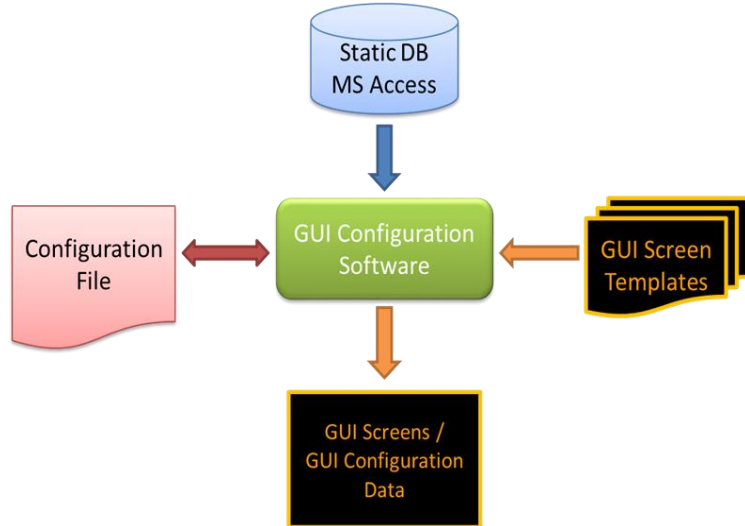


Figure 27: GUI Configuration

The configuration file is used by the Data Interchange Component to generate the GUI objects. The visualization component of the GUI consists of the generated GUI screens.

The GUIs for the UiS- and Ferrovia- Demo was build and implemented applying the approach and procedure model described above.

1.3.3.9 SEEDS Cache Configuration

The SEEDS Cache is the central element in the SEEDS system. The Cache stores all historical, present and future data of the SEEDS System. All components write their data to the cache and read the desired data from the cache. For SEEDS the relational database management system MySQL was evaluated and used.

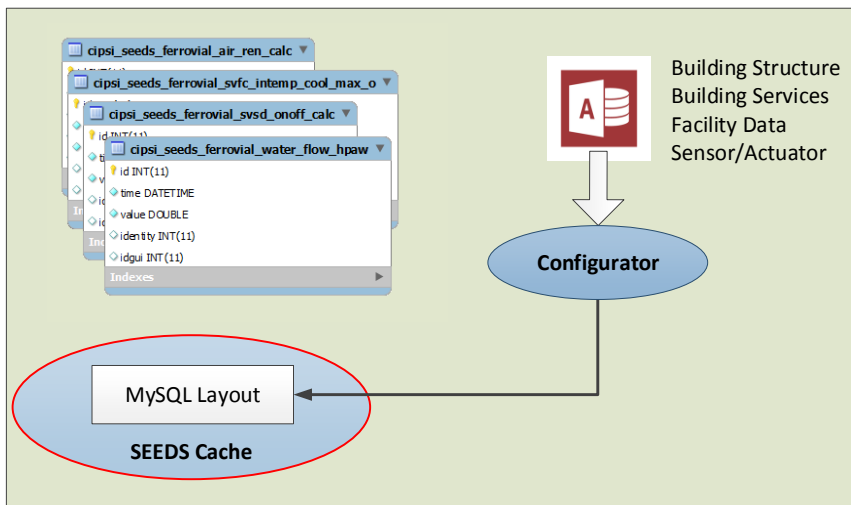


Figure 28. SEEDS Cache configuration

The Cache Configurator uses the information's stored in the MS ACCESS database to configure the SEEDS Cache and generate the necessary MySQL layout. Each data point of a building is identified by a unique ID. This ID is an incremental integer starting at one. To ensure the performance of the SEEDS Cache similar identifiers are grouped and stored as MySQL table. This is analogue to the JAVA identifier implementation of the controller.

	Madrid	Stavanger
Number of data points:	619	341
Number of generated SQL tables:	120	81

Table 7. SEEDS Cache generation statistic

1.3.4 SEEDS Commissioning

This section describes the plan that was tailored for the commissioning of SEEDS in the two pilots. It was first developed after the SEEDS concept was tested in the Helicopter Garage test bench in May 2013. The Commissioning flow includes the different tasks and subtasks and also the time schedule. Unfortunately, due to the problems arising in relation to the validation in the pilots, the deadlines had to be changed several times.

This section described both the Commissioning Flow for the validation of SEEDS and also the Test Plans that were developed to validate the performance of the different components independently and also the joint performance of all the components in open and closed loop. The drafting of the test plans is Task 2 of the Commissioning flow. These Test plans are then applied in tasks 5-8 of the commissioning flow.

1.3.4.1 Commissioning flow

The commissioning flow is the roadmap that shows all the steps (or tasks) that have to be accomplished to apply and validate SEEDS in any target building. It is structure in 9 tasks and each tasks includes several subtasks. These tasks are:

Task 1. Preconditions. MS Access file taking into account the selected scope for the demonstrator must be ready in order to start with the configuration of each SEEDS component. It is also necessary install the Control PC in the demonstrator with remote access available.

Task 2. Test plans. This task focus on the drafting of all the tests required to validate the performance of each components on its own and also the interaction among different components and the joint performance all of them. In this task, the testplans are planned and then, in tasks 5, 6, 7 and 8, the tests are carried out.

Task 3. Configuration. The goal of this task is the configuration of SEEDS components using the MS Access data base (for each demonstrator).

Task 4. MySQL/OpenTSDB. The installation of databases and interfaces with WISAN, GUI and Controller will be carried out.

Task 5. SEEDS Controller. This tasks performs the installation and testing of FM, OPT, SL and WISAN client will be done. The Controller will be also commissioned in order to properly manage the rest of components.

Task 6. Data collection. This task identifies the list of variables required for the performance of each one of the SEEDS components (in each pilot). The inputs and outputs managed by each SEEDS component are matched to the information included in the MS Access data base.

This task also includes the installation and commissioning of WISAN nodes in the demonstrator (or pilot). Once this task is finished, the data collection (for SL training) can start in order to gather enough information for the learning of SL.

Task 7. SEEDS Integration tests. The interactions among Controller, GUI and WISAN are tested in this stage.

Task 8. SEEDS System tests. In this stage, the first results of FM, SL, OPT and overall system using WISAN MockUp data are obtained. The WISAN MockUp generates random values for sensors within a reasonable range of possible values. SEEDS components will hand over their first results. This stage was design to be carried out meanwhile the WISAN nodes are installed and commissioned in the demonstrator in order to speed up the process.

Task 9. SEEDS Operating tests. First results of FM, SL, OPT and overall system using real data collected by WISAN. This is the last task of the Commissioning flow which ends with SEEDS managing the building.

Each of these tasks includes several detailed sub-tasks. The following table represents the generic commissioning plan for SEEDS project in any building or open space. This general schema was applied to each of the pilots so that the consortium has worked with one *Commissioning Flow* per pilot, each one of them with particular dates and comments suiting the pilot.

No	Task	Outcome	Responsible	Estimated time	Finalization Date	Status
1	Preconditions					
1.1	System Model	MS ACCESS available for the pilot	CEMOSA / CIDAUT	15 days		
1.2	Control PC	Control PC for the pilot available Required Standard Hardware and Software installed and configured Remote access available	UIS / FERROVIAL	5 days		
2	Testplans					
2.1	MySQL	Test plans for tasks 5, 6, 7 and 8 available	EAS	5 days		
2.2	BM		EAS	5 days		
2.3	Optimizer		UIS	5 days		
2.4	SL		USALF	5 days		
2.5	Controller		EAS	5 days		
2.6	WISAN		SOFTCRITS	5 days		
2.7	GUI		NSC	5 days		
2.8	Overall		CEMOSA / CIDAUT	5 days		
3	Configuration					
3.1	MySQL	Configuration of the SEEDS components using MS ACCESS for tasks 3, 4 available	EAS	10 days		
3.2	BM		EAS	10 days		
3.3	Optimizer		UIS	10 days		
3.4	SL		USALF	10 days		
3.5	Controller		EAS	10 days		

No	Task	Outcome	Responsible	Estimated time	Finalization Date	Status
3.6	WISAN		SOFTCRITS	10 days		
3.7a	GUI		NSC	10 days		
3.7b	Validation GUI	Screens provided by NSC are validated according to D6.4 [8]	CEMOSA / CIDAUT	10 days		
4	MySQL/OpenTSDB					
4.1	MySQL installation	MySQL server available on target PC	EAS	4 days		
4.2	MySQL layout deployment	MySQL layout deployed	EAS	5 days		
4.3	MySQL WISAN interface	WISAN writing to MySQL available and tested for any signal	SOFTCRITS	4 days		
4.4	MySQL GUI interface	GUI full access (r/w) to MySQL available and tested for any signal	NSC	4 days		
4.5	MySQL Controller interface	Controller framework installed and tested Controller full access (r/w) to MySQL available and tested for any signal	EAS	5 days		
4.6	OpenTSDB WISAN interface	WISAN writing to OpenTSDB available and tested for any signal	SOFTCRITS + UiS			
4.7	OpenTSDB GUI interface	GUI access to (read?) to OpenTSDB through web interface (iframe) available and tested for	NSC + UiS			
5	SEEDS controller					
5.1	BM installation	BM deployed, configured using MS ACCEESS scripts, and tested	EAS	5 days		
5.2	Optimizer installation	Optimizer deployed, configured using MS ACCEESS scripts, and tested	UiS	5 days		
5.3	SL installation	SL filters coded and tested. Stubs for each output coded and tested.	USALF	5 days		
5.4	WISAN Client installation	WISAN client deployed and tested.	EAS	2 days		
5.5	Controller commissioning	Interactions between the internal controller components tested	EAS	5.3 + 2 weeks		
6.	Data Collection					
6.1	Overall	List of variables that are being collected. Each component should have a list of inputs and outputs.	SOFTCRITS + CEMOSA / CIDAUT	10 days		
6.2a	Overall	Nodes received in the demonstrator	UiS / FERROVIAL + SOFTCRITS	X		
6.2b	Overall	Nodes installed in the demonstrator	UiS / FERROVIAL	Y=X+1 month		
6.3	BM	Compare what is collected and made available with what should be collected (according to Task 6.1) for each component.	EAS	Y + 2 days		
6.4	Optimizer		UiS	Y+2 days		
6.5	SL		USALF	Y + 2 days		
6.6	Controller		EAS	Y + 2 days		
6.7	Overall		Initial Training data collected.	USAL	Y + 2 weeks	

No	Task	Outcome	Responsible	Estimated time	Finalization Date	Status
7 SEEDS Integration Test						
7.1	Controller - GUI	Interactions between controller and GUI tested	EAS + NSC	5 days		
7.2	Controller - WISAN	Interactions between controller and WISAN tested	EAS + SOFTCRITS	Y + 3 days		
7.3	GUI - Controller - WISAN	Interactions between GUI and WISAN tested	NSC + SOFTCRITS	Y + 3 days		
8 SEEDS System Test						
8.1	BM (Pre-Test)	BM configured and deployed. BM delivers first results with WISAN MockUp	EAS	10 days		
8.2	SL (Pre-Test)	SL configured and deployed. SL are trained with WISAN MockUp data.	USALF	10 days		
8.3	OPT (Pre-Test)	OPT configured and deployed. OPT delivers first results with WISAN MockUp	UiS	10 days		
8.4	Overall (Pre-Test)	SEEDS system delivers first results with WISAN MockUp data.	CEMOSA	10 days		
9 SEEDS Operating Test						
9.1	BM	BM delivers first results	EAS	Y+2 weeks		
9.3	Optimizer	Optimizer delivers first results	UiS	Y+4.5weeks		
9.4	SL	SL is re-configured and re-deployed, if needed.	USALF	Y + 5 weeks		
9.5	Overall	SEEDS system delivers first plausible results. System ready to use	CEMOSA / CIDAUT	Y + 6 weeks		

Table 8. Commissioning flow tasks

1.3.4.2 Test plans

The second task in the commissioning flow is the definition of the “Test plans”. These tests were defined by each SEEDS component developer in order to ensure a proper functioning. CEMOSA also develop the testplans to validate the overall performance and tailored them for the UiS pilot while CIDAUT tailored them for Ferrovia pilot.

- SOFTCRITS delivered the test plans for WISAN configuration.
- EAS delivered the test plans for Controller, Facility Model and Cache.
- USAL delivered the test plans for Self-Learning.
- UiS delivered the test plans for Optimizer.
- CEMOSA delivered the test plans to check the performance of the WISAN system and tailored these tests for the UiS pilot. CIDAUT also particularized these tests for Ferrovia pilot.

59 tests were developed for UiS pilot while 64 tests were developed for Ferrovia.

The set of test plans have been divided in four steps in order to coordinate properly the process of testing.

The first and second set of tests can be performed at the same time.

- 1st Step: Check the WISAN Installation. After installing the nodes in the building it is necessary check their performance and review the values of the variables collected by WISAN.
20 tests have been defined by UiS pilot and 29 for Ferroviaal demo.
- 2nd Step: Check the Controller functionalities Off-Line (by WISAN Mock).
22 tests have been defined by UiS pilot and 21 for Ferroviaal demo

The third set of tests must be made after the first and second steps above.

- 3rd Step: Check the WISAN Integration. After testing the WISAN (1st step), it is necessary check the interfaces between it and the rest of components.
6 tests have been defined for both pilots

The fourth set of tests must be made after the third step.

- 4th Step: Check the Controller functionalities On-Line. This step tests the integration between the WISAN (real WISAN) and the rest of the components. After testing the WISAN, the Controller with the WISAN Mock, and the interfaces between WISAN and the rest of components, it is necessary to integrate the real WISAN and re-check the whole performance.
11 tests have been defined for both pilots

1.3.5 SEEDS Validation and energy analysis

SEEDS validation means the commissioning of SEEDS in each pilot following the procedure described above and the analysis of the energy performance of each pilot.

The last step of the Commissioning flow is the ‘Overall validation’ which is Task 9.5 of the Commissioning flow. In this task SEEDS is working in close loop and is delivering first results. It is very important to daily check all the values of most relevant variables to check on comfort conditions and energy performance. Six weeks were considered a long enough time to check the overall performance of the SEEDS system.

On the other hand, the analysis of the energy performance is designed to cover five main objectives:

- Assessment of energy savings because of the implementation of a SEEDS system in existing buildings. Two pilot demonstrators were planned in order to determine savings and a general methodology for energy savings calculation was firstly developed. Later on, this methodology was tailored according to the particularities of the two specific demonstrators.
- Evaluation of the environmental and economic impacts resulting from this energy saving. For this purpose, the whole life cycle of system components was considered and a reference methodology, following the ISO standards for life cycle assessment, was defined. The OpenLCA software was used, based on ReCiPe methodology and internationally recognized databases (ELCD and NREL).
- Development of a guide for “Best Practises for Energy Efficient Buildings and Open Spaces”. The guide has been elaborated by gathering the best practices identified during the different stages of the project development, in terms of economic and environmental impacts. The real experience obtained from the demo sites has allowed understanding the encountered drawbacks and success of deploying SEEDS’ technologies, what constitutes the baseline and the argument of this guide.

- Evaluation of the acceptability of the BEMS technology developed by the SEEDS team and its effectiveness in managing the thermal comfort of the occupants. By covering both pre and post occupancy surveys, the study addresses two core ideas; individual perspectives of comfort and satisfaction with control.
- Evaluation of the project performance from a scientific and technical point of view. During the full life period of the project a detailed evaluation of the performance, progress and impact of the project has been made. Potential deviations from the intended scope of the project and lessons learned have also been identified.

1.3.5.1 Assessment of SEEDS energy efficiency and energy savings

A novel general validation methodology has been developed in the SEEDS project and applied in two real cases with energy conservation measures from the ICT. The methodology identifies the most significant variables and develops statistical correlations between them and the building energy consumption in order to predict the hypothetical consumption if ECMs – Energy Conservation Measurements - were not applied.

The methodology includes the following stages:

- Collection of information about location and building features such as envelope, distribution, energy supply and demand. After that the measurement and verification plan is developed.
- The baseline and reporting periods are characterised using bills of energy suppliers and building monitored data. This information helps to take into consideration equations in order to foresee building behaviour based on dynamic variables, mainly HDD, CDD and Solar Irradiation. Energy consumption equations are obtained and after that some routine adjustments, such as the occupancy schedule, are foreseen to correct them.
- These equations allow us to compare the results obtained during the reporting period with the results that would have been during this period if ECM had not been applied (see Figure 29).

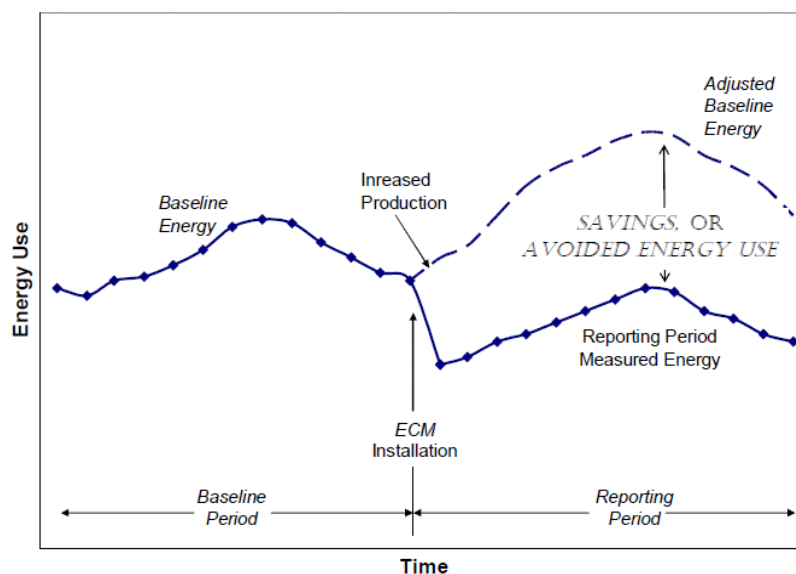


Figure 29. Scheme for savings determination during baseline and reporting periods.

The information generated includes:

- Collection of information about location and building features such as distribution, energy supply and demand, and measurement and verification plan.
- Equations to estimate monthly energy savings during the reporting period.
- Methodology to obtain annual energy savings and reduction in CO₂ emissions starting from monthly saving energy equations.

Finally a data analysis procedure has been developed in order to detect and understand the effects obtained by the Energy Conservations Measurements.

The results may be indicated in different types of energy or even in equivalent CO₂ emissions:

- **Calculated final energy savings**, directly obtained from the developed equations.
- **Primary energy savings**, obtained by applying conversion factors to final energy savings (these factors mainly depend on the country and type of energy).
- **CO₂ emissions**, through other conversion factors also depending on the country and type of energy.

The developed methodology is valid for all type of ECMs in buildings and open spaces.

1.3.5.2 Environmental impact

Regarding the environmental impact, a specific Life Cycle Assesment (LCA) methodology following the ISO standards has been developed for SEEDS system.

The environmental methodology uses OpenLCA software, based on ReCiPe methodology and internationally recognized databases (ELCD and NREL).

The highest environmental impact is made by electrical energy savings and the impact of electrical energy is very dependent on the production structure in each country. Only ELCD is able to provide reliable data of Electric Energy production in Norway (Demo 1) and Spain (Demo 2). Also ELCD is more comprehensive about waste recovery inventory.

On the other hand, environmental results with ELCD are poorly developed in OpenLCA: It does not cover all midpoint and endpoint categories and it has not been possible to arrive to a global result.

It is for this reason that a single LC tree has not been able to be deployed and, instead of that, smaller product systems have been developed in Open LCA starting from available data, some of them based on NREL databases and some others based on ELCD databases. Starting from this, partial results have been obtained and analyzed.

As it has been said, the most significant factor in SEEDS system is by far the energy savings and its main environmental impacts are related to Climate Change and Fossil Depletion. On the other hand, the environmental impact of electrical energy is very dependent on the percentage of renewable energy in the electricity mix.

Based on the same Life Cycle diagram, economic benefits have also been studied using Life Cycle Cost Analysis (LCC). Appropriate calculation tables considering the elements lifetime and the

discount rate have been developed for every demonstration case. In both demonstrators SEEDS produces positive effects in terms of LCC.

1.3.6 Conclusions

As a summary, SEEDS has produced significant scientific results. It was a very ambitious project which has successfully faced more challenges than originally planned in the DoW. Unfortunately, the underestimation of the difficulties linked to the validation in occupied buildings whose inhabitants/owners were not partners in the consortium and the fact that the main researcher in UiS working on Optimizer and developing the code left the project at a critical point has impeded the fully validation of SEEDS in the pilots.

SEEDS has developed an innovative BEMS to achieve an optimal energy and comfort management. It reduces the cost for building operation because of the reduction of energy consumption and the reduced cost of the installation and maintenance of the system with respect to traditional control systems.

The main results that SEEDS has provided are:

- A low cost platform of wireless sensors and actuators oriented towards Building Automation Systems.
- BIM modelling of energy facilities.
- SEEDS controller for energy and comfort optimal management. It includes three components (the energy calculator, the optimizer and the self-learning) managed by the Controller which is in charge of starting the energy calculator loop to continuous compute the energy consumption and of triggering the optimization cycle.
- Semi-automatic configuration of the SEEDS software based on a MS Access schema which is the result of SEEDS modelling methodology
- Optimization of energy and comfort supported by SL algorithms for the prediction of building and user behavior.

After the above results, some exploitable results have been identified although they will need further developments to reach the market. Some description of main exploitable results and barriers to overcome are provided in Section 1.4.4 of this report and in Deliverable D9.2 [10]

The main strengths of SEEDS are:

- The installation, actualization/update and maintenance of SEEDS system is very efficient and simplified since the building specific data are kept separated independent of the control algorithm.
- The SEEDS software for any building is automatically generated based on the creation of a SEEDS MS ACCESS data base which is partly based on IFC structured but enhanced to gather all SEEDS requirements. The integration or update of new building facilities only required the actualization of the MS ACCESS data base and the new execution of the configuration process.
- A Facility Model Library has been developed based on IFC structure (an open ISO standard used in BIM) and including more than 100 facility components and types with special emphasis on HVAC equipment. The models included in the library can be reused for different applications. Besides, as SEEDS is applied more and more in different types of buildings, the library components will enhance.

- SEEDS' Self-learning capability means that detailed analytical modelling of a building's behavior, which has been shown to make unreasonable assumptions and difficult, is not necessary, and instead continuously learning of building and user behavior is more effective and will lead to greater potential for saving energy .
- Hardware and software SEEDS wireless technologies developed will facilitate the deployment, commissioning and maintenance.

As a consequence of the above strength, SEEDS will have a high replicability and will facilitate the enhancement of market penetration of ICT solutions for energy efficient buildings.

1.4 Potential impact, main dissemination activities and exploitation of results

1.4.1 Potential impact

SEEDS develops a low cost BEMS which overcomes traditional BMS. Therefore SEEDS will allow for energy and cost savings along the lifecycle of the building. One of the paramount characteristic of SEEDS is its high replicability and its ability to be easily applied to any building. This will facilitate market penetration of novel customized ICT tools for building operation for the following reasons:

The replicability of SEEDS is high because of the following reasons:

- SEEDS modelling based on measurements. There is no need to have comprehensive information of the building and energy system physics
- Open and flexible architecture able to be applied to different types of buildings, with different types on energy equipment and sensors systems and able to be adapted to the new equipment requirements that may arise during the life of the building.
- BIM approach for the Configuration and the modelling of energy facilities
- Energy system model based on reusable Facility Model library components
- Semi-automatic configuration of the software based on MS Access schema
- Low cost WISAN
- Use of standards: i) BIM based (IFC) modelling, ii) OSGI for the controller, iii) IFC for the coverage tool in WISAN.

Other strengths of SEEDS are:

- It is able to learn the behaviour of the building and its inhabitants allowing for energy optimization without user awareness.
- Scalability and parallelization is suitable for Self-learning developments and GUI generation.
- The control strategy and the multiperiod optimization allows for an optimal energy and comfort management.

The main impacts and benefits of SEEDS are:

- Reduction of energy consumption, costs and CO2.
- Improved health, quality of life and comfort.
- Reduction of first adjustment and maintenance costs.

- Easy customization of SEEDS' BEMS to any building → Enhancement of market penetration of efficient control systems for building operation

1.4.2 SEEDS beneficiaries

One of the most important aspects to consider in any research project is to identify potential stakeholders or main beneficiaries of the technology developed in the project.

Once identified and analysed the main outcomes, it may be said that the SEEDS technologies are addressed to the following target groups:

- Facilities Management companies
- Architect, engineers...
- Public and private building managers
- ESCOs (Energy Service Companies)
- Energy Consulting companies
- Energy Agencies
- Electronic providers
- Researcher's in the field of building and control system

Of all of them, the main stakeholders are the Facility Manager such as SAUTER or Grandlund. A close cooperation with this type of organization would be required to reach full potential of exploitable SEEDS results.

1.4.3 Main dissemination activities

During the three and a half years of the project, the SEEDS partners were active in disseminating the project's results in high-quality conferences, liaising with related research projects, making promotional material, among other activities. 8 scientific papers have been prepared, submitted, accepted for publication, and presented in conferences (see Table A1). Besides, 29 dissemination activities have been conducted, including industrial workshops attended and fairs (see Table A2). The project's main dissemination activities are organized below in 3 categories: publications, workshops and, other activities.

1.4.3.1 Publications and Scientific Conferences

During the project some publications were written such as press releases, as well as scientific contributions to conferences.

Regarding to articles, papers and every kind of peer reviewed publication are being used to promote and share the project outline and expected results.

The Consortium has performed several submissions of articles that describe results of the research and developments related to SEEDS technology. The following table shows contributions that have been submitted or have already been published:

PAPER n.1 -	Overview of Time Series Storage and Processing in a Cloud Environment
PAPER n.2 -	Evaluation of self-learning methods for predicting energy consumption
PAPER n.3 -	Using a BIM for the design and operation of Building Energy Management Systems
PAPER n.4 -	Validation Methodology for a Self-Learning Building Energy Management System
PAPER n.5 -	SEEDS-SENS: a modular wireless sensor actuator platform for building automation
PAPER n.6 -	Performance of Data Extraction from OpenTSDB
PAPER n.7 -	Using a Multi-Model for a BIM-based Design and Operation of Building Energy Management Systems
PAPER n.8 -	An innovative Building Energy Management System. Developments of the SEEDS' project

Table 9: List of articles/papers

Moreover, the SEEDS project is included in the annual edition of 'EeB PPP Project Review'. SEEDS was included for first time in the 2nd edition (published 2012), and each year the factsheet is updated (see Figure 30).



Figure 30. SEEDS factsheet in the 2nd Edition 2012 (left), 3rd Edition 2013 (centre) and 4th Edition 2014 (right)

1.4.3.2 Workshops and Exhibitions

Some partners have attended to exhibitions or have participated in technical meetings/workshop (see Table A2).

Other key element of the successful dissemination has been the participation of the Consortium Partners in conferences, workshops, exhibitions and similar events. At the same time the participation in conferences provides dissemination of results as well as exploitation of the results. The list of project publications is given in the Tables A1 (peer-reviewed publications) and Table A2 (dissemination activities). In these events, the project has been actively presented and promoted with usage of dissemination tools and material. The participation in conferences has been mainly

focused on informing to the community about the SEEDS project, methodologies and systems developed, as well as results and benefits.

Moreover, the project consortium participated in two joint dissemination activities, organizing two special sessions/workshops, which were held during the *ICT for Sustainable Places Conference* (ICT4SP 2013) and *World Sustainable Building International Conference 2014* (WSB14).

1.4.3.3 Other dissemination activities

The SEEDS Team has produced promotional materials, as website, flyers and newsletters.

The detailed description of these other dissemination activities has been presented in the deliverable *D9.3 Dissemination and Exploitation Activities* [9].

The project website (Figure 31) was elaborated during the first three months of the project. It is opened to the general public. SEEDS website may be accessed both from <http://www.seeds-fp7.eu/> and from <http://www.seeds-fp7.com>.



Figure 31: SEEDS Home Page.

The website provides an introduction of the project, by describing the background, project objectives, work packages, demo buildings as well as details of the project Partners, links to Partner's websites, and contact details for the Project Coordinator. It also shows dissemination documents, news and events, related links and publications sections. The website is aimed at hosting all publicly available information of the project.

The brochure (Figure 32), consistent with the project logo colours and character, was created at the very beginning phase of the project. This brochure describes the project overview, its goals and

benefits. It is aimed not to have a detailed project description, but to give an immediate idea of what SEEDS is about. It also shows the contact points (Project Coordinator), and related links of the Consortium Partners.

The brochure has been used by the Partners within different events (e.g. conferences, workshops, etc.) and distributed among participants in order to promote the project and its results.

The brochure is also available on the website to be downloaded.

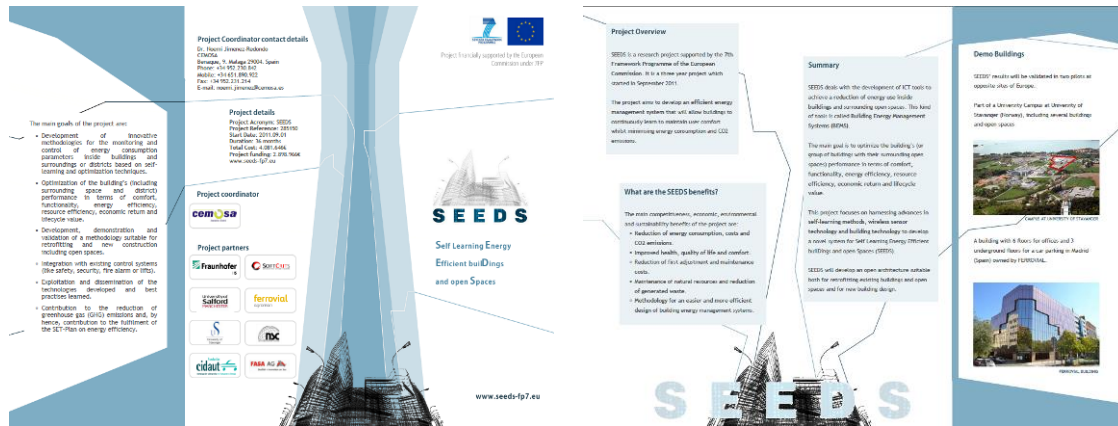


Figure 32. SEEDS leaflet

The three newsletters scheduled in the Description of Work (Annex I of the Grant Agreement) have been published; including key achievements reached, work status and news of upcoming events. The Newsletters have given the opportunity for Partners to comment on developments, experiences and project progress by means of interviews. Each Newsletter is adjusted to current project state and described selected issues related to the project’s development:

These Newsletters are mainly addressed to relevant target group (e.g. research communities and practitioners in the area of energy efficient buildings), but in practice they are distributed to general public. All newsletters are available on the website. The Newsletters have been also distributed towards contacts potentially interested in SEEDS via the mailing lists.

1.4.4 Exploitation activities and achievements

SEEDS has developed technologies with the main goal of improving energy efficiency in new and existing buildings, which encompasses the most diverse, largest and most cost-effective mitigation opportunities in buildings.

The main results that SEEDS has provided are:

1. Methodology to facilitate and partially automated the implementation of a Building Energy Management System to any building and group of buildings and/or open spaces. This methodology is based on a MS Access schema which represent and own ontology of a BIM. The information store in the database is used to configure the different components of SEEDS software.

2. Extended supervisory control of HVAC and lighting systems behaviour and energy consumption by Neural-Network-based prediction and optimization.
3. Adaptive techniques to continuously learn building characteristics and user behaviour and implementation of such self-learning and forecasting techniques in order to anticipate building requirements and achieve an optimal energy performance.
4. BIM modelling of energy facilities.
5. Optimal energy and comfort management for a predefined time horizon (e.g. 24 hours).
6. A low cost hardware and software platform of wireless sensors and actuators oriented towards Building Automation Systems and its associate software tools (e.g. .

The main exploitable results of the project are:

- The SEEDS BEMS which gather up the results 1-5 of the list above and
- The SEEDS-SENS which is WISAN hardware and software platform and is the result of item 6 above.

However, none of these results are still mature for market. We have identified the following market barriers which prevent a fast market penetration of SEEDS;

- External barriers: lack of users' awareness (believe in advantages of innovative energy management solutions), lack of users' willingness to accept or rely on new technology, security and safety reasons, economic conditions (investment costs vs. decreasing live cycle costs - believe in short ROI),
- SEEDS internal barriers: level of implementation (TRL 5 at the end of SEEDS), missing references, the lack or the inaccuracy of data of energy equipment provided by the manufacturers or building owners which are required for efficient BEMS initialization

Ongoing advancement of the SEEDS results in tight collaboration with Facility Managers or BAS providers would facilitate overcoming the barriers and would move SEEDS closer to the market favouring also the integration of SEEDS with other building control systems.

In relation to SEEDS-SENS, the main barrier is the difficulty for entering a marker in which few companies cope most of the installations of these type of technologies. Further development in SEEDS-SENS to get closer to the market includes the completion with standards and certification.

An initial Exploitation Plan was issued in April 2014 (Deliverable D9.2 [10])

1.5 Consortium and Contact details

The SEEDS consortium includes an appropriate mix of parctioners and researchers from industry and academia, with a range of expertise that aims to ensure a successful outcome. The consortium is made up of the following organizations: CEMOSA (Project Coordinator, Spain), Fraunhofer (Germany), SOFTCRITS (Spain), Fundacion CIDAUT (Spain), University of Salford (United Kingdom), University of Stavanger (Norway), NSC (Germany), Ferrovial Agromán (Spain) and FASA (Germany).

The contacts details can be addressed to www.seeds-fp7.eu and www.seeds-fp7.com

2 Use and dissemination of foreground

Section A (public)

This section includes two tables:

- Table A1: List of all scientific (peer reviewed) publications relating to the foreground of the project.
- Table A2: List of all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

TABLE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS

No	Title / DOI	Author(s)	Title of the periodical or the series	Publisher	Place of publication	Date of publication	Relevant pages	Open access?	Type
1	Overview of Time Series Storage and Processing in a Cloud Environment doi:10.1109/CloudCom.2012.6427510	Włodarczyk, T.W.	Cloud Computing Technology and Science (CloudCom)	IEEE	Taipei	December 2012	625-628	No	Peer reviewed
2	Evaluation of self-learning methods for predicting energy consumption	Vadera S., Wu J., Meziane F., Donath U., Gómez A., Redondo N.	Proceedings of the 2nd International Conference on Energy Systems and Technologies (ICEST2013)	Afaq scientific	Cairo (Egypt)	February 2013	Paper 65	No	Conference
3	Using a BIM flow for the design and operation of Building Energy Management Systems doi:10.2759/40897	Stenzel P., Haufe J., Jiménez N.	Proceedings of the 4th Workshop organised by the EEB Data Models Community ICT for Sustainable Places	European Commission	Brussels (Belgium)	January 2014	46-60	Yes	Conference
4	Validation Methodology for a Self-Learning Building Energy Management System doi:10.2759/42792	Nieto L., Castaño V.	Proceedings of the 1st Workshop organised by the EEB Data Models Community ICT for Sustainable Places	European Commission	Brussels (Belgium)	January 2014	42-56	Yes	Conference

No	Title / DOI	Author(s)	Title of the periodical or the series	Publisher	Place of publication	Date of publication	Relevant pages	Open access?	Type
5	SEEDS-SENS: a modular wireless sensor actuator platform for building automation ISBN-13: 978-84-695-8430-9	Diaz F., España J., Diaz M.	Proceedings of the Greencities & Sustainability Conference. Smart Solutions to Urban Sustainability	greencitiesmalaga	Málaga (Spain)	October 2013	93-103	Yes	Conference
6	Performance of Data Extraction from OpenTSDB ISBN 978-84-15814-97-9	Wlodarczyk, T. W.	International work-conference On Time Series (ITISE 2014)	University of Granada	Granada (Spain)	June 2014	1170-1181	Yes	Conference
7	Using a Multi-Model for a BIM-based Design and Operation of Building Energy Management Systems ISBN: 978-1-138-02710-7	Stenzel P., Haufe J., Jiménez N.	eWork and eBusiness in Architecture, Engineering and Construction: ECPPM 2014	CRC Press / Balkema	Leiden (The Netherlands)	September 2014	813-820	No	Conference
8	An innovative Building Energy Management System. Developments of the SEEDS' project	Jimenez-Redondo, N; Márquez, F.J; Haufe, J.; Díaz, M.	Proceedings of the World Sustainable Building International Conference 2014 (WSB14)	ICONDA@CIBlibrary	Stuttgart (Germany)	Pending to be published	Pending to be published	Yes	Conference

TABLE A2: LIST OF DISSEMINATION ACTIVITIES

NOTE: CHRONOLOGICALLY ORDERED DISSEMINATION ACTIVITIES

No.	Type of activities ⁴	Main leader	Title	Date	Place	Type of audience ⁵	Countries addressed
1	Articles published in the popular press	SOFTCRITS	New in the local newspaper "Malaga Hoy"	28/10/2011	Spain	Civil society	Local
2	Website/Application	CEMOSA	SEEDS project website	01/12/2011	Spain	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	International
3	Press release	CEMOSA	New in SOST (Spanish Office for Science and Technology) website	15/02/2012	Belgium	Scientific community (higher education, Research) - Industry	European
4	Press release	CEMOSA	Article in newsletter of TECNIBERIA (Spanish Association of Engineering, Consulting and Technical Services)	24/02/2012	Spain	Scientific community (higher education, Research) - Industry	National (Spain)
5	Flyers	CEMOSA	SEEDS brochure	08/02/2012	Spain	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	International

⁴ Dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

⁵ Type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias.

No.	Type of activities ⁴	Main leader	Title	Date	Place	Type of audience ⁵	Countries addressed
6	Workshop	CEMOSA	2nd Workshop on Impact of the Energy-efficient Buildings PPP	14-15/03/2012	Brussels, Belgium	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	European
7	Conference	CEMOSA	Conference "Energy efficient buildings and districts-Research to accelerate innovation"	15/05/2012	Brussels, Belgium	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	European
8	Conference	CEMOSA	2nd Eurekabuild International Brokerage Event	12/06/2012	Madrid, Spain	Industry	International
9	Press release	USAL	Media story report	20/08/2012	Salford, UK	Scientific community (higher education, Research) - Industry	International
10	Exhibition	CIDAUT	EXPOBIOENERGIA 2012. Technological Bioenergy Fair	23-25/10/2012	Valladolid, Spain	Scientific community (higher education, Research) - Industry - Civil society - Medias	International
11	Conference	UiS	4 th IEEE International conference on cloud Computing Technology and Science (CloudCom 2012)	3-6/12/2012	Taipei, Taiwan	Scientific community (higher education, Research)	International
12	Articles published in the popular press	CEMOSA	New in the local newspaper "Diario Sur"	13/01/2013	Spain	Civil society	Local
13	Conference	USAL	2nd International Conference on Energy	18-21/02/2013	Cario, Egypt	Scientific community	International

No.	Type of activities ⁴	Main leader	Title	Date	Place	Type of audience ⁵	Countries addressed
			Systems and Technologies (ICEST 2013)			(higher education, Research)	
14	Workshop	EAS	2nd VoCamp around Building Information Models (BIM)	21-22/02/2013	Brussels, Belgium	Scientific community (higher education, Research) - Industry	European
15	Workshop	CEMOSA	3rd Workshop on Impact of the Energy-efficient Buildings PPP	11-12/03/2013	Brussels, Belgium	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	European
16	Workshop	EAS	3rd VoCamp - Energy using and producing Products Management (EupP)	13-14/06/2013	Kaiserslautern, Germany	Scientific community (higher education, Research) - Industry	European
17	Conference	CEMOSA	Innovation in Energy Efficiency buildings and districts for smart built environment (EUSEW)	26/06/2013	Brussels, Belgium	Scientific community (higher education, Research) - Industry	European
18	Press release	FERROVIAL	New in P-net (Construction R&D Networking 2.0) website	01/07/2013	Spain	Scientific community (higher education, Research) - Industry	European
19	Press release	CEMOSA	New in newsletter of PTEC (Spanish Technology Platform for Construction)	15/07/2013	Spain	Scientific community (higher education, Research) - Industry	National (Spain)
20	Conference	CEMOSA, SOFTCRITS, EAS, CIDAUT	International Conference for Sustainable Places (ICT4SP) <i>Note: Four SEEDS' presentations (on preliminary results, wireless sensors, KPI and</i>	9-11/09/2013	Nice, France	Scientific community (higher education, Research) - Industry - Civil society - Policy	International

No.	Type of activities ⁴	Main leader	Title	Date	Place	Type of audience ⁵	Countries addressed
			<i>Data Models) were made during the conference.</i>			makers - Medias	
21	Conference	SOFTCRITS	4 th Greencities. Smart Solutions to Urban Sustainability	2-3/10/2013	Málaga, Spain	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	National
22	Press release	CIDAUT	New about ICT4SP in Cidaut newsletter	6/11/2013	Spain	Scientific community (higher education, Research) - Industry	National (Spain)
23	Workshop	CEMOSA	4th Workshop on Impact of the Energy-efficient Buildings PPP	1-2/04/2014	Brussels, Belgium	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	European
24	Workshop	CEMOSA	PTEC GT ciudad del Futuro	8/04/2014	Madrid, Spain	Industry	National
25	Conference	SOFTCRITS	DG CONNECT & ETSI Workshop on M2M Smart Appliances	27-28/05/2014	Brussels, Belgium	Scientific community (higher education, Research) – Industry – Policy maker	European
26	Conference	UiS	International work-conference On Time Series (ITISE 2014)	25-26/06/2014	Granada, Spain	Scientific community (higher education, Research)	International
27	Press release	CIDAUT	New in Cidaut Newsletter	10/09/2014	Spain	Scientific community (higher education, Research) - Industry	National (Spain)

No.	Type of activities ⁴	Main leader	Title	Date	Place	Type of audience ⁵	Countries addressed
28	Conference	EAS	European Conference on Product and Process Modelling (ECPPM 2014). 5th Workshop on eeBuilding Data Models	17-19/09/2014	Vienna, Austria	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	European
29	Conference	CEMOSA	World Sustainable Building 2014	28-30/10/2014	Barcelona, Spain	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	International

3 Report on societal implications

A General Information *(completed automatically when Grant Agreement number is entered.)*

Grant Agreement Number:

285150

Title of Project:

Self learning Energy Efficient builDings and open Spaces

Name and Title of Coordinator:

Dr. Noemi Jimenez-Redondo

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?

No

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'

2. Please indicate whether your project involved any of the following issues (tick box) :

RESEARCH ON HUMANS

- | | |
|---|-----------|
| • Did the project involve children? | <i>No</i> |
| • Did the project involve patients? | <i>No</i> |
| • Did the project involve persons not able to give consent? | <i>No</i> |
| • Did the project involve adult healthy volunteers? | <i>No</i> |
| • Did the project involve Human genetic material? | <i>No</i> |
| • Did the project involve Human biological samples? | <i>No</i> |
| • Did the project involve Human data collection? | <i>No</i> |

RESEARCH ON HUMAN EMBRYO/FOETUS

- | | |
|---|-----------|
| • Did the project involve Human Embryos? | <i>No</i> |
| • Did the project involve Human Foetal Tissue / Cells? | <i>No</i> |
| • Did the project involve Human Embryonic Stem Cells (hESCs)? | <i>No</i> |
| • Did the project on human Embryonic Stem Cells involve cells in culture? | <i>No</i> |

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

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	0
Work package leaders	5	10
Experienced researchers (i.e. PhD holders)	7	26
PhD Students	0	1
Other	2	6

4. How many additional researchers (in companies and universities) were recruited specifically for this project?

Of which, indicate the number of men:

2 (1 man
and 1
woman)

D Gender Aspects																				
5. Did you carry out specific Gender Equality Actions under the project?	<input type="radio"/> Yes <input checked="" type="radio"/> No																			
6. Which of the following actions did you carry out and how effective were they? <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 60%;"></th> <th style="width: 20%; text-align: center;">Not at all effective</th> <th style="width: 20%; text-align: center;">Very effective</th> </tr> </thead> <tbody> <tr> <td><input type="checkbox"/> Design and implement an equal opportunity policy</td> <td style="text-align: center;">○ ○ ○ ○ ○</td> <td style="text-align: center;">○ ○ ○ ○ ○</td> </tr> <tr> <td><input type="checkbox"/> Set targets to achieve a gender balance in the workforce</td> <td style="text-align: center;">○ ○ ○ ○ ○</td> <td style="text-align: center;">○ ○ ○ ○ ○</td> </tr> <tr> <td><input type="checkbox"/> Organise conferences and workshops on gender</td> <td style="text-align: center;">○ ○ ○ ○ ○</td> <td style="text-align: center;">○ ○ ○ ○ ○</td> </tr> <tr> <td><input type="checkbox"/> Actions to improve work-life balance</td> <td style="text-align: center;">○ ○ ○ ○ ○</td> <td style="text-align: center;">○ ○ ○ ○ ○</td> </tr> <tr> <td><input type="radio"/> Other: <input style="width: 300px;" type="text"/></td> <td></td> <td></td> </tr> </tbody> </table>				Not at all effective	Very effective	<input type="checkbox"/> Design and implement an equal opportunity policy	○ ○ ○ ○ ○	○ ○ ○ ○ ○	<input type="checkbox"/> Set targets to achieve a gender balance in the workforce	○ ○ ○ ○ ○	○ ○ ○ ○ ○	<input type="checkbox"/> Organise conferences and workshops on gender	○ ○ ○ ○ ○	○ ○ ○ ○ ○	<input type="checkbox"/> Actions to improve work-life balance	○ ○ ○ ○ ○	○ ○ ○ ○ ○	<input type="radio"/> Other: <input style="width: 300px;" type="text"/>		
	Not at all effective	Very effective																		
<input type="checkbox"/> Design and implement an equal opportunity policy	○ ○ ○ ○ ○	○ ○ ○ ○ ○																		
<input type="checkbox"/> Set targets to achieve a gender balance in the workforce	○ ○ ○ ○ ○	○ ○ ○ ○ ○																		
<input type="checkbox"/> Organise conferences and workshops on gender	○ ○ ○ ○ ○	○ ○ ○ ○ ○																		
<input type="checkbox"/> Actions to improve work-life balance	○ ○ ○ ○ ○	○ ○ ○ ○ ○																		
<input type="radio"/> Other: <input style="width: 300px;" type="text"/>																				
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? <p> <input type="radio"/> Yes- please specify <input style="width: 150px;" type="text"/> </p> <p> <input checked="" type="radio"/> No </p>																				
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)? <p> <input type="radio"/> Yes- please specify <input style="width: 150px;" type="text"/> </p> <p> <input checked="" type="radio"/> No </p>																				
9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)? <p> <input type="radio"/> Yes- please specify <input style="width: 150px;" type="text"/> </p> <p> <input checked="" type="radio"/> No </p>																				
F Interdisciplinarity																				
10. Which disciplines (see list below) are involved in your project? <p> <input type="radio"/> Main discipline⁶: 2.2 </p>																				

⁶ Insert number from list below (Frascati Manual).

<input type="radio"/> Associated discipline: 2.1	<input type="radio"/> Associated discipline:
---	--

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)	<input type="radio"/> Yes <input checked="" type="radio"/> 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)?	<input type="radio"/> Yes <input type="radio"/> 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?

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

13c If Yes, at which level?		
<input type="radio"/> Local / regional levels <input type="radio"/> National level <input type="radio"/> European level <input type="radio"/> International level		
H Use and dissemination		
14. How many Articles were published/accepted for publication in peer-reviewed journals?	1	
To how many of these is open access⁷ provided?	0	
How many of these are published in open access journals?		
How many of these are published in open repositories?		
To how many of these is open access not provided?	0	
Please check all applicable reasons for not providing open access:		
<input type="checkbox"/> publisher's licensing agreement would not permit publishing in a repository <input type="checkbox"/> no suitable repository available <input type="checkbox"/> no suitable open access journal available <input type="checkbox"/> no funds available to publish in an open access journal <input type="checkbox"/> lack of time and resources <input type="checkbox"/> lack of information on open access <input type="checkbox"/> other ⁸ :		
15. How many new patent applications ('priority filings') have been made? (<i>"Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant.</i>)	0	
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	
	Registered design	
	Other	
17. How many spin-off companies were created / are planned as a direct result of the project?	0	

⁷ Open Access is defined as free of charge access for anyone via Internet.

⁸ For instance: classification for security project.

<i>Indicate the approximate number of additional jobs in these companies:</i>		<input type="text"/>
18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:		
<input checked="" type="checkbox"/> X Increase in employment, or	<input checked="" type="checkbox"/> X	In small & medium-sized enterprises
<input type="checkbox"/> Safeguard employment, or	<input type="checkbox"/>	In large companies
<input type="checkbox"/> Decrease in employment,	<input type="checkbox"/>	None of the above / not relevant to the project
<input type="checkbox"/> 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:		<i>Indicate figure:</i>
Difficult to estimate / not possible to quantify		<input checked="" type="checkbox"/> X

I Media and Communication to the general public														
<p>20. As part of the project, were any of the beneficiaries professionals in communication or media relations?</p> <p><input type="radio"/> Yes <input checked="" type="radio"/> No</p>														
<p>21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?</p> <p><input type="radio"/> Yes <input checked="" type="radio"/> No</p>														
<p>22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?</p> <table border="1" data-bbox="188 875 1445 1200"> <tr> <td><input checked="" type="checkbox"/> Press Release</td> <td><input checked="" type="checkbox"/> Coverage in specialist press</td> </tr> <tr> <td><input type="checkbox"/> Media briefing</td> <td><input type="checkbox"/> Coverage in general (non-specialist) press</td> </tr> <tr> <td><input type="checkbox"/> TV coverage / report</td> <td><input type="checkbox"/> Coverage in national press</td> </tr> <tr> <td><input type="checkbox"/> Radio coverage / report</td> <td><input type="checkbox"/> Coverage in international press</td> </tr> <tr> <td><input checked="" type="checkbox"/> Brochures /posters / flyers</td> <td><input checked="" type="checkbox"/> Website for the general public / internet</td> </tr> <tr> <td><input type="checkbox"/> DVD /Film /Multimedia</td> <td><input checked="" type="checkbox"/> Event targeting general public (festival, conference, exhibition, science café)</td> </tr> </table>			<input checked="" type="checkbox"/> Press Release	<input checked="" type="checkbox"/> Coverage in specialist press	<input type="checkbox"/> Media briefing	<input type="checkbox"/> Coverage in general (non-specialist) press	<input type="checkbox"/> TV coverage / report	<input type="checkbox"/> Coverage in national press	<input type="checkbox"/> Radio coverage / report	<input type="checkbox"/> Coverage in international press	<input checked="" type="checkbox"/> Brochures /posters / flyers	<input checked="" type="checkbox"/> Website for the general public / internet	<input type="checkbox"/> DVD /Film /Multimedia	<input checked="" type="checkbox"/> Event targeting general public (festival, conference, exhibition, science café)
<input checked="" type="checkbox"/> Press Release	<input checked="" type="checkbox"/> Coverage in specialist press													
<input type="checkbox"/> Media briefing	<input type="checkbox"/> Coverage in general (non-specialist) press													
<input type="checkbox"/> TV coverage / report	<input type="checkbox"/> Coverage in national press													
<input type="checkbox"/> Radio coverage / report	<input type="checkbox"/> Coverage in international press													
<input checked="" type="checkbox"/> Brochures /posters / flyers	<input checked="" type="checkbox"/> Website for the general public / internet													
<input type="checkbox"/> DVD /Film /Multimedia	<input checked="" type="checkbox"/> Event targeting general public (festival, conference, exhibition, science café)													
<p>23 In which languages are the information products for the general public produced?</p> <table border="1" data-bbox="188 1290 1002 1373"> <tr> <td><input type="checkbox"/> Language of the coordinator</td> <td><input checked="" type="checkbox"/> English</td> </tr> <tr> <td><input type="checkbox"/> Other language(s)</td> <td></td> </tr> </table>			<input type="checkbox"/> Language of the coordinator	<input checked="" type="checkbox"/> English	<input type="checkbox"/> Other language(s)									
<input type="checkbox"/> Language of the coordinator	<input checked="" type="checkbox"/> English													
<input type="checkbox"/> 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 SIT 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 SIT activities relating to the subjects in this group]

4 References

- [1] SEEDS project. D8.6. Report on 'Best practises for Energy Efficient Buildings and Open Spaces'
- [2] SEEDS project. D2.8. Energy control strategy. First release
- [3] SEEDS project. D2.3. Modelling methodology
- [4] SEEDS project. D2.7. Complete libraries necessary for the demonstrators
- [5] SEEDS project. D2.8. Energy control strategy. First release
- [6] SEEDS project. D2.9. Energy control strategy. Final Version
- [7] SEEDS project. D5.5. Implementation and refinement of self-learning algorithms and global optimization in the two pilots
- [8] SEEDS project. D6.4. Validated Graphical User Interface
- [9] SEEDS project. D9.3. Report on dissemination & exploitation activities
- [10] SEEDS project. D9.2. Exploitation plan.