BaaS

Building as a Service

FP7-ICT-2011-6: ICT Systems for Energy Efficiency
Small or Medium-scale Focused Research Project
Grant Agreement No. 288409

Deliverable D6.4:

Deployment of BaaS ECM in Pilot Buildings

Deliverable Version:	D6.4, v.1.2
Document Identifier:	baas_wp6_d6.4_deployment_of_baas_ecm_in_pilot_buildings_v1.2
Preparation Date:	September 20, 2016
Document Status:	Final
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Dissemination Level:	PU - Public

SEVENTH FRAMEWORK PROGRAMME

Project funded by the European Community in the 7th Framework Programme

European Commission
Information Society and Media

ICT for Sustainable Growth

Deliverable Summary Sheet

Deliverable Details

Type of Document:	Deliverable
Document Reference #:	D6.4
Title:	Deployment of BaaS ECM in Pilot Buildings
Version Number:	1.2
Preparation Date:	September 20, 2016
Delivery Date:	September 20, 2016
Author(s):	Susana Martín, Jose Luis Hernandez 1, Javier Martín, Óscar Hidalgo, Alfonso Gordaliza 2, Juan Rodriguez 3, Dimitros Rovas 4, Jiri Rojicek 5, Mischa Schmidt 6, Karsten Menzel 7 (1 CARTIF, 2 DALKIA, 3 FHG, 4 TUC, 5 HON, 6 NEC, 7 UCC)
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Document Status:	Final
Dissemination Level:	PU - Public

Project Details

Project Acronym:	BaaS
Project Title:	Building as a Service
Project Number:	288409
Call Identifier:	FP7-ICT-2011-6
Call Theme:	ICT Systems for Energy Efficiency
Project Coordinator:	Fundacion Cartif (CARTIF)
Participating Partners:	Fundation Cartif (CARTIF, ES); NEC Europe Ltd. (NEC, UK); Honeywell, SPOL, S.R.O (HON, CZ); Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V. (Fraunhofer, DE); Technical University of Crete (TUC, GR); University College Cork, National University of Ireland, Cork (UCC-IRU, IE) Dalkia Energia y Servicios (DALKIA, ES)
Instrument:	STREP
Contract Start Date:	May 1, 2012
Duration:	48 Months

Deliverable D6.4: Short Description

This document contains the specification and installation process about the implementation of the BaaS ECM in the pilot building, as well as the analysis of the potential application of BaaS and its economic viability in other projects as a part of an ESCo business models for energy retrofitting solutions.

Keywords: ESCo, ECM, IRR, NPV, RoI, payback perido

Deliverable D6.4: Revision History

Version:	Date:	Status:	Comments
0.0.1	16/05/2015	Draft	VEOLIA: First draft and document structure
0.0.2	17/07/2015	Draft	VEOLIA: Second draft and document structure
0.0.3	06/08/2015	Draft	CARTIF: draft description of the implementation of the BaaS system in CARTIF building.
0.0.4	12/08/2015	Draft	Fraunhoufer: draft description of the implementation of the BaaS system in ZUB building.
0.0.5	20/08/2015	Draft	NEC: draft description of the middleware components deployment within the BaaS solution
0.0.6	20/08/2015	Draft	UCC: draft description of the data ware house platform
0.0.7	26/08/2015	Draft	TUC: draft description of the deployment of the application layer components developed in BaaS system
0.0.8	28/08/2015	Draft	HON: TBM analytics implementation
0.1	24/09/2015	Draft	VEOLIA: Introduction and Conclusions
0.2	17/11/2015	Draft	CARTIF: Revision of the document
0.3	13//01/2016	Draft	VEOLIA: Introduction and Conclusions
0.3.1	20/02/2016	Final	CARTIF: Revision of the document
1.0	28/04/2016	Final	ALL: Revision of the document
1.1	14/09/2016	Revision	CARTIF: Details of the ECMs
1.2	16/09/2016	Revision	VEOLIA: Application of BaaS in real case studies

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Abbreviations and Acronyms

BaaS	Building as a Service
BAC	Building Automation Control
BIM	Building Information Modelling
BMS	Building Management System
CPU	Central Processing Unit
DACM	Data Acquisition and Control Manager
DC	Domain Controller
DoW	Document of Work
DWH	Data Warehouse
EPC	Energy Performance Contract
ESCO	Energy Services Company
ETL	Extract, Transform and Load
ECM	Energy Conservation Measure
FTP	File Transfer Protocol
HTTP	Hypertext Transfer Protocol
IPMVP	International Performance Measurement and Verification Protocol
IRR	Internal Rate of Return
KPI	Key Performance Indicator
NPV	Net Present Value
RoI	Return on Investment
SES	Sierra Elvira School
SQL	Structured Query Language
SOAP	Simple Object Access Protocol
TBM	Technical Building Management
WP	Work package
WSHP	Water Source Heat Pumps

Executive Summary

The aim of this document is the description of the different tasks carried out for the effective implementation of the BaaS solution as Energy Conservation Measure (ECM) in the three pilot buildings (i.e. CARTIF, ZUB and SES) and the confirmation of BaaS potential in ESCO business models in the field of energy efficiency.

The baseline and reporting period have been previously defined, studying the different independent variables that affect to the energy consumption and the comfort requirements in each building. The use cases proposed for each pilot building were analysed in order to identify the most representative operating parameters of the systems that will be controlled and optimised by the BaaS solution.

The implementation procedure includes all the necessary stages that should be undertaken in order to ensure the correct functionality, usability and interoperability of the overall BaaS system as an ECM in the pilot buildings. This methodology can serve as a set of guidelines to deploy this solution in new buildings.

Finally, the application potential of BaaS constitutes a very useful and innovative tool for Energy Services Companies (ESCO) business models, both for existing and new energy efficiency retrofitting projects. To that end, the possible implementation of BaaS and its feasibility in real projects related to energy efficiency retrofitting has been here analysed through two real case studies of ESCo model projects managed by Veolia in Spain.

1. Introduction

1.1 Purpose

The objective of this deliverable is the definition of the stages that are required for the effective implementation of the BaaS solution according to the different functionalities defined in the use cases proposed for the demo sites, and then, the assessment of its application potential within ESCO business models projects related to energy efficiency.

After this introductory section, the rest of the document is organised as follows. Section 2 describes the implementation procedure of the BaaS solution in the three pilot buildings (i.e. CARTIF, ZUB and SES) following the necessary stages for its correct development; Section 3 describes the main ESCO business models and financing schemes related to energy retrofitting projects and highlights the main benefits of the integration of BaaS as an ECM to complement existing projects or to enhance the scope of new case studies; and Section 4 includes the main conclusions of this report. Finally, last section contains all the References on which this report is based.

1.2 Contribution of partners

This task is headed by VEOLIA, who is supported and monitored by the rest of partners.

Partner	Deliverable Focus
DAL	Definition of the specification and installation process to implement the BaaS ECM in each pilot. Implementation of BaaS system in Sierra Elvira School (SES) demo site ensuring alignment with end-user needs.
CAR	Implementation of BaaS system in CARTIF demo site. Bridge between the end user requirements and the RTD purposes. Support the middleware platform in the demo sites.
FHG	Implementation of BaaS system in ZUB demo site.
HON	Support of the rest of the partners in the implementation of the ECM defined for each use case.
NEC	Definition of the specifications for the middleware implementation.
TUC	Test the implementation of individual components of BaaS solution in TUC test bed.
UCC	Definition of the requirements for the standardization of the data and Data Ware House implementation.

Table 1: Summary of Contributions of Partners

1.3 Relation to other activities in the project

This deliverable continues with the work in the demonstration activities in the project (started in D6.1), and also the Research and Technological Development activities, which aims to the BaaS solution validation and standardization.

Deliverable	Relationship
D1.2	D1.2 established the M&V methodology in order to validate the BaaS solution and the requirements of metering and monitoring for the demonstration buildings.
D4.1	D4.1 provides information about the simulation models in the buildings.
D4.4	D4.4 is related to the evaluation of the results under different KPIs.
D5.1.b	D5.1 identifies the Uses Cases and the KPI associated.
D5.4	D5.4 collects the high-level services implementation in pilot buildings

D6.1	D6.1 selected and provided the information of the demonstration buildings to be adapted in this task.
D6.2	D6.2 will be in charge of the analysis of the operation inefficiencies of the demonstration buildings, in order to deploy the M&V plan, baselining and reporting.
D6.3.1	D6.3.1 defines the IPMVP Plan.
D6.3.2	D6.3.2 develop baseline period for IPMVP Plan.
D6.3.3	D6.3.3 establishes reporting period for IPMVP Plan.

Table 2: D6.4 tasks relationship with other BaaS activities

2. Implementation procedure of the BaaS solution

This section describes the different stages that are necessary for the implementation of BaaS as an ECM. The accomplishment of all of them will allow ensuring the correct functionality, usability and interoperability of the overall BaaS system in the pilot buildings, and it can serve as a set of guidelines to deploy this solution in new buildings.

The most relevant stages of this procedure are the ones included below:

- Preparation and planning in the pilot buildings.
- Data collection and integrity checking.
- Pre-commissioning and operational testing.
- Testing of control strategies based on simulation models
- Evaluation of the control algorithms performance
- Commissioning and final integration of BaaS as ECM

All of these stages are firstly here introduced and then customized for each pilot building (i.e. CARTIF, ZUB and SES).

2.1 Preparation and planning

The main goal of the initial stage is to obtain a general overview of the original condition of the building under study in order to characterise it as much as possible before the direct implementation of BaaS. This initial phase is very important as it provides with the information about how to apply BaaS in each particular case, and in addition its correct completion greatly facilitates the development of the subsequent stages.

Some of the main features that should be identified here are listed below:

- Location of the building.
- Building typology: non-residential (research centre, offices, school, hotel, commercial…) or residential.
- Heated and cooled area.
- Distribution of the building: zones, floors, rooms…
- Operation modes (winter, summer, inter-season…), schedules, set-points…
- Description and characteristics of the energy facilities: generation, distribution, monitoring, data acquisition (DAQ)… equipment.
- Control systems.
- Sensors and meters.
- Historical data (energy consumption profiles, external conditions, indoor temperatures…).
- Access to data and data acquisition (metering, monitoring, gathering, warehousing…).
- Inefficiencies detected.
- End-users requirements/expectations.

In addition, at the end of each part, a diagram of the BaaS platform in each building as well as its general description has been included in this section.

2.1.1 CARTIF pilot building

As expressed in D6.1, Appendix C [1], the Cartif Technological Centre is a research foundation located in the technological park of Boecillo, 15 km south of Valladolid, Spain. The building is situated in sector 205 of technological park. The heated area covers 2592.90 m^2, meanwhile the cooled area is 1870.13 m^2, distributed in three floors and 21 zones. For the heating season (winter), the building has installed radiant floor through thermal active slabs as main thermal contributor, although it disposes of water source heat pumps, fan coils and convective radiators as support. On the other hand, cooling season (summer) is covered by water source heat pumps (WSHP) and fan coils.

Figure 1: CARTIF offices building

Nevertheless, some deficiencies were detected and determined in two use cases, as stated in D5.1 [2]. First of all, during winter, cold zones at the very beginning in the morning and overheating during nearby noon are the main inefficiencies. As well, the solar thermal system is underused. For these reasons, the first use case to be solved by the BaaS operation is focused on improving the comfort at the same time that is being optimal-controlled from the energy point of view, being the objective twofold: energy efficiency and comfort. Secondly, during summer, based on end-user comfort constraints [3], the aim is to reduce the electricity consumption because the main system (i.e. heat pumps) operated deficiently.

Having in mind the two scenarios, it is required to assure the accessibility to the information both for gathering data and setting new improved control strategies. In that sense, CARTIF building contains initially several and heterogeneous Building Management Systems [1] to be integrated into the platform as follows:

- Generation side: old LonWorks network which is accessible through labview application to monitor without the capability of remote actuation.
- Distribution side: Symmetre (Honeywell) is available for reading via SQL Server database. However, it does not allow actuation.
- Demand side: LonWorks network with several LON network interfaces. In particular:
    - iLON 227, accessible via FTP/IP, HTTP
    - iLON 239, accessible via SOAP, FTP, HTTP
- Weather station: accessible via FTP to a file repository
- Weather forecast: external service
- Additionally, unique-device meters are available for measuring both CARTIF I and CARTIF II thermal and electricity consumptions.

With all these systems and their lacks, some adaptations were necessary to carry out BaaS control system [4]. In summary, the next systems are now accessible in the CARTIF building:

- Generation side: new LonWorks network with LON network interface, iLON 101, accessible via SOAP, FTP, TCP/IP to communication bi-directionally (monitor and control).

- Distribution side: new ARENA (update from Symmetre) system with a LON network interface added by CARTIF staff:
  - iLON 103, accessible via SOAP, FTP, TCP/IP
  - LNS database translation to be compatible with the new iLON
  - Standard reading and writing available thanks to the iLON
- Demand side: Addition of new network interfaces to balance the load of the Building Automation Network and increase the performance.
  - iLON 105, accessible via SOAP, FTP, TCP/IP

However, not only the devices for the communication require updates, but also new devices installations (adaptation) for measuring additional variables are already installed [4]:

- New Gas meter, metering only CARTIF I gas consumption (CVM-MINI-LON) in order to distinguish the consumption from the boiler of the building I and II.
- New Electric meter, metering only CARTIF I electric consumption (Delta QD (Itron)) instead of the overall measurement from the electrical company.
- 3 new Flowmeters, metering the energy consumption in different points (summer and winter energy systems):
  - F14 measures the flow from the cooling tower to the WSHP in summer and the flow from inertia tank to WSHP secondary circuit during winter.
  - F15 that gathers the flow in the main-folder to air heaters (industrial zone).
  - F17 which collects the flow from the boiler to inertia tank.

Finally, for the deployment of the BaaS systems, taking into account the requirements of CPU and memory, among others, two computers have been designated. The first one (ener20) hosts the Domain Controller (DC) of the Communication Logic Layer (middleware) [5] and the second one (ener54) host the Application Layer Kernel, as well as the specific BAC and TBM analytics for the CARTIF building. Both computers have VPN connection and certificates for assuring secure communication.

Once all the pillars are combined, i.e. adaptation of the pilot, DataWarehouse (DWH), Communication Logic Layer or middleware, start-up of the Application Layer and, finally, the tests are run and completed, the BaaS platform is commissioned. Then, the ECM for the CARTIF building is represented in Figure 2 where the entities are drawn and the interactions marked with arrows. Basically, as it has been already expressed, the ener20 computer connects the multiple data sources of the building. On the other hand, ener54 deploys the Kernel with the configuration files and a local MySQL database for storing local data. Both computers are connected via secure channels with the DACM that is, at the same time, communicated with the main data repository (DWH) and the BIM Server. The DACM also offers a Graphical User Interface for accessing monitoring information and KPIs, but also, configuration properties (i.e. schedulers and users).

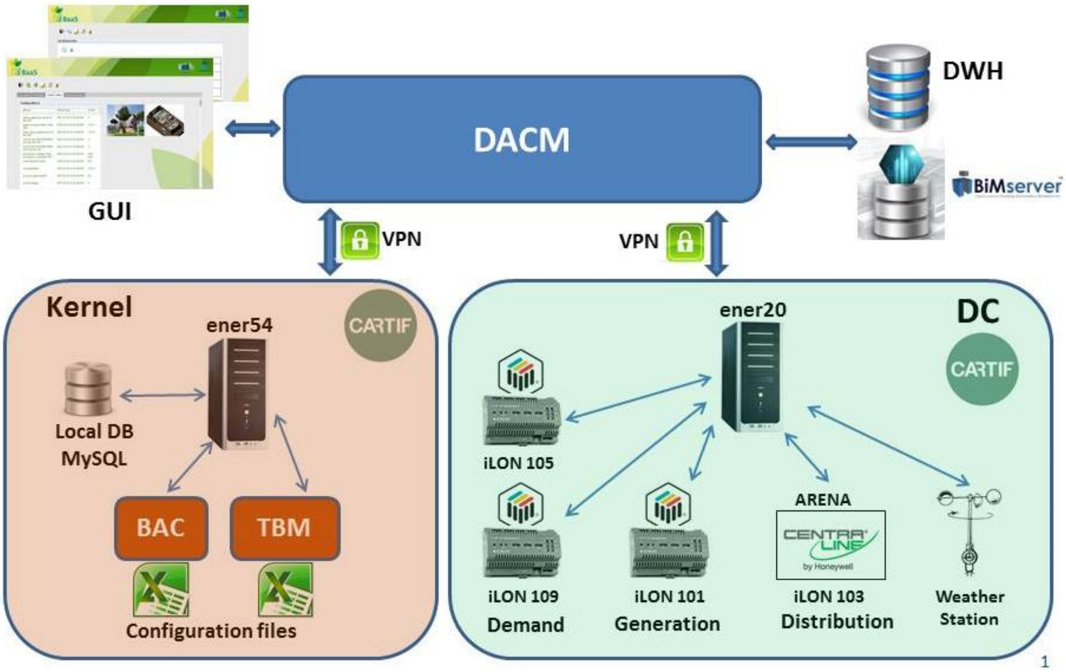

Figure 2: BaaS ECM deployed in the CARTIF pilot building

2.1.2 Sierra Elvira School pilot building

The operating mode of the heating system in Sierra Elvira School demo site worked according to a set schedule depending on the needs of the user, the weather conditions and the experience of the users and the maintenance staff. The use cases proposed in this case was focused on the management of the heating system according to the real demand of the building considering the efficiency of the boiler, weather forecasts and the comfort levels of the end users.

Figure 3: Sierra Elvira School pilot building

The Sierra Elvira School (SES) building was renovated, a few years ago, under an energy service contract in order to improve the energy performance of the heating system. The Building Management System (BMS) installed in the scope of the Energy Services Company (ESCO) interventions was designed in order to manage the generation and distribution of the boiler room, focusing the investment in the optimization of the energy performance of the system.

The energy performance contract applied in this case is based in the energy savings obtained after the implementation of the refurbishment of the boiler room as Energy Conservation Measure (ECM). The implementation of this renovation process caused an improvement in the energy performance of the heating system and through the reduction of the primary energy consumed was been amortized the necessary investment performed by the ESCO.

The first step in the deployment of the BaaS solution in Sierra Elvira School was the implementation of the Bacnet® protocol in the existing BMS in order to establish the communication rules between devices providing an open and standard interface for the communication with the sensor network both reading and writing values.

The intervention related to the necessary remote connection required a public and fixed direction for the internet connectivity. The implementation of a new router with the necessary security requirement through a virtual private network based in 3G solution solved this issue. This mechanism is able to communicate with the BMS of the building inside of the ESCO network allowing only the communication with the services provided by the BaaS consortium.

Sierra Elvira School building was improved with the installation of several sensors and energy meters in the boiler room, indoor temperature sensors in each zone in order to adapt the power generated to the real demand of the system and thermostatic valves on radiators to improve the flow management of the distribution system. A weather station, including: outdoor temperature, humidity, irradiance, wind-speed and direction sensors, was commissioned in order to obtain the relevant data about the external conditions of the location.

The components related to the BaaS platform implemented in Sierra Elvira School are represented in the next figure.

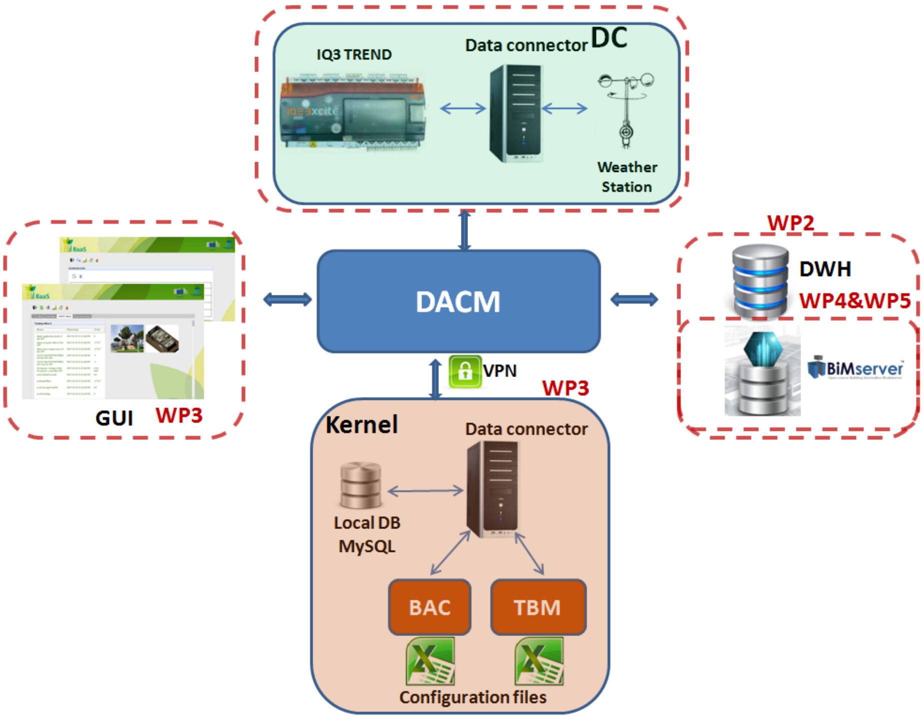

Figure 4: BaaS ECM deployed in the Sierra Elvira school building

2.1.3 Fraunhofer pilot site building

The ZUB building, as it was explained in previous deliverables, was created as a demonstration of how low energy demanding office buildings should be designed. With that purpose, the number of sensors installed into the building able to evaluate behaviour of thermal masses, ventilation system, heating and cooling demands, etc. is pretty elevated.

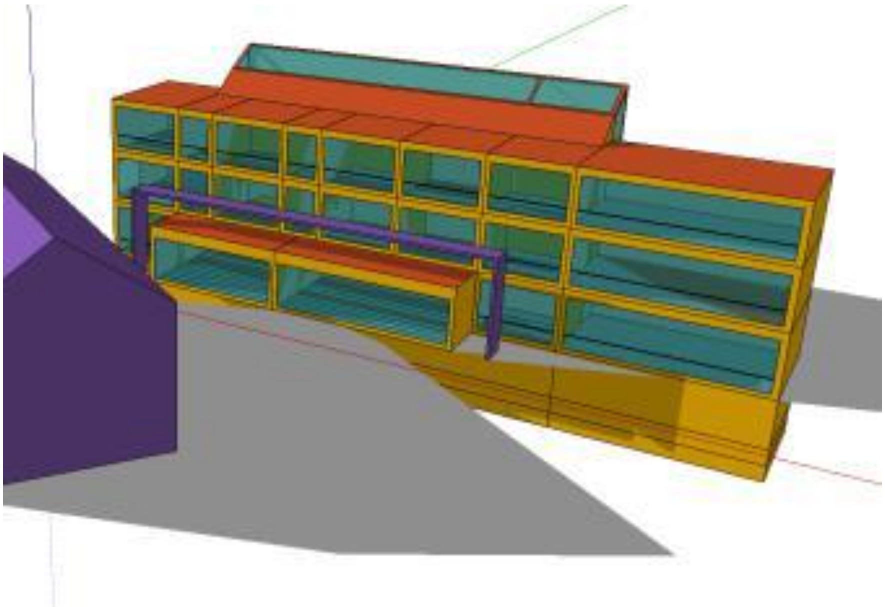

Figure 5: ZUB pilot building

The first preparation work done, was the delimitation of the number of signals that were to be managed by BaaS to validate the pre-defined work cases to be developed in the demonstration phase. From the initial more than 800 sensors and similar number of controlling signals, it was defined a list with 400 measurements and 430 controlling values that could perfectly manage the ZUB pre-defined demonstration cases.

During this initial phase, it was controlled the quality of the measurements corresponding to the chosen sensors and some of them were changed, as it happened with the energy meter installed to control the energy delivered through radiant floors in one of the three over- monitored office rooms. Also the critical temperature sensors to be used in the ZUB cases were controlled and calibrated.

Modifications on the way the building acquire values from the installed weather station were realized. ZUB weather station used to store values in a separate data acquisition system, which was not able to be connected with the use of any available commercial solution due to the “exclusive” protocol used to connect pyrometers, thermometers, humidity and wing probes among them. The unique serial protocol of those sensors was translated and sent to a web server that did the values available to be acquired by the data warehouse.

The components related to the BaaS platform implemented in ZUB building are represented in the next figure.

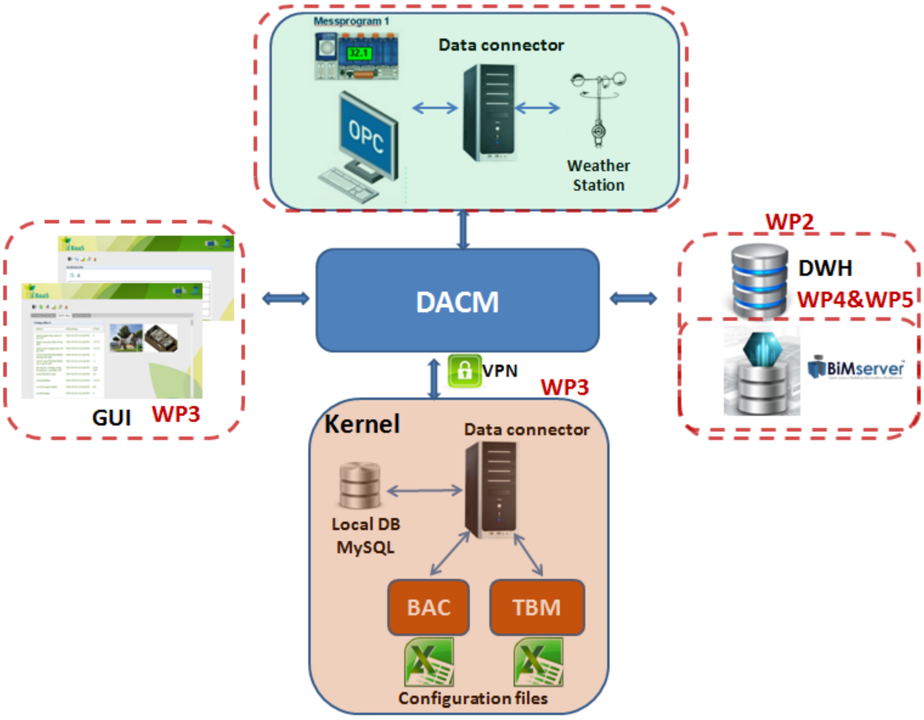

Figure 6: BaaS ECM deployed in ZUB pilot building

2.2 Data collection and integrity checking

This stage deals with the systems and protocols for data gathering and also with the checking that all the equipment and systems are as it was defined in the specification, such as developed in WP2. As first step, the data collection activity is required for allowing the proper operational stage of the control systems. In this way, individual DWH schemas have been deployed for each building with the aim of easing the management of the data, as well as avoiding data collapse due to great amount of data-points. All these schemas are similar and developed under IFC4 standard model to apply in buildings.

Afterwards, the consistency of the operating data collected from the different meters and sensors that have been installed in the three pilots must be verified before completing the reference period established in each case. This data characteristic is a key element for the proper design and validation of the mathematical regression models that are going to be the tool to assess the energy savings related with the implementation of BaaS, as an energy conservation measure (ECM) itself, in the pilot buildings. The better adjust the models to real data, the more accurate are the predictions of energy consumptions and the more contrasted/verified/justified are the energy savings that are estimated to be achieved with BaaS in the reporting period.

The data processing environment applied to BaaS DWH involves source, intermediate and target layers. Providing multiple layers or databases enables their associated applications to run independently of each other, putting in data and extracting data at different times and frequencies, as necessary. Data is moved from source to intermediate to target databases by extract, transform, and load (ETL) steps. When a subset of the data is selected from the source database (i.e. building selected as demo-site) according to the schema for that database, the data is modified (or transformed) to fit the schema of the target DWH. The data transformation was performed in form of conversion the format from *.csv into IFC-based DWH format during the loading process, while in operational phase, the middleware was feeding the DWH. During the time of DWH operated for BaaS purposes, it is accumulated the following:

DWH for BaaS buildings

  

	CARTIF	ZUB	SES
Data Sets	31,385,134	17,574,144	801,073
Last Reading	14-APR-16 13:58:05	14-APR-16 14:00:16	14-APR-16 13:56:09

**Table is updated before the final submission.*

Table 3: BaaS-related data available in DWH

As previously described in BaaS D2.5, the Oracle OLAP tool (Analytic Workspace Manager for Oracle OLAP) implemented for the DWH. The four available data categories are reflecting energy consumption by time dimension. The calendar allows specifying the time dimension from years, through month, to single days. The following sections will represent the status of the DWH in terms of data amount per demonstration site building, as generated by the OLAP.

During the latest stage of the BaaS project it was agreed among partners again to manually populate the data was missing during the time when middleware was inactive (MW implementation period).

2.2.1 CARTIF pilot building

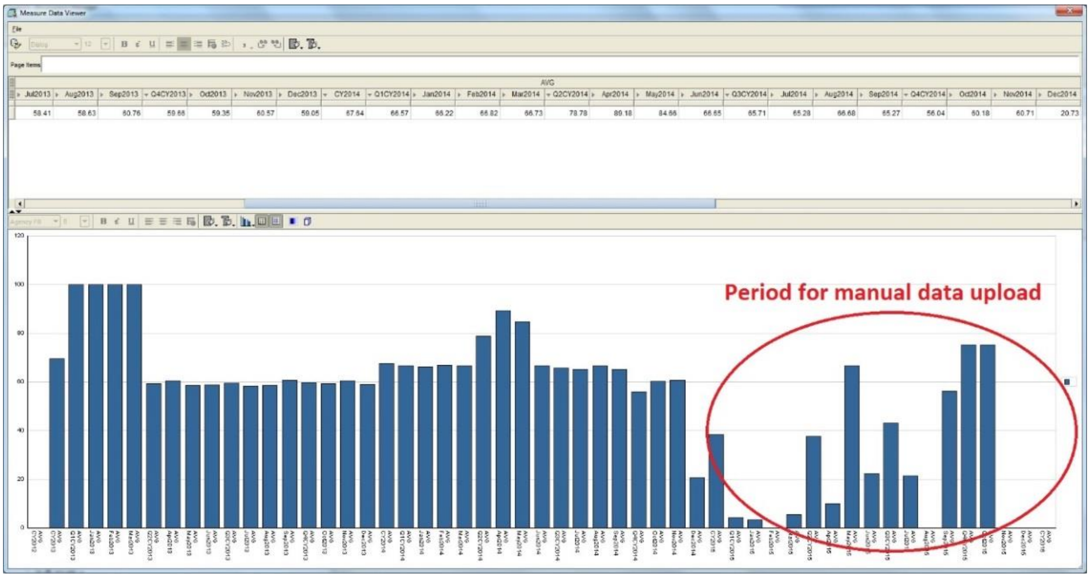

Figure 7: Data quality representation for CARTIF Demo site

During the work of manual data upload it was experienced the duplicated values loaded to DWH, so the data cleansing algorithm was used to normalise the data. Results of this can be seen on the following Figure 8.

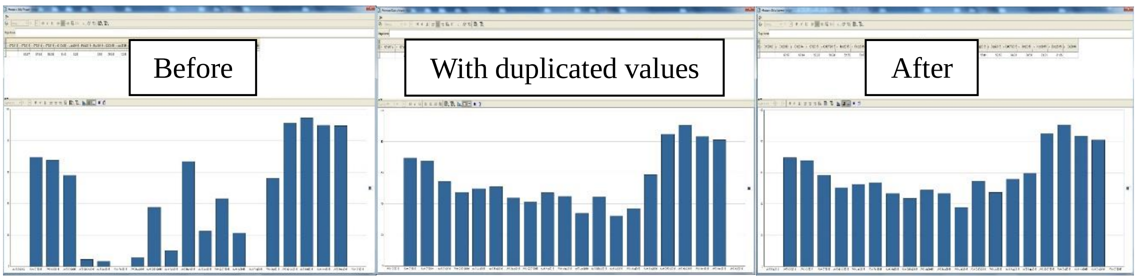

Figure 8: Example of data normalization, CARTIF building

2.2.2 *Sierra Elvira School pilot building*

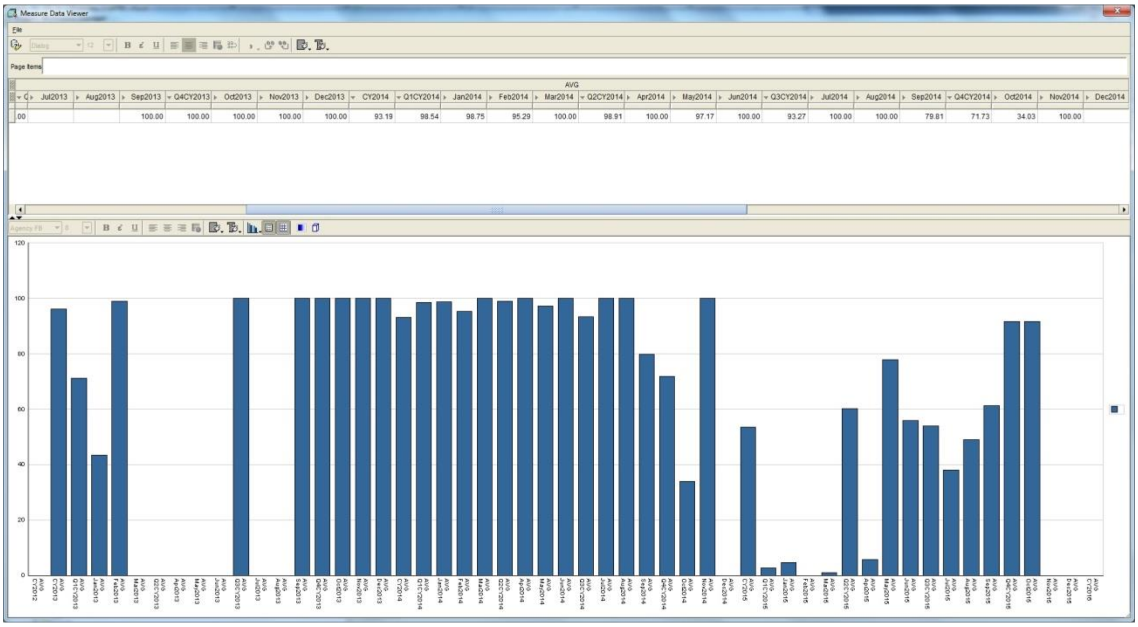

Figure 9: Data quality representation for Sierra Elvira Demo site

2.2.3 *Fraunhofer pilot building*

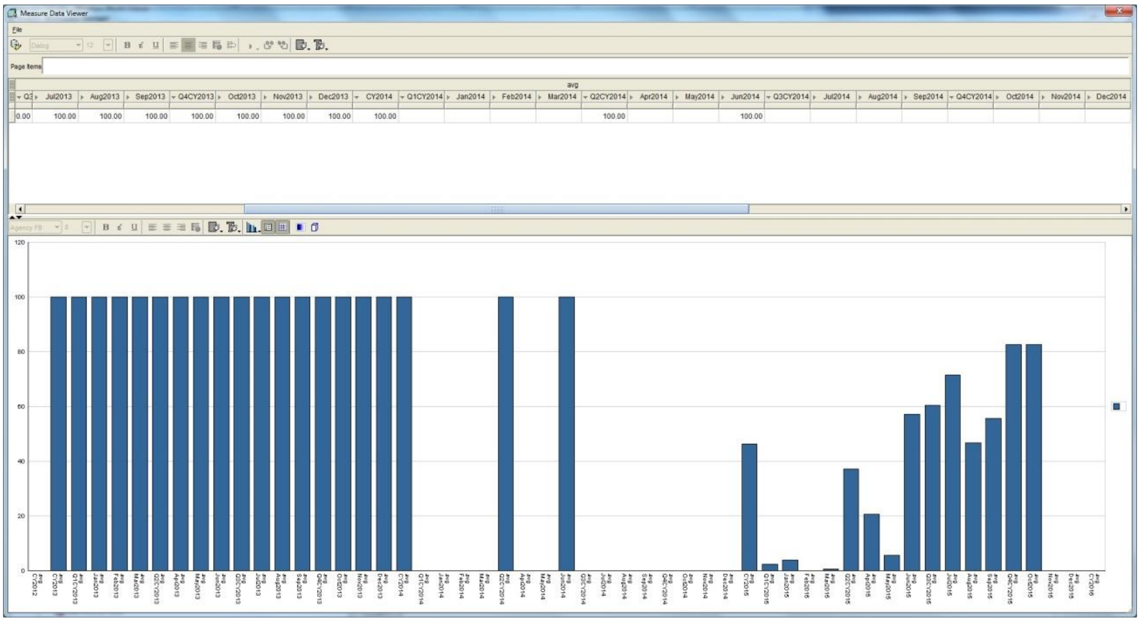

Figure 10: Data quality representation for Fraunhofer Demo site

2.3 Pre-commissioning and operational testing

The main goal of this stage is to verify that the BaaS system is ready to be put into operation, and it includes calibration tasks, equipment tests, experiments with different control strategies, etc.

This phase takes place before the official commissioning, and it starts when it has been checked that all the equipment and systems are as they were defined. This task includes different activities, such as connectivity tests, BMS discovery, ICT discovery, historical data retrieval…

As part of Task 3.4, WP3 conducted extensive platform tests in preparation of Middleware deployment, as documented in D3.8 [5] at the different sites. We reproduce the most important results put refer to D3.8 [5] for more extensive discussion and documentation.

The tests were split into two consecutive phases. The first phase focused on basic platform functionality. The second test phase verifies complex usage scenarios as needed by optimization scenarios, e.g. triggered by the Application Layer kernel. These tests comprise several actions including readings, calculations and actuation of data points according to calculated results.

Next tables include the list of all these operational tests that have been conducted in the three pilot buildings (i.e. CARTIF, SES and ZUB) and the obtained results (i.e. passed, pending, failed…).

2.3.1 Test phase 1

Results 31.03.2015		Results 24.04.2015		Results 21.05.2015	
Tests total:	67	Tests total:	72	Tests total:	72
Tests passed:	37	Tests passed:	57	Tests passed:	72
Tests pending:	10	Tests pending:	10	Tests pending:	0
Tests failed:	20	Tests failed:	8	Tests failed:	0

Table 4: Results of test phase 1

Test / Building	CARTIF	SES	ZUB
Connectivity test	✔, ✔, ✔	✔, ✔, ✔	✔, ✔, ✔
BMS discovery	✔, ✔, ✔	✔, ✔, ✔	✔, ✔, ✔
ICT discovery	✔, ✔, ✔	–	✔, ✔, ✔
External discovery	✘, ✔, ✔	✘, ✔, ✔	✘, ✔, ✔
Live Data retrieval (BMS)	✔, ✔, ✔	✔, ✔, ✔	✘, ✔, ✔
Live Data retrieval (ICT)	✔, ✔, ✔	–	✘, ✔, ✔
Historical Data retrieval	✘, ✔, ✔	✘, ✔, ✔	✘, ✔, ✔
BMS Actuation	✔, ✔, ✔	✘, ✘, ✔	✘, ✔, ✔
KPI discovery	✔, ✔, ✔	✔, ✔, ✔	✔, ✔, ✔
KPI data request	✔, ✔, ✔	✔, ✔, ✔	✔, ✔, ✔
Store KPI data	✔, ✔, ✔	✔, ✔, ✔	✔, ✔, ✔
OPT data request	✔, ✔, ✔	✔, ✔, ✔	✔, ✔, ✔
Store OPT data	✔, ✔, ✔	✔, ✔, ✔	✔, ✔, ✔
Write Data to DWH	–, ✔, ✔	–, ✔, ✔	–, ✔, ✔
Read Ext Data	–, ✘, ✔	–, ✘, ✔	–, ✘, ✔

Table 5: Phase 1 - Per-site test results

2.3.2 Test phase 2

ID	Test / Building	Triggered by	CARTIF	SES	ZUB
G1	BMS discovery	Emulator, APO-kernel	✔	✔	✔, ✔
G2	Retrieve Live Data	Emulator, APO-kernel	✔	✔	✔, ✔
G3	Retrieve Historical Data	Emulator, APO-kernel	✔	✔	✔, ✔
G4	Live-feed into the DWH	Emulator / GUI	✔	✔	✔
G5	Schedulers auto-start, demonstrate with data retrieval		✔	✔	✔
G6	Schedulers creation/deletion	GUI	✔	✔	✔
G7	Actuation of Building Devices	Emulator, APO-kernel	✔	✔	✔, ✔
G8	Configuration of new KPIs using the Application Layer	Emulator, APO-kernel	✔	✔	✔, ✔

Table 6: General functionality test results for 2nd phase tests

ID	Test	Status	Tested / Closed
CAR1	Discovery of complex data points	✔	29.06.15
CAR2	Reading of complex data points	✔	29.06.15
CAR3	Actuation of complex data points	✔	29.06.15

Table 7: CARTIF complex data points 2nd phase test results

ID	Test / issue	Status	When tested
ZUB-APO-1	Complex actuation using the Application Layer. Test scenario of a blind controller module	✔	24.06.15
ZUB-APO-2	Test scenario of a FDD module using schedule abstraction through the APO connector.	✔	24.06.15
ZUB-APO-3	Test scenario of a virtual sensor module using the signal abstraction through the APO connector.	✔	24.06.15

Table 8: ZUB 2nd phase test results

ID	Test / issue	Status	When tested
CARTIF-APO-1	Actuation using the Application Layer. Test scenario of WSHP unit.	✔	20.08.2015
CARTIF-APO-2	Test scenario of a FDD module using schedule abstraction through the APO connector.	✔	20.08.2015
CARTIF-APO-3	Test scenario of a virtual sensor module using the signal abstraction trough the APO connector.	✔	20.08.2015

Table 9: CARTIF 2nd phase test results

ID	Test / issue	Status	When tested
SES-APO-1	Reading of use case relevant data points	✔	23.09.2015

Table 10: SES 2nd phase test results

2.4 Testing of control strategies based on simulation models

This section describes the testing of control strategies on the simulation models developed within the project, concretely under the scope of WP4. The objective of the task should be checking the effective application of BaaS as ECM reaching the objectives of the project (i.e. energy savings, comfort increase…) with the expected operational performance. In that sense, most proprietary BMS solutions in existing buildings provided with a set of rules compiled by experts in order to achieve the comfort requirements of the users improving the energy performance of the building.

Towards testing considered control strategies based on models, a model-based approach could be adopted. In this approach, a detailed and validated thermal simulation model of the building is used, in order to test the efficiency of control strategies generated by the BaaS system.

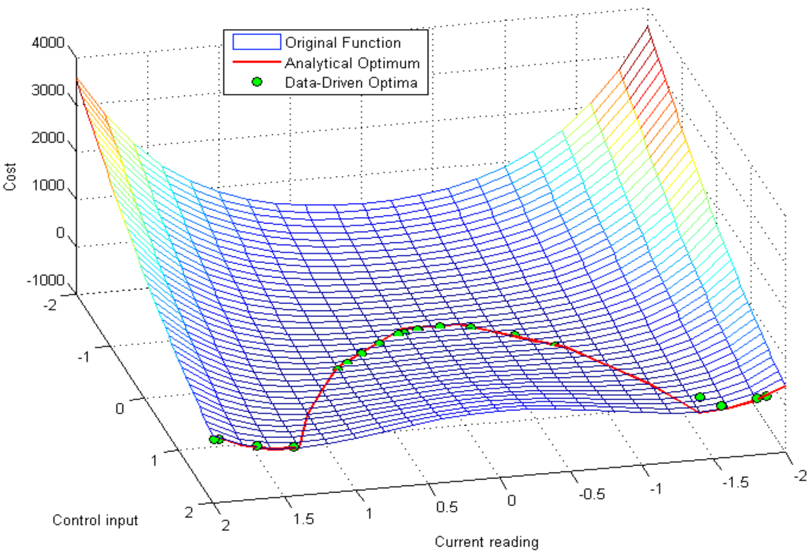

Figure 11: Data driven model

The model-based control design process was applied in order to improve the energy performance of the buildings while ensuring comfortable occupancy levels. The simulation model of the buildings, as well as forecasts on the weather conditions and the occupant schedules, were used to design control actions adapted to the forecasted thermal response of the building.

The thermal model of the building plays a central role and is required to interact with the baseline control algorithm. This is achieved through the co-simulation setup, which incorporates into the simulation historical weather and in-building sensor data

The deployment and validation of the building thermal simulation model can be used to evaluate user comfort levels using historical sensor measurements from the building and to predict future ones, using forecasts and the simulation model.

The dynamic interaction between the model and the control algorithm is achieved through co-simulation, which enables the use of different software for run-time coupling.

2.5 Evaluation of control algorithms performance

This process involves the necessary tests of all the individual components before their integration as part of the component of the BaaS solutions. The purpose of these evaluation methods is to compare performance of the proposed control algorithms in each pilot building according to the specifications of the BaaS system. These control strategies are developed under WP5 of the project with the aim of optimally controlling the energy sources.

During the deployment of this task various Technical Building Management (TBM) functionalities were evaluated in order to detect anomaly situations in the control strategies implemented in the BMS of each building. The main aim of the TBM functionalities is to assure comfort in the building reducing costs related to their exploitation. This approach provides add value consists in significant reduction of work load needed for the analyses of the operating parameters of the pilot buildings.

The rule-based functionalities performed in this project consist in comparison of measured values and in aggregation of those comparisons over time. All of them are implemented or intended to be implemented as Matlab functions having on input time considered time-series and some configuration parameters. These functionalities require qualitative context information, namely selection of appropriate data-points as inputs to the functions.

The knowledge of analyst who reports anomalies manually is often rather implicit. The experts might omit some important aspects and some critical anomalies might be ignored. The rule-based diagnostics has many advantages to define common symptoms for detection of different faults. The major benefit of the rule-based approach is the possibility to automate expert knowledge. The configuration requires rich context information, provided from BIM. The most serious drawback of the rule-based diagnostics is the need of rich context information which might be costly to be provided and for this reason the BIM model support functionalities to facilitate the model-based diagnostics.

The rule-based diagnostics is limited to qualitative assessment. The quantitative assessment of the system was addressed by context-free and model-based diagnostics. The method identifies anomalies in the trend of a pair of measured sensor signals by calculating the cross-correlation function between them and comparing the cross-correlation function parameters with the values calculated using the historical data base. The cross-correlation analyzes two sources of data at time and measures the linear association between them relaxing the assumption on the context information and works with the observed data.

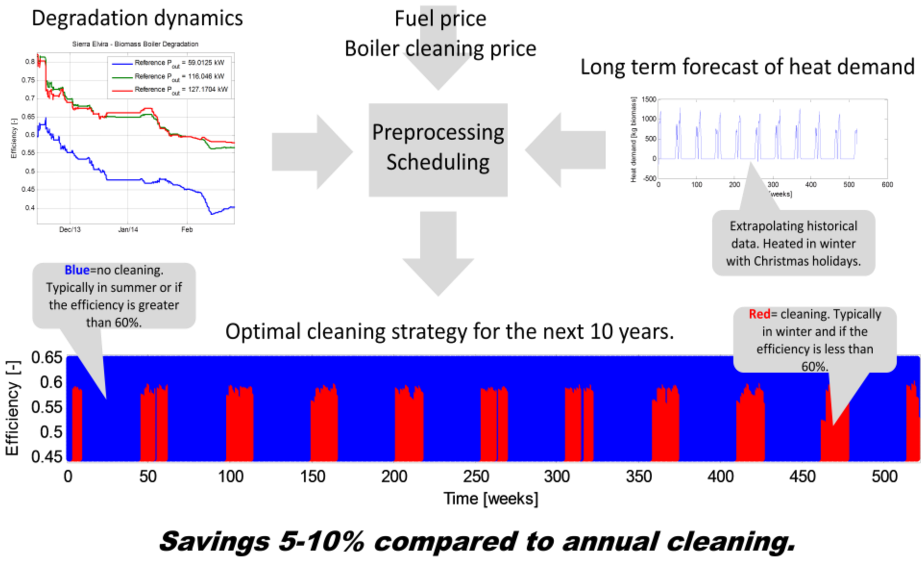

Figure 12: Model-based on boiler degradation

The method proposed here is based on the calculation of a cross-correlation function between the measured quantities of interest or quantities that are function of the measured values.

The cross-correlation is a measure of the correlation of two sets of data, and in order that a change in its parameters is expressive of an anomalous event, the data have to be collected in comparable conditions.

The ideal case for evaluation of control algorithms is to ensure the same conditions during the reference and the reporting period because the control systems never operate under exactly the same conditions. This environment could have a significant impact on achieved outputs and consumed resources, which makes the comparison of two alternative solutions difficult.

The context-free diagnostics is applicable to any system and subsystems and does not require any configuration effort. It can run in parallel with rule-based diagnostics.

The main innovative functionality of the BaaS solution is the development of an advance Building Automation Control (BAC) functionalities using forecasts and model-based optimization techniques.

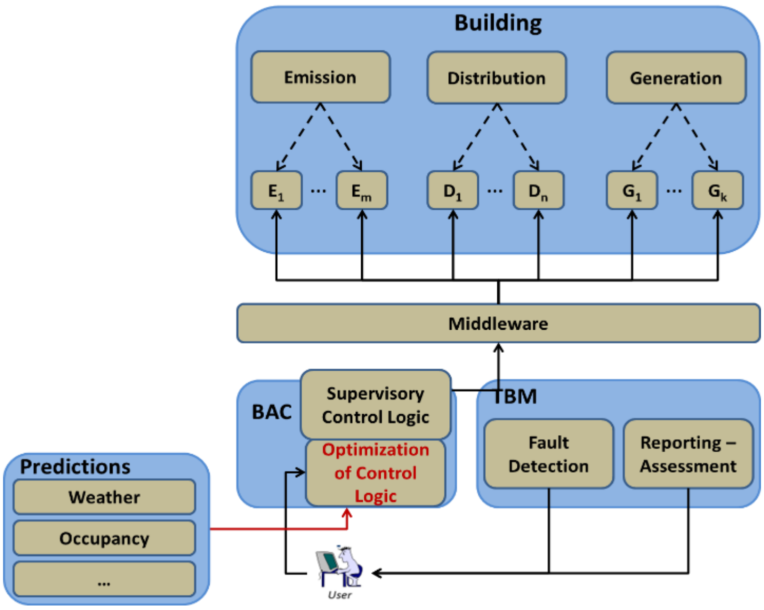

Figure 13: BAC advance functionalities implemented

The algorithm of prediction and optimization kernel is a set of core software components responsible for support of the execution of installed services and supporting their data access requirements. All services requiring access to current and historical data as part of their execution process. The pre-processing functionality is achieved on a set of software abstractions which provide methods for accessing signals and data points through a standard interface.

2.6 Commissioning and final integration of BaaS as ECM

The commissioning process of the BaaS system has been performed through a collaborative work between all the partners involved, including the different components as part of the complete solution. Different activities have been executed for the implementation of BaaS solution ensuring the proper operation of the installation. Some inspections, tests and checking should be carried out during the installation and start-up of the BaaS system in the pilot buildings in order to keep the fulfilment of the targets without interfering with the normal operation of the building.

This procedure has been carried out assuring the accomplishment of the standards and requirements provided by the design team and the building owner, following the building owner experience, end user needs, specific sustainability and energy efficiency goals and ESCO requirements for the proper implementation of the BaaS system in each pilot building.

It is important to remark that, within this stage, it is necessary to include the end-user training about the performance and operation of the BaaS system, as it constitutes a key factor in order to achieve the expected results (i.e. energy savings, comfort improvements, increased efficiency…).

Usually the system integrators focus their effort on the commission of the installation without paying attention to energy efficiency of the systems. Therefore building owners should spent time to understand the control strategies implemented in the BMS in order to detect the potential improvements of the system.

Actually the non-residential building with a long life period usually changes the original functionality with modification in their environmental spaces, occupancy schedules or behaviour patterns. This renovation frequently contributes to increase the energy consumption and reduce the comfort levels of the users if not followed by a reconfiguration of the strategies implemented according to the new functionalities.

To summarise, the integration of the Application Layer containing the kernel, BAC analytics and TBM functionalities with the middleware platform is part of the deployment of the complete BaaS system in the different demonstration sites.

Figure 14 represents the ECM of the BaaS system where the multiple DCs with the specific features highlighted below. In the middle, as core of the communication, the DACM connects the DCs with the DWH and the application layer. Finally, this application layer is in charge of the high-level services for optimal control and fault detection services.

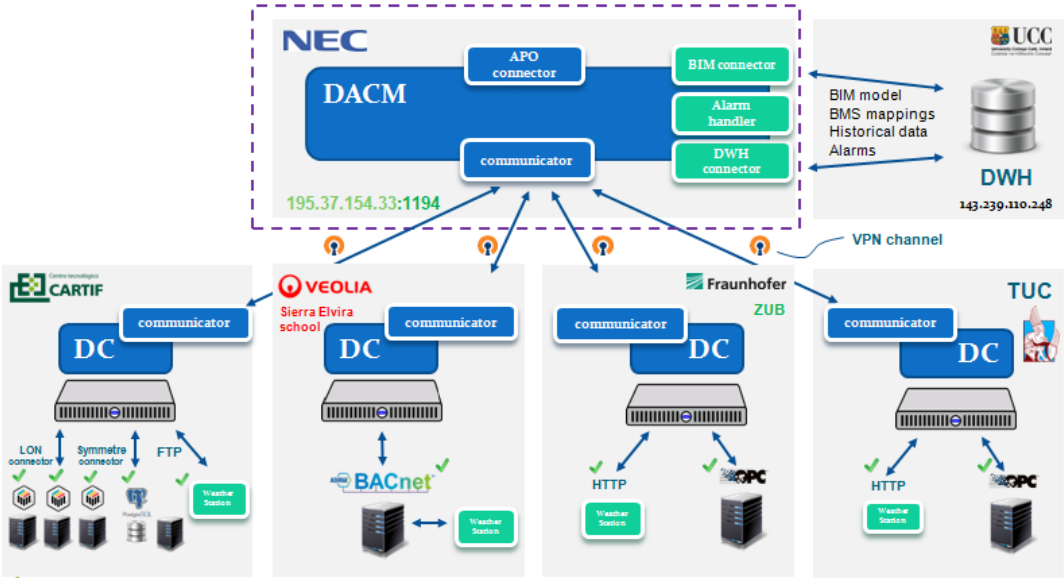

Figure 14: BaaS solution implementation scheme

2.6.1 *BaaS as ECM in CARTIF building*

As it has been explained, BaaS is the proper ECM for the project because it is the only solution that treats the energy efficiency. In this way, despite having a common framework, each building has its own characteristics and, hence, its own peculiarities. In this first case, more detailed information about the deployment of the ECM in CARTIF building is described.

Although, apparently the only implementation that handles energy is the application layer, the combination of all the pieces is necessary to make the ECM up. In this way, the ECM is divided into several with specific functions that allow carrying out the optimal control with the aim of determining the ECM. In particular, commonly for all the pilots, the DC, DACM, application layer (including kernel), BIM Server and DWH are the five pieces.

In the CARTIF building, these pieces are distributed in multiple computers. From lower level, the DC is deployed into a Linux-based computer running 24/7 with the software components that connect the data sources, i.e. iLON Smart Servers, Weather Station and PostgreSQL with the information already described in section 2.1.1. The functionalities of this DC are the periodic data gathering from the sources in order to keep record of the building behaviour. Moreover, it allows the acquisition of instantaneous data for the application of control strategies and, finally, actuation with the objective of overriding the signals so as to improve the performance of the facilities.

Secondly, the DWH is deployed in the offices of UCC and it is an Oracle-based database whose schema is IFC4-compliant. It also includes data quality methodologies to detect gaps, data completeness and data range checkers, such as section 2.2.1. This DWH is populated with the information coming from the DC through periodic schedulers.

The communication between both entities is made by the DACM which centralizes all the connectivity into pieces. The deployment of the server is the NEC offices under Linux-based server 24/7. The DACM contains the pieces for connecting DWH, BIM Server, DCs and application layer. It also embeds the GUI in the deployment which gives some advantages such as less network requirements for the communication. Additionally, the DACM contains alarm manager and handler. All the DACM-deployed modules are common for all the pilots, although due to the communication issues, several test for commissioning were completed with the aim of assuring its operation with each specific data sample (see section 2.3).

Next, the application layer is the container for the control strategies. In all the cases, a kernel is deployed which manages the signals from lower layer, at the same time than the modules for control strategies. In the CARTIF building, the kernel basically manages the communication with the DACM, the knowledge-based control algorithms and the FDD services. It is deployed in another Linux-based machine with certain requirements in terms of memory and processor. In contrast with the section 2.4, where the control strategies based on simulation are described, CARTIF ECM consist in a knowledge-based control which makes use of the simulation for self-learning about the building dynamics due to low level of accuracy of the simulation results.

Bringing all the pieces together, the BaaS ECM applied in the CARTIF building consists in the DC that connects the physical level of the building, DACM acting as server for the interoperability, DWH which stores data and applied data quality methodologies, BIM Server for the static information of the building and the application layer with the control strategies and FDD services. In short, these services are basically deployed to detect malfunctioning of the heat pumps (operating out of the schedule or in wrong mode), anomalous temperatures in the rooms and determining the accuracy and quality of the "estimated" values from the model-based controllers (more information described in WP5 deliverables). All these pieces are deployed in a distributed way, being hosted each one in different machines which are interconnected via distributed OSGi services through secure channels, i.e. Virtual Private Networks (VPN). Then, the interrelation among all the pieces, working together to determine the optimal parameters for certain comfort conditions in order to save energy is the clear example of the ECM, with the peculiarities of CARTIF building.

2.6.2 BaaS as ECM in ZUB building

In the case of ZUB building, the details of the ECM are pretty much similar to the CARTIF offices. That is to say, the ECM is the combination of the different pieces deployed in distributed machines connected to each other through secure channels, i.e. VPN. However, one of the differences with CARTIF building is the DC itself. While CARTIF DC components communicate multiple and heterogeneous data sources (i.e. 3 iLON Smart Server via Web Services, one Weather Station via FTP and Symmetre system via PostgreSQL database), DC in ZUB offices only connects two systems, the network interface based on OPC protocol and the Weather Station under HTTP requests/responses. Therefore, the DC deployment is simpler, gathering a reduced number of data samples in contrast to CARTIF case.

On the other hand, there is another difference in the ECM deployment because the application layer contains a co-simulation module, taking into consideration that the ZUB control is full model-based and simulations are running "on-the-fly". Furthermore, the FDD services are slightly different too, although they are mainly focused on room temperatures, malfunctioning and virtual sensors. More information is explained in the WP5 deliverables.

In spite of these differences, the rest of elements remain similar, being part of the global ECM for the ZUB building. Although, it has not been explicitly stated, the DC for the ZUB building is deployed in ZUB offices, as well as the application layer, whereas DWH is in UCC facilities and DACM in NEC. Therefore, the schema is equal to the case of CARTIF with the modification of the location. Also, the case of the BIM Server because, due to exploitation of resources, one instance of it is in TUC facilities with the TUC and ZUB models, meanwhile the Sierra Elvira y CARTIF BIM models are deployed in the CARTIF server.

2.6.3 BaaS as ECM in Sierra Elvira school

Last but not least, Sierra Elvira school is the least complex of the three pilots, although, again, the deployment schema is the same, i.e. distributed entities across different locations in order to host functionalities. Thus, the DC in this case is placed in the Sierra Elvira school, whose connection is the simplest one, requiring only the communication with a single device under the BACnet protocol connected in the same network than the machine. This device contains data measurements from the weather station too, but the total amount of data points is much reduced compared with the two previous cases.

Moreover, the application layer differs from the previous cases. While the other pilots deploy model-based (or quasi-model-based) control strategies, the ECM in Sierra Elvira school cannot hold a model-based strategy owing to the lack of accuracy of the simulation results. That is why this ECM is focused on control algorithms based on data-driven and context-free models which use mainly data and business intelligence to run processes with the aim of determining the optimal parameters so as to manage the energy sources efficiently. Additionally, the FDD module aims a different objective, which is mainly centered into the maintenance of the facilities. In particular, a service that evaluates the boiler degradation complements the control algorithms.

Taking these considerations into account, the deployment scheme of the ECM follows the same approach, where these application services are integrated in the same kernel than the other buildings. The communication is also secured by VPNs. In this way, the combination of these pieces results in the ECM for the Sierra Elvira school. In this specific case, it is remarkable that, as the control is not model-based, although a BIM model is deployed in the BIM Server, this is not necessary to complete the ECM. Then, this pilot reduces the number of pieces that defines the ECM.

3. Application potential of BaaS in ESCO business model

Once described the main characteristics of BaaS, its validation and implementation and the impact of BaaS solutions on the energy performance of three different pilot buildings (i.e. CARTIF, ZUB and SES), the next step is to evaluate the real potential of BaaS in ESCO business model when applying this solution itself in the scope of energy efficiency retrofitting projects.

This innovative solution could complement the ESCO methodologies and enhance the results obtained by the ESCO alone, as it is considered as an effective ECM in the scope of the improvements in BMS of the non-residential buildings in operational phase. BaaS has been developed to improve the energy performance and operation of the systems in order to ensure parsimonious use of energy while attaining end-user thermal comfort objectives.

To this end, two real projects have been evaluated at the end of this section.

3.1 General framework about ESCO business model

Before describing the integration of BaaS in this kind of business model, it is necessary to provide a general framework to introduce the ESCO business model and financing schemes related to this sort of energy retrofitting projects in non-residential buildings.

The assessment process of an ESCO aimed to find the best solution is divided into different stages, such as the description of the original state of the installations, the estimation of the energy performance before and after the interventions, cost of the solutions and energy savings expected and the technical technologies to implement in the renovation of the energy systems of a building.

The main inconvenient of this type of projects is the estimation of the energy savings that will be achieved after the implementation of the ECM. Generally, there is no information on the energetic demands of the buildings that can support the decision-making process. Therefore, the technical and economic calculations are usually based on modelling and simulation tools that try to reflect the real situation of the building in the most realistic and accurate way.

The typical business model of an ESCO is mainly related to the optimizing of the energy services. The main objective of this model is to find the most cost-effective solution in order to improve the energy performance of the systems, obtaining economic saving that will support the financial aspect for the necessary investment.

The main scope of ESCO projects is on non-residential buildings and consists in obtaining enhancement in the energy efficiency of the different facilities by implementing technical and innovative solutions that allow obtaining benefits through part or the totality of the economic savings achieved. In the scope of this business model ESCO performs a double function: technical and financial assuming the economic risk.

The first step to understand the basis of the ESCO business model is to identify who are the main stakeholders involved in this type of contracts. There are three principal actors: building owner, ESCO and financing entity.

- ***Building owner***
  The building owner is the customer of this kind of projects and should be the key partner to implement an ECM through the Energy Performance Contract (EPC). The building owner has the main interest of increasing the value of the building while reducing the cost associated for the normal operation with the minimum investment possible.
- ***Energy Services Company (ESCO)***
  ESCO provides energy services (i.e. heating, cooling, domestic hot water, etc.) to end-users, including the implementation of energy-efficient equipment, the supply of energy, the building refurbishment or complementary ECMs and the maintenance, operation and guarantee of the all the equipment. ESCOs are the best positioned to lead the energy-efficiency services market because they usually have a large experience and

have gained an extensive know-how in the development, operation, maintenance and optimization of the installations in the buildings.

Some companies are also providing their customer with advanced control systems, smart metering solutions and demand management services as a source of differentiation with the rest of energy market competitors.

The most important objective of these activities is to obtain energy and economic savings while improving the quality of life and comfort level of the end users and accomplishing technical requirements, environmental certifications and aesthetic changes trying to avoid possible disturbances produced in the refurbishment project.

- ***Financing entity***

  The financial entity is a partner interested in maximizing the returns of the initial investment with a determined risk within a determined return period, usually between 5 and 15 years. The funding entity wants to see stable and predictable cash-flows and an assumable risk associated. The lack of experience in the field of energy efficiency projects is a clear barrier in the penetration of this key partner in the energy services business models.

3.2 Energy Performance Contracting (EPC)

Once described the key stakeholders involved in the ESCO business model, the next step is to describe the one that better adapts to these kinds of energy efficiency projects. This is the case of Energy Performance Contracting (EPC).

Energy Performance Contracting (EPC) is a form of 'creative financing' for capital improvement which allows funding energy upgrades from cost reductions. Under an EPC arrangement an external organisation (i.e. the ESCO) implements an energy efficiency project, or a renewable energy project, and uses the stream of income from the cost savings, or the renewable energy produced, to repay the costs of the project, including the costs of the investment. Essentially the ESCO will not receive its payment unless the project delivers energy savings as expected. For more details see reference [8].

The approach is based on the transfer of technical risks from the client to the ESCO based on performance guarantees given by the ESCO. In EPC ESCO remuneration is based on demonstrated performance; a measure of performance is the level of energy savings or energy service. EPC is a means to deliver infrastructure improvements to facilities that lack energy engineering skills, manpower or management time, capital funding, understanding of risk, or technology information. Cash-poor, yet creditworthy customers are therefore good potential clients for EPC. For more details see reference [8].

Basically, an EPC is based on the three main pillars:

- ***Energy***. The ESCO is in charge of the energy supply contracts, transforming and providing energy to the customer.
- ***Maintenance***. All the preventive and corrective maintenance activities at the facility will be conducted by the ESCO. The installations should have a remote management system and assistance service of 24 hours, 365 days a year.
- ***Investments***. The initial investment is done by ESCO from own funds and it will be annually recovered by a fixed fee throughout the entire contract.

In order to facilitate the understanding of the typical ESCO business model related to non-residential buildings, it has been deployed a general example of a real case study. The original situation consists on a centralized generation system fed by fossil fuels (gas or petrol), where the main contribution to the operation costs in the facility is the fuel supply cost, being the remaining part due to maintenance activities.

The energy-efficient solution proposed in this case is to change the generation system for an efficient biomass-fuelled boiler to improve the performance of the system. In the future situation, after the deployment of the renovation project, there would be also two different factors that constitute the cost: the fuel cost of the primary energy (biomass) and the maintenance & guarantee costs.

Due to the fact that the cost of the biomass fuel (also the gas, but much less than in the previous situation) will be much lower than the original one in petrol and gas, important savings will be obtained in terms of energy and cost. In addition, as the system efficiency is higher, energy savings will be obtained as well.

These expected savings will be used not only to amortize the investment required to implement the ECM in the facility, but also to give economic savings to the final users of the heating system. These savings make the proposed interventions and improvements, as well as the project itself, more attractive and thus replicable to other potential customers.

Next graph illustrates in a very visual way the previous example, showing the comparison between the previous and the future situations in terms of costs share.

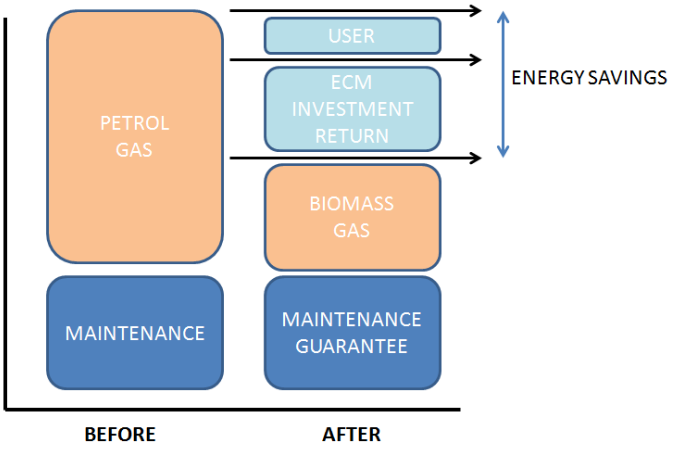

Figure 15: Comparison of the costs distribution

There are typically two methods of structuring an EPC under the scope of ESCO business model: guaranteed savings or shared savings.

- ***Guaranteed savings contract***

  Under this model, the ESCO provides to the customer a guarantee of the targets of energy saving that will be obtained through the implementation of the Energy Conservation Measures proposed in the project.

  The client provides the investment and will pay for the contractor services and the performance guarantee after the M&V protocol. In this model, the ESCO guarantees the performance parameters measured according to the M&V process (i.e. IPMVP) previously defined.

  Therefore, the ESCO assumes economic and technical risk on the project and enables the customer to raise finance for the project directly with the potential economic and energy savings expected. The estimated energy savings should be guaranteed by the ESCO and well-sized so as to be sufficient to meet the customer's financing costs in servicing its debt.

  Next figure shows a simple scheme of this kind of contract.

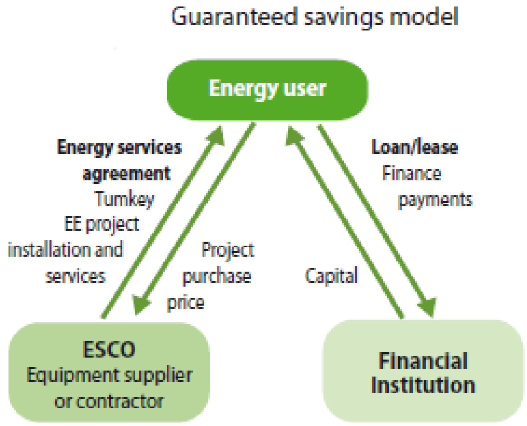

Figure 16: Scheme of a guaranteed savings contract (Source: [9])

- ***Shared saving contract***

  Under this type of EPC, the ESCO provides the whole financing of the costs of the renovation project, rather than its customer, assuming the total financial risk. The ESCO gets the return of the investment and the benefits from the energy savings obtained by the ECM proposed to be implemented. The EPC specifies in which share are the savings divided between the customer and the ESCO and during which period of time following the project implementation. The share of costs savings allocated to the ESCO tends to be higher than the rest for the customer compared with a guaranteed savings contract in order to amortizing the ESCO financial requirements. Next figure shows a scheme of this kind of financing model.

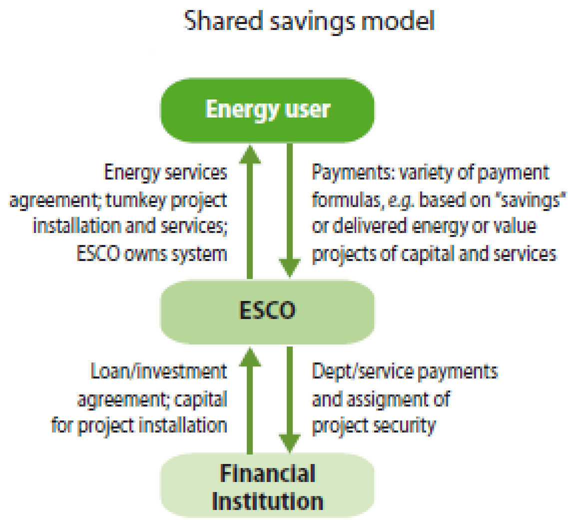

Figure 17: Scheme of a shared savings contract (Source: [9])

3.3 Interrelation between ESCO and ICT solutions

ESCOs business models are wide open to innovation on their strategic and formulations. However, there is a significant exigency of transparency in the terms of the contract. For that, energy evaluation procedures and verification of the estimated energy savings will be the main tools to present liability of the ESCOs´ market.

Technological innovations present new opportunities in the field of Information and Communication Technologies (ICT) for the energy management. Researching projects are working with emerging technologies developing new products and technical solutions with additional value-added services such a wireless sensors, monitoring platforms, graphical user interfaces, data solutions, optimizing algorithms, etc.

The implementation of ICT solutions is an innovative strategy in the business model of the ESCOs. There are a lot of opportunities in ICT business related to energy efficiency and energy management in the scope of non-residential buildings. The introduction of this new solution in the refurbishment energy market should be in charge of the ESCOs who have a good opportunity to learn about the potential improvements of this solution applied to the typical business model.

As it was mentioned before, some companies are already providing their customer with advanced control systems, smart metering solutions and demand management services as a source of differentiation with the rest of energy market competitors.

3.4 BaaS potential as an innovative business model in the ESCOs market

Once described the main concepts of the ESCO business model in the scope of non-residential buildings by the implementation of ECMs and ICT solutions, the next step is to the application potential of BaaS in this kind of projects as a vector between the ECMs implemented and the ICT solutions installed in the building.

Building as a Service (BaaS) provides an added value for ESCO business model in new energy retrofitting projects, because it constitutes an energy savings measure or ECM that does not mean an extra cost in terms of energy facilities and equipment. Its scope of actuation is in the scope of non-residential buildings with existing installations that have already implemented or are going to implement any kind of ECM. Therefore, BaaS solution enables the optimization of the building improving the initial/original conditions in terms of energy efficiency, comfort level, operability and usability, etc.

This outcome will be a key aspect in the scenario of new contracts and tender processes, due to the fact that BaaS endow the ESCO with a differential factor compared to similar utilities. Starting from the same original situation, BaaS solution could result very beneficial in the relation energy savings & financial investment in comparison with other possible alternatives offered other companies. While other competitors would need to undertake comprehensive interventions in order to obtain high energy savings, with the consequences that this entails in terms of costs, duration, an ESCO that has BaaS solutions integrated in its model could obtain better results with minor interventions in the facilities. This will lead to new innovative business models based on EPC with low investment.

Moreover, BaaS can enable a significant reduction on the exploitation costs in ESCO projects already running, by optimizing the operation & control strategies and making a better use of the resources that are already there (i.e. modelling and simulating with real data, predicting future inefficiencies, etc.).

The know-how gained within the experience through BaaS project demonstrates that future business models associated to energy efficient solutions in non-residential buildings must engage the end user as a key partner in the process because this specific ESCO business model is close related to the energy behaviour and the comfort conditions of the occupants of the building. Therefore, the innovation in this field should also focus on the future perspective of the business strategy process based on the customer requirements and business environment. In that sense, within the ESCO business model, Figure 18 represents the evolution from the implementation of the usual ECMs to the integration of BaaS in buildings, passing through simpler ICT solutions. As it is remarked in the picture, the energy savings obtained in each step of the process is being incremented, therefore, the benefit (i.e. it could not only mean economic aspects) extracted by the ESCO is even increased.

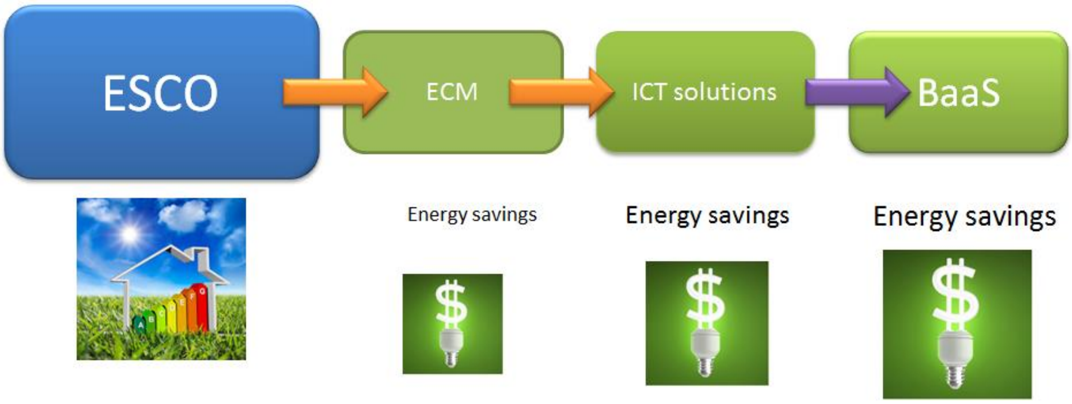

Figure 18: From ESCO business to ICT integration

The ESCOs need the support of the people who occupy the buildings and technical staff because they have a big knowledge about the performance of the building. One of the most important premises for the introduction of this new concept is to encourage people to invest in this innovative solution that allow understanding about the behaviour of the systems, obtain energy savings for the payment of the financial issues and generate economic benefits directly related to their comfort behaviour pattern. With this new approach the end user of the building will have enough information to suggest the best strategy to meet the comfort conditions minimizing the energy consumption.

3.5 Application of BaaS in Veolia's business model: Real examples

This final section is aimed to analyse the potential implementation of BaaS solution as a new tool for real energy efficiency projects that are being developed nowadays. To that end, two real examples have been selected among the different facilities managed by Veolia as an ESCo in Spain.

Firstly, section 3.5.1 deals with a building typology already taken in BaaS project as a pilot, such as a school building. Moreover, considering the different public schools managed in Granada in order to have a higher level of comparability with Sierra Elvira School, we have sought one that could have similar characteristics to SES from the ECM implementation point of view: building features, energy system, operation and timetables, location, etc. In addition, the business model is exactly the same: energy contract (EPC), client (Granada Municipality) and ESCo (Veolia).

Secondly, section 3.5.2 extends the analysis to another building typology that was initially considered in the project but not finally implemented. This is the case of health-care centres. For this example, the choice was indented to seek a building that could be comparable to CARTIF pilot building in some point: new-construction building, two energy use cases (i.e. heating and cooling), conventional generation systems (i.e. natural gas and electricity), climate region (i.e. north-centre of Spain), etc.

3.5.1 Case Study 1: School

In addition to Sierra Elvira School, Veolia also conducts the energy management and operation of other 16 school buildings in Granada Municipality. For instance, this is the case of Juan Ramón Jiménez School. This public school was opened in 1980 and it has different facilities in good condition, with different rooms for the classes, dining room, multimedia, library, playground, etc. Working with morning and afternoon timetables to cover the different activities, it also has a biomass-fired boiler using a comparable energy system and operation strategy to provide heating to the different areas of the school.

Figure 19: General view of Juan Ramón Jiménez public school

Therefore, considering that several features of Juan Ramón Jiménez School are very similar to Sierra Elvira School (i.e. building characteristics, location, heating system, timetables...), it can be assumed it is suitable to extrapolate the results that have been obtained in SES with the implementation of BaaS solution in terms of energy savings and comfort improvement, taking into account that this is a first-approximation for a preliminary study.

General information

Typology	Location	Constructed area	Conditioned area	Energy service	Energy consumption
School	Granada (Spain)	2,470 m^2	1,976 m^2	Heating	28,746 kWh/yr

Table 11: General data of Juan Ramón Jiménez School

Energy, economic and environmental expectations

The fuel is the same than in Sierra Elvira School (i.e. biomass from olives stones) and the price of the final energy is the same (0.06824 €/kWh), as they have a similar energy contract.

The integration of BaaS solution in the energy system is analogous to SES and the facilities have many aspects in common, so that it can be assumed that the energy results would reach at least the same levels. Therefore for this first estimation we will consider the share level of energy savings (as it was evaluated in D6.3.3, the overall share of energy savings due to BaaS achieved in SES during the heating season was 18%).

Next table presents the most relevant results of the analysis in terms of energy and economic savings. Even though the deployment of BaaS will lead to a reduction in the fuel consumption, the CO_2 emissions will be still zero as biomass is considered a 100% renewable energy source.

Energy savings	Economic savings	CO_2 emissions	Comfort
5,174 kWh/yr	353 €/yr	Zero (biomass)	Improvement

Table 12: Expected results in Juan Ramón Jiménez school

BaaS Deployment costs

Following the same methodology than the one described and applied in the sensibility analysis conducted in Task 1.3 (see D1.3: "*End-user acceptance*" for more details), we will calculate the costs that the deployment of BaaS solution in Juan Ramón Jimenez school would entail. As it was explained in D1.3, the deployment costs of BaaS ECM in the buildings are calculated as the sum of the licence cost and the implementation cost. The implementation, in turn, is divided into modelling costs and configuration costs.

First of all, the licence cost represents an amount that would be yearly paid, depending on the level of energy savings achieved with BaaS solution.

Secondly, the regarding the implementation of BaaS system, the modelling costs depend on the total conditioned area by heating or/and cooling. In this case, as stated before, the heated area was 1,976 m^2.

BaaS deployment costs	
Licence cost	70.62 €/yr
Modelling cost	4,940.00 €
Configuration cost	988.00 €

Table 13: BaaS deployment costs in Juan Ramón Jiménez school

Economic analysis

The following table shows the cash-flow from the investment/deployment year (YR 0) to the final year considered (YR 15) in Juan Ramón Jimenez School:

JRJ	YR 0	YR 1	YR 2	…	YR 15
Configuration	- 988.00 €				
Modelling	- 4,940.00 €				
Licence		- 70.62 €	- 70.62 €	- 70.62 €	- 70.62 €
Savings		353.00 €	353.00 €	353.00 €	353.00 €
TOTAL	**- 5,928.00 €**	**282.38 €**	**282.38 €**	**282.38 €**	**282.38 €**

Table 14: Juan Ramón Jiménez school cash-flow

Based on the previous cash flows, some key economic indicators for the evaluation of energy retrofitting projects described in Task 1.3 (see the sensibility analysis in D1.3: "*End user acceptance*") have been calculated. The results are presented in the next table:

CAR	5 yr	10 yr	15 yr
IRR	n.a.	-12%	-4%
RoI	-76%	-52%	-29%
NPV	-4,506.88 €	-3,325.00 €	-2,254.53 €
Payback	20.99 yr		

Table 15: Juan Ramón Jiménez school economic parameters

As it can be observed, the economic results obtained in this preliminary analysis show that the deployment of BaaS solution as an ECM for Juan Ramón Jiménez school is not feasible at the current conditions (i.e. high energy savings but low economic ones due to the current energy prices, total heated area vs. energy consumption, etc.). Therefore, even though the Veolia as

ESCo and Granada Municipality as client/end user were very interested on this solution, it must be rejected by now and further analysis should be considered.

3.5.2 Case Study 2: Health-care centre

In this second analysis, it is proposed to evaluate the potential of BaaS solution in a real example of facility in which Veolia is currently implementing its business model as an ESCo. The considered study is Alba de Tormes, a health-care centre located in Salamanca (Spain) which has both heating and cooling services. As it is a new-construction building (dated from 2004) and the energy services are comparable to CARTIF building (i.e. heating provided by a gas boiler and electric cooling), the share of savings obtained with BaaS in CARTIF pilot will be extrapolated as first step to analyse the possible deployment of this ECM in Alba de Tormes.

Figure 20: Main entrance to Alba de Tormes health-care centre

General information

Typology	Location	Constructed area	Conditioned area	Energy service
Health-care	Salamanca (Spain)	1,193 m^2	938 m^2	Heating and Cooling

Table 16: General data of Alba de Tormes health-care centre

Use Case	Reference period	Energy consumed
Heating	Winter 2009	284,476 kWh_{gas}
Cooling	Summer 2009	20,761 kWh_e

Table 17: Reference energy consumption by type of service

Energy, economic and environmental expectations

Assuming the same shares of energy savings than the ones achieved with BaaS in CARTIF pilot building (i.e. 10% in heating and 24% in cooling), we can obtain a first estimation of the energy savings that could be potentially obtained in the real case of Alba de Tormes building.

In order to carry out the different calculations, it has been considered that:

- Energy and environmental calculations: IDAE (*Instituto para la Diversificación y Ahorro de la Energía)* [10].

- Economic calculations: The same energy prices (natural gas and electricity) than in CARTIF have been assumed for Alba de Tormes.

Use Case	Energy source	Primary energy factor (kWh_{PE}/kWh_{FE})	Unit price (€/kWh)	CO_2 emissions factor (kg CO_2/kWh_{FE})
Heating	Natural gas	1.195	0.039 €/kWh_{gas}	0.252
Cooling	Electricity	2.461	0.069 €/kWh_e	0.649

Table 18: Factors for energy, economic and environmental calculations

Next table presents the main results of the analysis. As it can be observed, the expected outcomes show quite compelling figures in terms of energy savings, costs savings and emissions avoided.

ESCo service	Energy savings	Economic savings	CO_2 emissions avoided
Heating	28,448 kWh/yr	1,099 €/yr	7,169 tCO_2 / yr
Cooling	4,983 kWh_e / yr	346 €/yr	3,234 tCO_2 / yr
TOTAL	**46,257 kWh_{PE} / yr**	**1,445 € / yr**	**10,403 kg CO_2 / yr**

Table 19: Results of the BaaS analysis in Alba de Tormes

BaaS Deployment costs

Following the same methodology than the one described and applied in the sensibility analysis conducted in Task 1.3 (see D1.3: "*End-user acceptance*" for more details), we will calculate the costs that the deployment of BaaS solution in Alba de Tormes health-care centre would entail. As it was explained in D1.3, the deployment costs of BaaS ECM in the buildings are calculated as the sum of the licence cost and the implementation cost. The implementation, in turn, is divided into modelling costs and configuration costs.

First of all, the licence cost represents an amount that would be yearly paid, depending on the level of energy savings achieved with BaaS solution.

Secondly, regarding the implementation of BaaS system, the modelling costs depend on the total conditioned area by heating and cooling. In this case, as stated before, the conditioned area in Alba de Tormes was 938 m^2.

BaaS deployment costs	
Licence cost	288.99 €/yr
Modelling cost	4,690.00 €
Configuration cost	938.00 €

Table 20: BaaS deployment costs in Alba de Tormes

Economic analysis

The following table shows the cash-flow from the investment/deployment year (YR 0) to the final year considered (YR 15) in Juan Ramón Jimenez School:

Alba de Tormes	YR 0	YR 1	YR 2	…	YR 15
Configuration	- 938.00 €				
Modelling	- 4,690.00 €				
Licence		- 288.99 €	- 288.99 €	- 288.99 €	- 288.99 €
Savings		1,444.99 €	1,444.99 €	1,444.99 €	1,444.99 €
TOTAL	**- 5,628.00 €**	**1,156,00 €**	**1,156,00 €**	**1,156,00 €**	**1,156,00 €**

Table 21: Alba de Tormes cash-flow

Based on the previous cash flows, some key economic indicators for the evaluation of energy retrofitting projects have been calculated, following the methodology described in D1.3: "*End user acceptance*". The results are presented in the next table:

Alba de Tormes	5 yr	10 yr	15 yr
IRR	1%	16%	19%
RoI	3%	105%	208%
NPV	-175,73 €	4.662,62 €	9.044,85 €
Payback	4.87 yr		

Table 22: Alba de Tormes economic parameters

The results obtained from this economic analysis show that the deployment of BaaS as ECM in Alba de Tormes health-care centre is feasible at short-term and especially profitable in a medium or long-term project. Therefore, Veolia could study the possibility of integrating BaaS solution in the ESCo model this real case-study.

4. Conclusions

This document provides a description of the general methodology for the effective implementation of the BaaS solution as Energy Conservation Measure (ECM) in the three pilot buildings involved in the project (i.e. CARTIF, ZUB and SES) and the confirmation of its potential in ESCO business models.

The implementation procedure here defined includes all the necessary stages that should be carried out in order to ensure the correct functionality, usability and interoperability of the overall BaaS system in the pilot building and it can serve as a reference to deploy this solution in new buildings.

In addition, it is important to remark that the end users have a key role in this kind of projects as their behaviour will significantly affect to the results obtained (i.e. energy consumption, indoor temperatures, operating hours…). Therefore, training activities on BaaS solution are necessary.

Finally, the application potential of BaaS in other projects related to energy efficiency retrofitting constitutes a very useful and innovative tool for Energy Services Companies (ESCO) business models, both for existing and new energy efficiency retrofitting projects. This innovative solution could complement the existing methodologies and technical solutions, providing the ESCO with an added value in comparison with other utilities due to the improvements in energy efficiency and cost-effectiveness that BaaS solution entails.

To that end, as a practical example of this, the analysis of the potential results of BaaS solution and its economic feasibility has been conducted for two real case studies of buildings in which the energy management and operation is currently performed by Veolia as an ESCO.

On the one hand, a school similar to SES was selected and the feasibility of BaaS was analysed concluding that the implementation of this kind of solution as ECM was not viable at the current situation of the energy market.

On the other hand, among the other building typologies, the choice was a health-care centre with some features comparable to CARTIF building ones. In this case, the economic results of this analysis are quite promising in relation to the potential implementation of BaaS for the heating and cooling systems of this building, resulting on a very feasible project at short, medium and long-term.

5. References

[1] BaaS Consortium. "BaaS Deliverable 6.1: Identification and definition of BaaS demonstration buildings". Technical Report. May 2013.

[2] BaaS Consortium. "BaaS Deliverable 5.1.2: BaaS advance use cases." Technical Report. June 2014.

[3] BaaS Consortium. "BaaS Deliverable 1.1: Definition of Theoretical Case Studies including Key Performance Indicators". Technical Report. September 2012.

[4] BaaS Consortium. "BaaS Deliverable 6.2: Operative pilots after adapting". Technical Report. August 2013.

[5] BaaS Consortium. "BaaS Deliverable 3.8: Prototype documentation, deployment, evaluation, monitoring and support". Technical Report. April 2016.

[6] IPMVP 2012. International Performance Measurement and Verification Protocol 2012

[7] CARTIF and DALKIA. "BaaS Deliverable 1.2: Definition of Theoretical Case Studies including Key Performance Indicators". September 2012.

[8] European Commission. Joint Research Centre (JRC). Institute for Energy and Transport (IET). Energy Efficiency. Energy Efficiency Activities. Energy Services Companies. http://iet.jrc.ec.europa.eu/energyefficiency/european-energy-service-companies/energy-performance-contracting. Last visit: 29/04/2016.

[9] International Energy Agency OECD/IEA (2011). Joint Public-Private Approaches for Energy Efficiency Finance. Policies to scale-up private sector investment.

[10] "*Factores de emisión de* CO_2 *y coeficientes de paso de energía primaria de diferentes fuentes de energía final consumidas en el sector edificios en España*", IDAE ("*Instituto para la Diversificación y Ahorro de la Energía*"), 2014.