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End-user acceptance

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Deliverable Summary Sheet

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Deliverable D1.3: Short Description

This document contains the end-user acceptance of BaaS project obtained from the fulfilment of technical requirements as well as from the different end-users perception. Moreover, this deliverable also includes a sensibility analysis that evaluates the feasibility of BaaS solution as ECM for the pilot buildings in addition to an study of the replication potential in other building categories considering the current European energy context.

Keywords: Requirements, end-user, ECM, sensibility, replication, viability

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Table of Contents

List of Figures

List of Tables

Abbreviations and Acronyms

BaaS	Building as a Service
BIM	Building Information Modelling
BMS	Building Management System
DACM	Data Acquisition and Control Manager
DC	Domain Controller
DoW	Document of Work
DWH	Data Warehouse
ECM	Energy Conservation Measure
ESCo	Energy Services Company
IPMVP	International Performance Measurement and Verification Protocol
IRR	Internal Rate of Return
KPI	Key Performance Indicator
M&V	Measurement & Verification
NPV	Net Present Value
RoI	Return on Investment
SES	Sierra Elvira School
WP	Work Package

Executive Summary

The aim of this document is to assess the end-user acceptance of the BaaS ECM deployment in each pilot building (i.e. CAR, ZUB and SES). For this assessment, different aspects should be considered: technical requirements fulfilled energy savings generated, cost savings obtained, environmental and comfort improvements, enhancement of the operation and maintenance of the systems, etc.

The technical requirements have been described, evaluating the degree of fulfilment in each of the pilot buildings. Some of the main objectives are energy savings, comfort improvement and fault detection.

One of the main outcomes of this document are the positive conclusions obtained from the end-users perception, which have been collected after the project ending.

By using the results obtained in WP6 related with energy and economic savings, the viability of BaaS solution as ECM in the three pilot buildings has been evaluated. For this evaluation, a specific sensibility analysis has been conducted in each of the buildings, considering the different cost associated to BaaS system (i.e. licence, configuration and modelling).

Finally, a replication potential has been analysed considering the current European market and context and also other building typologies that were initially proposed in the project.

1 Introduction

1.1 Purpose

The objective of this deliverable is to assess the end-user acceptance of the deployment of the BaaS ECM in the pilot buildings (i.e. CAR, ZUB and SES). After the present introductory section the rest of the document is structured as follows:

- Section 2 is dedicated to describe the technical requirements achieved from end-users point of view, specifying for the particular features of BaaS system in the three pilot buildings;
- Section 3 presents the main outcomes regarding the end-users' perception that have been collected in terms of energy performance and comfort improvements in the pilot buildings during BaaS project;
- Section 4 conducts the sensibility analysis of BaaS ECM in the three pilot buildings considering different economic parameters as well as other energy and environmental results;
- Section 5 includes the analysis of the replication potential of BaaS solution in the other building's typologies that were initially proposed in the project in the current European context;
- Finally, the main conclusions of this task are presented in Section 6 and all the references on which this document is based are listed in Section 7.

1.2 Contribution of partners

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

Partner	Deliverable Focus
DALKIA	Evaluate economic parameters and replication potential.
CARTIF	Monitoring and evaluation of technical requirements and end-user acceptance.

Table 1: Summary of Contributions of Partners

1.3 Relation to other activities in the project

Deliverable	Relationship
D1.1	D1.1 provides the typologies of buildings and analysis the energy potential.
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
D2.5	D2.5 provide requirements achieved
D3.8	D3.8 provide requirements achieved
D4.4	D4.4 provide requirements achieved
D5.4	D5.4 provide requirements achieved
D6.3.3	D6.3.3 provides energy and economic savings in each building.

Table 2: D1.3 tasks relationship with other BaaS activities

2 Fulfilment of the requirements defined in Task 1.1

From an end-user point of view, the most important issue in any software development, i.e. ICT tool, is to cover all the requirements. In this way, after any software development, the acceptance is traditionally carried out by means of mapping the initial requirements in contrast to the final product. Then, within this section, the same procedure is applied with the aim of determining which are the requirements achieved for each one of the pilots.

On the other hand, in the BaaS project specific case, apart from the requirements, the results are also very important because the primary goal is to obtain energy savings by ensuring comfort parameters. However, this analysis is out of the scope of the present document, being responsibility of D4.4 [5] and D6.3.3 [6].

However, the evaluation is out of the scope of the WP1 and, in particular, this deliverable. Nevertheless, the requirements already establish the necessity for energy and comfort management which needs to be also determined whether achieved or not. In this way, Table 3 summarizes the requirements and their achievement per building.

Requirement	ZUB	CARTIF	Sierra Elvira
FR-01: Human Machine Interaction	Achieved	Achieved	Achieved
FR-02.1: System Configuration	Achieved	Achieved	Achieved
FR-02.2: Interoperability	Achieved	Achieved	Achieved
FR-02.3: Openness	Achieved	Achieved	Achieved
FR-03: Data Management	Achieved	Achieved	Achieved
FR-04: Data Sources	Achieved	Achieved	Achieved
FR-05: App modules	Achieved	Achieved	Achieved
FR-06: FDD	Achieved	Achieved	Achieved
FR-07: Energy and comfort management	Achieved	Achieved	Achieved
FR-08: Optimal control	Achieved	Achieved	Achieved
FR-09: Modelling and simulation	Achieved	Achieved	Not achieved
NFR-01: Performance	Almost achieved	Almost achieved	Almost achieved
NFR-02: Security	Achieved	Achieved	Achieved

Table 3: Compliance of the requirements per building

In order to validate the results, it is remarkable the meaning of the requirements from D1.1 [1], Appendix C. First of all, FR-01 highlights any mechanism to interact with the users, having different access roles and showing monitoring information.

Within the WP3 [2], a graphical user interface has been developed and deployed where the information per building in terms of monitoring and results is displayed, as demonstrated in Figure 1 left. Besides, this graphical interface allows the configuration of the properties of the system (FR-02.1), such as schedulers (Figure 1 right) or users which apply for all or any of the buildings.

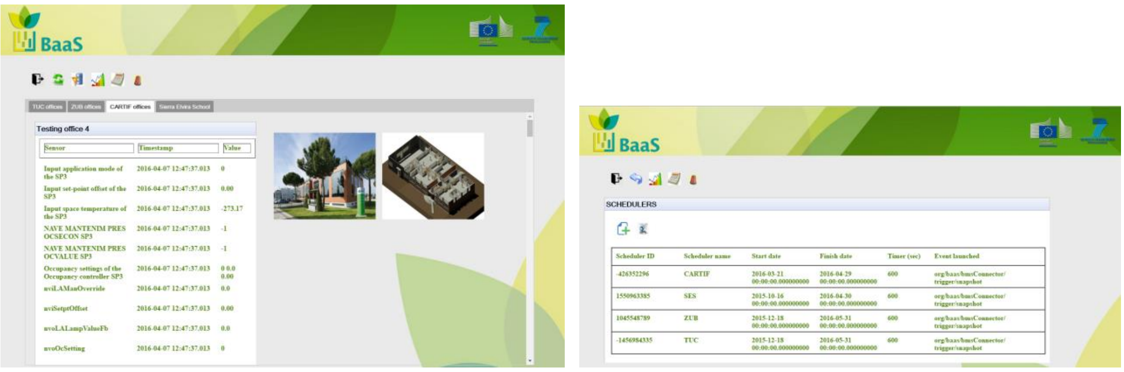

Figure 1: Human Machine Interaction

Next, FR-02.2 remarks interoperability which is the main objective of the middleware [2]. In this way, the middleware has been deployed in the three buildings, working with heterogeneous data sources (i.e. BMS, ICT systems…) and providing information to the application layer transparently and homogeneously.

The middleware is the core of the communication and, then, it works in a distributed way among the multiple entities of the BaaS platform, permitting the interworking among all the pieces. All these exchange messages are working under free licence software, such as Java, Hibernate framework, etc., as well as the development of the high-level services. Therefore, the development is also compliant with the FR-02.4.

Data Management (FR-03) is also something that in the three demo buildings have been achieved because the maintenance of data quality has been done within the DWH methodologies [3].

As well, as mentioned before, the middleware is continuously retrieving data from the data sources and persistently storing data into DWH which runs quality checks. Of course, the data resources allow the actuation for the control perspective, therefore, this requirement is ensured within the BaaS project. Similar applies for the FR-04 because the middleware is able to interwork within the heterogeneous networks and data sources.

Following with the requirements, the application layer relates FR-05, FR-06, FR-07 and FR-08. Multiple and diverse application modules [4] have been developed and deployed from the kernel for the communication with the middleware to the optimal controllers, passing through the co-simulation modules (FR-05).

The functionalities also include fault detection mechanisms which are running on-line for detecting malfunctioning [5] (FR-06). Moreover, the main objectives of these application modules are to optimally control the building facilities according to a set of KPIs for energy and comfort (FR-07 and FR-08).

Related to the control, FR-09 is partially achieved because some of the controllers are not making use of simulation tools, as happens in Sierra Elvira school where the control is data-driven/context-free.

Finally, the performance requirement is almost reached because, in spite of the fact that scalability, reliability, alarm management and replicability (analysis below) are ensured, the response time is not completely assured in the complete behaviour. However, that does not affect the operation of the system because it is only applicable with great amounts of information.

The retrieval of big amounts of data from the DWH delays the application of a few functionalities, although it does not affect the normal operation of the BaaS platform as a whole. Last but not least, security is also achieved because the BaaS system offers secure channels and security methods.

2.1 CARTIF building

Going in detail within the CARTIF building, it has completed all the requirements with the exception of the performance (time response) which is partially. In this case, all the data sources are connected as highlighted in the Energy Conservation Measure - ECM (Figure 2) for the CARTIF building.

In the case of CARTIF building, all the data sources related to the energy generation sources, distribution systems and demand side have been connected via the DC (Domain Controller) part in Figure 2. In this way, a big set of heterogeneous data samples is collected in order to determine the energy performance, as well as comfort. These data sets, through the interface DC-DACM, go into the DWH to be stored and keep record of historical data. In this way, the requirements FR-03 and FR-04 are fulfilled.

Furthermore, the DACM is able to communicate the DC installed in CARTIF facilities, the BIM Server, DWH and control strategies. This means, the DACM is the responsible for assuring the interoperability among entities, i.e. requirement FR-02.2. Another module that is connected within this deployment scheme is the Graphical User Interface (GUI) that allows the interaction of the multiple users for CARTIF management, therefore, FR-01. One of the possibilities of the GUI is the configuration of multiple parameters to set up the BaaS platform operational conditions (e.g. schedulers), therefore, FR-02.1 is completed with these features.

Going a step forward, the application layer is deployed in a server which is composed by multiple modules in order to execute different control strategies. First of all, the kernel is in charge of managing the application modules (FR-05). As it has been explained in other deliverables [4][5], the control deployment in CARTIF building is model-based, which is simulation based, although the co-simulation module is not running on-line. However, these simulations have been used for self-learning, hence, FR-09 is achieved. Besides, the full control algorithms have been deployed in the building with the aim of managing the energy sources, distribution systems and demand facilities with the aim of improving the energy efficiency, keeping certain comfort constraints. In this sense, the controllers treat to optimally control the facilities, being reached FR-08. Finally, related to the application layer, a set of TBMs has been deployed and running on-line

Last but not least, all the aforementioned components are developed under Java and OSGi technologies, which are open-sources, contributing to the openness of the platform (FR02.3).

Until now, the only functional requirement that has not been mentioned in the text is the FR-07. Nevertheless, it is also demonstrated its achievement with the results established in [5] and [6]. There, the evaluation of the energy and comfort has been calculated via several KPIs (some of them obtained on-the-fly because they determine the best actuation parameters). Then, the application modules, in one hand, and the assessment, on the other hand, have determined the energy and comfort parameters. In some cases, the KPIs have been used as decision-making factors for control, while, in other situations, KPIs have been calculated off-line. Anyway, this management of the energy and comfort is something done.

In summary, CARTIF building covers all the requirements from D1.1 [1] which highlight the needs of the end-user. It is only remarkable, within the non-functional requirements, that the performance is the only which is not fully achieved. This comment can be extrapolated to the rest of the pilots, although it is considerable in the CARTIF building. The amount of data-points makes a great data-set of measurements, increasing the size of the database. In this line, although the normal operation of the BaaS platform is completely ensured, when massive data are requested (note that is not a common task at all), the response time is high from the end-user point of view (scope of the present document). That is why, the requirement is almost achieved, having the remaining performance parameters assured within the ranges.

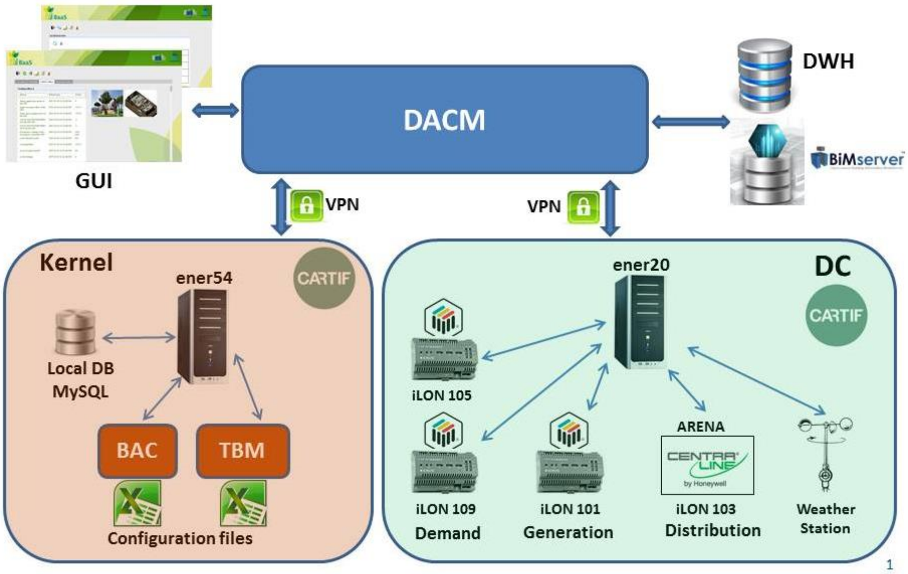

Figure 2: ECM of the CARTIF building

2.2 ZUB building

ZUB building presents a very similar scheme than CARTIF, including the facilities that are being managed. Therefore, as it could be expected, the results in terms of achievement of requirements from the end-user perspective are approximately the same.

Regarding data, the same approach is used, where the DC manages all the data sources, which are reduced in number with respect to CARTIF. The DC, once the data variables are gathered, exchanges information with the DACM and, this, at the same time, with the DWH. In this way, the data management and data sources requirements are assured (FR-03 and FR-04).

For FR-01 and FR-02.1, the same GUI is developed for all the pilots, whose monitoring information is divided in tabs, while the configuration screens are shared in all the cases. This demonstrates the achievement of the end-user requirements.

Regarding control, a full model-based control strategy is deployed, also including co-simulation modules. The approach is similar than CARTIF, with the kernel, the controllers according to energy cost functions and comfort constraints, FDD modules and the co-simulation module. Hence, if, in the case of CARTIF, these requirements were fulfilled, ZUB offices would ensure the same. Additionally, the KPIs have been necessary for the determination of the optimal control parameters, such as described above. Apart from them, another set of KPIs have been used for the assessment of the energy and comfort parameters by means of the simulation model. Therefore, all the requirements FR-05, FR-06, FR-07, FR-08 and FR-09 are reached.

In the case of the performance, the explanation is exactly the same than the previous pilot with the only difference that the number of data points in ZUB is reduced in contrast to CARTIF, being this response time slightly lower, but still high from the end-user point of view.

2.3 Sierra Elvira school

The last pilot building is Sierra Elvira school, which is also the simplest one. Again, as the previous cases, the deployment scheme is very much similar, with a DC entity which connects the data sources of the building that are centralized in a single BMS, as illustrated in Figure 3. Then, DC exchanges information with the DACM in order to store data into the DWH. Thus, FR-03 and FR-0.4 are completed.

As previously mentioned, the DACM ensures interoperability between entities, including BIM Server and GUI. This second entity is common for the three pilots. Therefore, FR-02.2, FR-01 and FR-02.1 are fulfilled.

The big difference with the previous cases lies in the control strategies. In spite of the fact that the application modules have been fully deployed (FR-05) with the kernel and multiple controllers to optimally control the energy sources (FR-08). However, the lack of a validated simulation model for the school implies that the controllers are neither model-based, nor useful from the self-learning algorithms. That is why the FR-09 requirement is not achieved, although it is not a concern for the end-user acceptance. The reason is that, within WP5, several discussing have been conducted to other control techniques which do not consider the model. These data-driven and context-free control strategies have been also agreed with the end-user in order to obtain the acceptance beforehand. From this perspective, it is true that the initial requirement is not reached, although it does not affect the final end-user acceptance because the alternative controllers also follow energy and comfort management premises. Thus, the objective of energy savings and comfort improvement is still aligned.

Finally, one of the potentials in the Sierra Elvira building for the end-user acceptance is the fault detection modules (FR-06) which give very valuable information for the maintenance staff. The reason is because a degradation module for the boiler is implemented in order to facilitate the maintenance of the energy systems in the school.

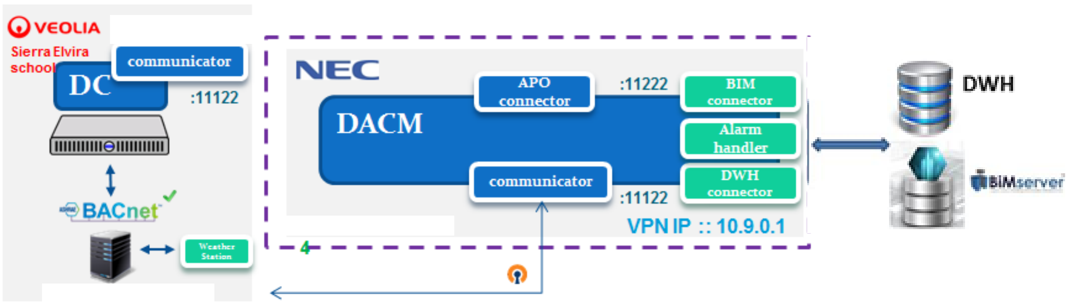

Figure 3: ECM of the Sierra Elvira School

2.4 Conclusion

In any software development, the view should be focused on the end-user because this is the one who establishes the requirements. The technicians look for solutions, technologies and developments that fulfil the requirements. In fact, the end-point of the software developments is the end-user acceptance of the “product”. Traditionally, it has been consisted in mapping the requirements with the functionalities that have been implemented. Nevertheless, BaaS does not work with an end-user, although presents a set of requirements that affect the end-user. That is the reason why, within BaaS, the same procedure than traditional software development has been followed.

Having said that, it is also important to remark that modification and changes with respect to the original design are always agreed with the end-user before their final implementation. In this case, those modifications have been internally discussed between the partners, keeping in the loop to the end-user. In this case, the only affected pilot is Sierra Elvira, where the responsible for the maintenance was informed about the new control strategy, which was agreed.

Finally, as it has been broken down in the previous sections, the end-user requirements established in the T1.1 [1], which set the minimum conditions to cover the commitments from DoW, have been achieved. Then, from the technological solution, it may be concluded the end-user would accept the product. Another aspect would be how the control algorithms have managed the energy sources so as to ensure comfort. This analysis is treated in the next section where the feedback from the owners of the buildings has been collected in order to determine the feelings from a subjective point of view.

3 End-user perception

One of the key points when talking about the end-user is her/his feeling. Usually, they prevail with respect to the economic aspects (evaluated in the next sections) and/or technical achievements (see section above). From experience, customers are easily convinced about the convenience of efficient energy solutions when they are satisfied. Therefore, this section assesses the impact of BaaS solution in CARTIF and Sierra Elvira buildings. In the first case, as CARTIF is already owner of the building, the experiences and opinions of the people working in the offices have been collected. On the other hand, in Sierra Elvira, a final survey has been completed at different levels: Veolia's operations manager in Granada, Veolia's technical and maintenance staff, Granada municipality, school head and personnel, parents and students... Thus, following chapters will explain these results.

3.1 CARTIF offices

First case is the CARTIF offices. As stated before, CARTIF is the owner and the end-user at the same time than project partner, therefore, instead of surveys; the opinion from the workers has been compiled with the aim of determining the feeling. In general terms, it has to be noted that the experience is very satisfactory. In fact, there is an internal plan to fully deploy BaaS in the building in order to continue with the solution managing the energy sources, distribution and demand side.

Two roles have been the main affected by the deployment of BaaS in the CARTIF building: maintenance staff and workers. Starting with the workers, a continuous follow-up has been established where the people working in BaaS has been daily asking for the conditions inside the building. Several workers were selected, mainly in the Energy and Vision 2D departments. Within Energy division, due to its size, multiple roles were selected, i.e. near the window, near the door and intermediate. Same happens in Vision 2D and people close to the door and the window have been asked.

In the case of summer, it is the most satisfactory from the people, owing to the noise. Thanks to BaaS, the heat pumps have been working less hours, even reducing the number of starts/stops, what means decrease of the noise. In this way, both people from Energy and Vision 2D departments agree saying these conditions have been improved with a high degree of satisfaction. In terms of comfort, people are satisfied without major claims during the deployment of BaaS. All the obtained responses go in the same direction, indicating that, along the day, the indoor conditions are good without cold/hot feelings, either in the morning or in the noon.

On the other hand, winter has been the season which the people satisfaction is reduced. In this case, both people from Energy and Vision 2D departments coincide with the fact that, early in the morning, the situation is still cold (as demonstrated in D4.4 with the comfort analysis [5]). Nevertheless, this answer does not show dissatisfaction with the BaaS solutions because it is also stated that the situation is not worse than previously (i.e. before BaaS). In this sense, it may be concluded that the satisfaction level with BaaS for winter, early in the morning is irrelevant. However, the situation when the end-user satisfaction is incremented, basically, lies in the "noon" hours, i.e. when the sun is beaming, above of all, in Energy division. The received feedback establishes that people are happy with the new deployment because the overheating in the main working hours has been reduced, generating a better environment for working. Vision 2D people is less delighted with the situation due to the orientation (north) and, hence, sun gains. Anyway, they reported that the situation has been better than previous winters. The fact that confirms these sentences is the number of manual modifications of the set-points, which is decreased.

From the maintenance staff point of view, BaaS has been fruitful and they are the people with major interest in the BaaS deployment in CARTIF. In fact, in spite of the fact that the economic savings are not really stunning (see D6.3.3 [6]), the produced energy savings are numerous, which has always been an objective of the maintenance staff. Several tests were run in the past by the staff in order to try to reduce the energy consumption and improve the comfort, then, decreasing the claims of the workers. In this way, BaaS has achieved this goal and maintenance staff has required less time for handling the energy sources with the aim of satisfying the needs from the people. In fact, these workers are encouraged to keep and learn about BaaS, which is demonstrated by the follow-up of the whole process. They have been always interested in the situation, continuously asking about what BaaS does, what BaaS manages and how. On the other hand, and even more important according to the responses from the maintenance staff, it is the time saved thanks to BaaS. The implementation of the FDD rules helps in the detection of fails and malfunctioning. The clear example is the issue with the locked circuits of the radiant floor documented in D4.4 [5]. This anomaly, which the simulation results demonstrate, is happening, at least, since one year ago and it was not detected previously. In this way, the maintainers reported a high level of satisfaction with the project because the results are very helpful for the day-by-day work, facilitating the detection of anomalies so as to solve them faster. The only concern that has been remarked is the lack of knowledge about the solution, as well as these technologies, and the probability of being unable to manage the solution without the help of any technician.

3.2 Sierra Elvira school

In the case of SES, VEO is the energy services company (ESCo) that manages, operates and maintains the heating system in Sierra Elvira School under an energy performance contract (EPC) with Granada Municipality which is the owner of the building. In this case, the end users are the personnel of the school (represented by the head and teachers) and the students (represented by their parents or tutors).

According to the above, the main objective in this task was to gather the impressions of the different people that are directly affected by the implementation of BaaS solution in the heating system. To that end, a final survey was launched to the different stakeholders involved:

- ESCo’s operation manager: Veolia’s operations manager in Granada.
- ESCo’s technical and maintenance staff: Veolia’s technical staff in charge of the energy management and maintenance of the facility in Sierra Elvira School.
- EPC client and owner of the building: Maintenance responsible of Granada Municipality.
- End users working in the building: Head and teachers of Sierra Elvira School.
- Other end users of the building: Children studying in SES and their parents.

Using this new approach, a general picture of the end users acceptance of the use of BaaS in the case of SES can be obtained. Technical, economic and social considerations are addressed, reflecting both the positive and negative aspects of the deployment of BaaS system in Sierra Elvira School from the real experience of the aforementioned stakeholders.

The questions proposed in this final survey were the following ones:

- *In your opinion, which are the main positive and negative aspects of the implementation of BaaS solution in Sierra Elvira School?*
- *Which improvements have you observed throughout the Project compared to the original situation previous to the use of BaaS in Sierra Elvira School?*
- *According to your experience with BaaS, would you like to use this solution in other similar facilities?*

In the first question about the positive/negative aspects regarding the implementation of BaaS system in Sierra Elvira School, this experience has been very satisfactory in general terms. On the one hand, the **positive aspects** of BaaS system are that all the equipment installed within project, both in primary (generation) and secondary (distribution) sides as well as field elements, have improved the follow-up of the facility and its energy efficiency and performance. The most remarkable systems are the thermostatic valves on the radiators, frequency converters on the pumps (variable flow pumping system), weight control in the biomass silo, temperature sensors in the different zones, etc. On the other hand, the only **negative issue** is related to some stops or shutdowns that happened during the first stages of implementation in the facility due to programming or connection fails of the different control systems that were managed by remote access. Even though these situations sometimes provoked certain annoyance among the end users in the school, it is assumed that this problem is typical during the commissioning and test of new solutions in pilot project and these issues were solved throughout the deployment of BaaS Project.

In the second part of the survey, talking about the benefits and disadvantages that have been observed in Sierra Elvira School with respect to the original situation of the heating system previous to the implementation of BaaS system, the general impressions are very positive and the people affected are very pleased with this new solution. Several enhancements have been obtained in the energy performance of the facility thanks to the installation of different equipment, control systems and operation strategies that are integrated under BaaS solution.

- From the ESCo’s operations manager experience, the different measures implemented in Sierra Elvira School throughout the course of BaaS project have had a direct effect on its better performance, increasing the regulation and control points as well as the possibilities to follow-up and supervise the operation. In addition, it should be highlighted that all the actuations carried out in the different points of the facility have increased the performance and improved the operation of the heat generator (i.e. biomass-fired boiler). Moreover, the energy consumption has been reduced while improving the comfort conditions (i.e. indoor temperature) during the heating season when BaaS was actuating. The energy consumption was a key constraint of the client (i.e. Granada Municipality) while the comfort improvement was an urgent requirement for the end users (i.e. teachers, children…).

- From the ESCo’s operational and technical staff point of view, they appreciate positively that the operation of the facility has significantly improved due to the different measures accomplished during BaaS project. However, they consider as a negative aspect the lack of access to the control system compared to the original situation when they did have this possibility.

- From the EPC client and owner point of view, Granada Municipality is very satisfied with the results of BaaS project in Sierra Elvira School because this pilot solution has improved the operation and performance of one of their facility without any additional cost for them. Besides the annual energy consumption in terms of heating has been reduced thanks to the ECMs implemented in BaaS. Despite the connection issues already mentioned, complaints received from the teachers and children-parents no longer exist.

- In general terms, Sierra Elvira School personnel have a positive feeling about the heating system performance during BaaS project and their working conditions are better than before the project in terms of thermal sensation.

- Last but not least, parents and children studying in the center value the heating service outcomes from the use of BaaS very positively. The comfort level in the different classrooms and areas of the school has been significantly increased compared to the original situation in which the indoor temperature dropped below admissible levels to perform le. The uncertainty regarding the different tests conducted during some stages of BaaS project generated certain mistrust among the end users.

After the experience of using BaaS in Sierra Elvira School as pilot building of the Project, the results obtained show some interesting conclusions.

- From the ESCo point of view, BaaS system enables a great enhancement in the operation and management of the facility, improving the performance and increasing the energy efficiency of the system without needing a great investment in building retrofitting and renovation of equipment. For this reason, Veolia as an ESCo is willing to continue using BaaS in SES in the next years and also to try to adapt and replicate in other similar facilities.

- From the client and owner point of view, the implementation BaaS in SES shows that a significant reduction in the energy consumption of the building can be achieved without any extra cost for the end user, while keeping and even increasing the comfort conditions inside the building. Therefore, as the energy savings is a very important factor due to its impact in the budget of the client, BaaS system is a very attractive solution to be deployed in other schools owned by Granada municipality.

According to the above, Veolia will try to integrate BaaS solution as a part of its business model based on energy efficient solutions. From the experience gained with the implementation of BaaS in Sierra Elvira School, a business model (type EPC) based on BaaS as ECM could be replicated in 16 other public schools owned by Granada Municipality, where Veolia already manages and operates the energy systems. These future projects will be analysed within the company, considering other technical, exploitation and strategic criteria as well.

As an example of this replication potential, D6.4 "*Deployment of BaaS ECM in Pilot Buildings*" includes a real case study of the possible application of BaaS solution in a public school in Granada Municipality in which Veolia is the ESCO that manages and operates the heating system and its maintenance, following the same methodology than in SES.

4 Sensibility analysis

Once BaaS system is deployed successfully from a technical point of view and the requirements defined in D1.1 are achieved, it is necessary to evaluate BaaS ECM through an economic, environmental and comfort study.

BaaS is an energy retrofitting solution and it is considered in this analysis as **a unique tool**. The sensibility analysis is divided into four different parts:

1. Costs and savings. This part contains the BaaS deployment costs and the economic savings obtained during the project.
2. Economic parameters. The economic parameters used to asset BaaS solution in each pilot building are described and calculated here. Besides, key values for each parameter are considered.
3. Sensibility analysis. A two variables (costs and savings) sensibility analysis is developed in this part for three different temporally scenarios.
4. Conclusions. The last part contains the main conclusions for each pilot building.

4.1 BaaS deployment costs and savings.

One assumption is considered to conduct this: BaaS deployment costs are calculated as if BaaS were a current market tool.

In order to evaluate BaaS deployment costs it is necessary to distinguish the two main costs: *licence* and *implementation*.

Licence cost:

BaaS licence cost includes the DC, DACM, application layer (including kernel), BIM and DWH. In this stage of the project, BaaS system has no licence price. The aim of this study is to calculate the economic parameters in each pilot building to assess BaaS viability. Therefore, a proposal of licence costs is considered here independently of the BaaS Consortium final decision about this.

Licence cost is considered variable and yearly, depending on energy savings.

$$\text{Licence cost} = 20\% \times (\text{Energy savings})$$

Implementation cost:

BaaS implementation costs include the costs of **configuration** of BaaS in each building and the **modelling** costs.

One of the main parts of the BaaS system is the energy model of each building. This energy model simulates different situations according specific conditions (weather forecast, occupancy, operational parameters, use cases, etc.) and chooses the best one.

All the requirements and functionalities of the energy model are described in depth in WP4, but related with BaaS deployment cost, modelling needs high-skilled professionals in building energy modelling.

Modelling costs have two different ways of calculation depending on two parameters: building surface and energy consumption. Surface has influence in the definition of the BIM model and energy consumption has influence in the definition of the energy model (TRSYS, E+, IFC …) through their energy systems definition.

Costs related with BIM model depend on building surface and architectural complexity. Current market practices are very different to evaluate modelling costs. However, two common agreements do exit:

- fix price related with the building surface (i.e. total conditioned area)
- fix price per person-hour.

Regarding the building surface, the following average prices could be considered:

Building surface	Price	Building surface	Price
Up to 100 m^2	10.0 €/m^2	From 1,501 to 2,000 m^2	2.5 €/m^2
From 101 to 200 m^2	7.0 €/m^2	From 2,001 to 3,000 m^2	2.2 €/m^2
From 201 to 400 m^2	6.0 €/m^2	From 3,001 to 6,000 m^2	1.9 €/m^2
From 401 to 1,000 m^2	5.0 €/m^2	From 6,001 to 10,000 m^2	1.7 €/m^2
From 1,001 to 1,500 m^2	3.5 €/m^2	Above 10,001 m^2	1.5 €/m^2

Table 4: BIM model average price [7]

Considering the unit cost of the modelling work (per person and hour), the average price could be from 50 €/person-hour to 75 €/person-hour [7].

On the other hand, costs related with energy model depend on the energy systems definition. Current market practices calculate this cost depending on energy consumption. Moreover, special buildings need a unique study to calculate modelling costs. The following table considers the average prices:

Energy consumption	Price
Up to 1 GWh/yr (Small building)	5 k€
From 1 to 10 GWh/yr (Medium building)	10 k€
Above 10 GWh/yr (Big buildings)	20 k€

Table 5: Energy model average price [8]

Depending on the complexity of the buildings, knowledge based strategies are more suitable than model based strategies. Consequently, in less complex buildings, modelling costs could be reduced or even avoided.

In our analysis of BaaS ECM, BIM-approach is considered to be the best way to calculate 'Modelling costs', because it has more variability depending on the surface. Anyway, the order of magnitude is closer to the current market prices, so that it is better to analyze the results.

To calculate the "*Configuration cost*", the following hypothesis has been considered to assess the BaaS solution:

Configuration cost = 20% x (Modelling cost)

In conclusion, taking into account all the above considerations; BaaS Deployment costs are calculated using the following formula, which at the end depends on two variables: energy savings and modelling costs.

<u>BaaS Deployment costs</u> = [Licence cost] + [Implementation cost]

= [Licence cost] + {[Configuration cost] + [Modelling cost]}

= 20% x (**Energy Savings**) + [(1+20%) x (**Modelling costs**)]

4.1.1 CARTIF building costs and savings

This section is dedicated to calculate the BaaS deployment costs and savings in CARTIF building.

Energy and economic savings

Next table presents the shares of energy savings obtained with BaaS solution in CARTIF as pilot building (see D6.3.3: "*Reporting period in the pilot buildings*").

Pilot Building	Use Case	Reporting period	Energy consumed	Energy savings	
CAR	Uc1 (Winter)	14/02/2016 – 01/04/2016	2,908 kWh_{th}	284 kWh_{th}	10%
	Uc2 (Summer)	17/08/2015 – 06/09/2015	1,962 kWh_e	756 kWh_e	24%

Table 6: CAR building energy results [6]

Based on the energy savings achieved with BaaS ECM during the reporting period, the potential economic savings during a whole year (winter + summer) of full-performance of BaaS have been estimated using the unit prices from the natural gas and electricity bills (for more details see D6.3.3: "*Reporting period in the pilot buildings*"). :

Pilot Building	Use Case	Potential Energy savings	Unit price	Potential Economic savings
CAR	Uc1 (Winter)	1.08 MWh_{gas}	0.038643 €/kWh_{gas}	**42 €/season**
	Uc2 (Summer)	1.79 MWh_e	0.069378 €/kWh_e	**124 €/season**

Table 7: CAR building economic results [6]

CO_2 emissions and comfort improvement

In addition to the energy savings, it is important to remark the environmental outcomes of BaaS system in terms of CO_2 emissions and indoor comfort. In an overall analysis, they should be included together with the economic benefits.

Pilot Building	Use Case	CO_2 emissions avoided[1]	Comfort level
CAR	Uc1 (Winter)	272 kg CO_2	Improved
	Uc2 (Summer)	1,162 kg CO_2	Improved

Table 8: CAR Building environmental results

BaaS Deployment costs

Licence costs: It is a yearly cost that depends on the energy savings achieved.

Modelling costs: Taking into account the previous section, modelling costs depend on the building surface (i.e. total conditioned area by heating and cooling). Heated and cooled area in CARTIF Building is 2,592 m^2, which is the range from 2,001 to 3,000 m^2.

Using the formulas previously presented in at the beginning of Section 4.1, we obtained the following costs for BaaS deployment in CARTIF building:

BaaS deployment costs	
Licence cost	33.20 €/yr
Modelling cost	5,702.00 €
Configuration cost	1,140.40 €

Table 9: BaaS deployment costs in CAR building

[1] This calculation has been conducted using the CO_2 emission factor from the IDAE [10]

4.1.2 ZUB building costs and savings

This section is aimed to calculate the BaaS deployment costs and savings in ZUB building, following the same methodology than in CARTIF building.

Energy and economic savings

Next table summarizes the overall energy savings obtained with BaaS solution in ZUB as pilot building (see D6.3.3: "*Reporting period in the pilot buildings*").

Pilot Building	Use Case	Reporting period	Energy consumed	Energy savings	
ZUB	Uc1 (Winter)	10/12/2016 – 15/03/2016	12,462 kWh_{th}	2,566 kWh_{th}	17%

Table 10: ZUB Building energy results [6]

Extending the shares of energy savings achieved in BaaS experiments to the whole period, we can determine the potential energy savings, and thus economic savings that would be achieved with BaaS system (see D6.3.3: "*Reporting period in the pilot buildings*" for deeper details). The economic savings have been calculated using the unit price of the district heat paid by Fraunhofer in ZUB building, which is quite low as the building is connected to a DH network in the University of Kassel. Next table presents those results:

Pilot Building	Use Case	Potential Energy savings	Unit price	Potential Economic savings
ZUB	Uc1 (Winter)	4.34 MWh_{th}	0.10 €/kWh_{th}	**434 €/season**

Table 11: ZUB Building economic results [6]

CO_2 emissions and comfort improvement

Even though the energy consumption has been significantly reduced in ZUB building due to the implementation of BaaS in the heating system, we cannot talk about CO_2 emissions avoided as the final energy is district heat in which the energy source is CHP with biogas, which is considered 100% renewable. In addition, it is important to highlight in this analysis that the energy and cost savings have been achieved while keeping comfortable levels in terms of indoor temperature in the building.

Pilot Building	Use Case	CO_2 emissions	Comfort level
ZUB	Uc1 (Winter)	Zero (CHP with biogas from waste)	Improved

Table 12: ZUB Building environmental results [6]

BaaS Deployment costs

Licence costs: This term is a yearly cost that depends on energy savings.

Modelling costs: Taking into account the previous section, modelling costs depend on the building surface (i.e. total conditioned area by heating and cooling in the building). Heated and cooled area in ZUB Building is 596 m^2, which is the range from 401 to 1,000 m^2.

Using the formulas previously presented in at the beginning of Section 4.1, we obtained the following costs for BaaS deployment in ZUB building:

BaaS deployment costs	
Licence cost	86.80 €/yr
Modelling cost	2,980.00 €
Configuration cost	596.00 €

Table 13: BaaS deployment costs in ZUB building

4.1.3 Sierra Elvira school building costs and savings

This section is dedicated to calculate the BaaS deployment costs and savings in Sierra Elvira school building, following the same approach than in the other two buildings.

Energy and economic savings

Next table summarizes the overall energy savings obtained with BaaS solution in SES as pilot building (see D6.3.3: "*Reporting period in the pilot buildings*").

Pilot Building	Use Case	Reporting period	Energy consumed	Energy savings	
SES	Uc1 (Winter)	11/11/2015 – 21/03/2016	31,360 kWh_{th}	6,843 kWh_{th}	18%

Table 14: SES Building energy results [6]

Extending the shares of energy savings achieved in BaaS experiments to the whole period, we can determine the potential energy savings, and thus economic savings that would be achieved with BaaS system (see D6.3.3: "*Reporting period in the pilot buildings*" for deeper details). The economic savings have been calculated using the energy price from the ESCo contract between Veolia and Granada Municipality. Next table presents those results:

Pilot Building	Use Case	Potential Energy savings	Unit price	Potential Economic savings
SES	Uc1 (Winter)	20.44 MWh_{th}	68.24 €/MWh_{th}	**1,395 €/season**

Table 15: SES Building economic results [6]

CO_2 emissions and comfort improvement

Apart from the economic calculations, it is relevant for this study to include also other inputs from non-monetary results such as the environmental impact of BaaS and the comfort improvement that have been achieved with its implementation and use during the project.

Even though the energy consumption has been significantly reduced in Sierra Elvira School by the use of BaaS ECM in the heating system, we cannot talk about CO_2 emissions avoided as the fuel used is biomass, which is considered 100% renewable.

Regarding the comfort level inside the building, with the use of BaaS solution it has been greatly improved compared to the original situation of thermal discomfort and low indoor temperature. Considering the different experiments that have been carried out during the project, the indoor temperature in the classrooms of Sierra Elvira School has overcome 19ºC or 20ºC most of the working days. This discomfort issue was one of the main requests of the end-users (i.e. teachers and parents of the children), and hence according to the results of the different experiments, it has been successfully fulfilled.

Pilot Building	Use Case	CO_2 emissions	Comfort improvement
SES	Uc1 (Winter)	Zero (biomass)	Usually T_{in} > 20 ºC

Table 16: SES Building environmental results

BaaS Deployment costs

Licence costs: This term is a yearly cost that depends on energy savings.

Modelling costs: Taking into account the previous section, modelling costs depend on the building surface (i.e. in the case of SES, total conditioned area by heating the building). The heated area in SES Building is 4,253 m^2, which is the range from 3,001 to 6,000 m^2.

Using the formulas previously presented in at the beginning of Section 4.1, we obtained the following costs for BaaS deployment in SES building:

BaaS deployment costs	
Licence cost	279,00 €/yr
Modelling cost	8,081.00 €
Configuration cost	1,616.20 €

Table 17: BaaS deployment costs in SES building

4.2 Economic parameters

The main parameters applied to assess the viability of BaaS project are the same parameters applied in the current market to assess whatever energy retrofitting project:

- **Net Present Value** (NPV): This parameter is the difference between the present value of cash inflows and the present value of cash outflows.
- **Internal Rate of Return** (IRR): It is a discount rate that makes the net present value of all cash flows equal to zero.
- **Return on Investment** (RoI): It is the amount of return on an investment relative to the investment's cost.
- **Payback period**: It represents the duration or length of time required to recover the cost of an investment.

Before presenting the economic results of this analysis in the three pilot, these four parameters are explained in more details. In addition, the formula or expression for its calculation has been here included.

Net Present Value (NPV)

The net present value method is a recurring method of investment appraisal and is considered to be one of the most appropriate investment methods. A present value is the value today of a future expense or income. The method is based on all expected receipts and payments, being calculated to the same given point of time, for the actual investment. This current value is compared with the size of the investment. The discount rate is the firms minimum required rate of return on an investment in order for them to consider the investment worthwhile.

$$NPV_T = \sum_{t=1}^{T} \left(\frac{Inc_t - C_t}{(1+r)^t} \right) - (Inv)$$

NPV_T	Net Present Value [€]
Inc_t	Total incomes in the year t [€]
C_t	Total annual energy cost (i.e. supply, operation, maintenance and financing, if applies) in the year t [€]
Inv	Total investment to deploy BaaS solution in the building [€]
r	National standard interest rate [%]
T	Duration of the economic analysis period: T=10, 15 and 20 [yr]

Internal Rate of Return (IRR)

The internal rate of return (IRR) method is an alternative method to the net present value method. However, an IRR calculation is based on the cash flow streams and finds the discount rate whereas the NPV outflows and inflows are equal. In other words, the IRR method is used to calculate the interest rate at which the investments' NPV is equal to zero; this is referred to as the investment's internal rate of return. The project is acceptable when the IRR is higher than the minimum required rate, i.e. the cost of capital that would have arisen for an alternative investment.

$$IRR_T \rightarrow \text{Solve the equation } NPV(r) = 0$$

IRR_T Internal Rate of Return [%]

T Duration of the economic analysis period: T=10, 15 and 20 [yr]

Return on Investment (RoI)

The return on investment (RoI) is an economic variable that enables the evaluation of the feasibility of an investment or the comparison between different possible investments. This parameter is defined as the ratio between the total incomes/net profit and the total investment of the project, usually expressed in %.

$$RoI_T = \frac{\sum_{t=1}^{T}(Inc_t - C_t) - Inv}{Inv}$$

RoI_T Return on Investment [%]

$Inc_t - C_t$ Cash flow in the year t [€/yr]

Inv Total investment of BaaS deployment in the building [€]

T Duration of the economic analysis period: T=10, 15 and 20 [yr]

Payback period

The payback period is the length of time required to recover the cost of the total investment in the energy retrofitting project. For instance, by using the payback method one can estimate how quickly the initial costs of an energy efficient measure can be retrieved through the cost savings from lower energy consumption. The method is known for its simplicity, e.g. it is suitable when a general estimation is to be made.

$$Payback = \frac{Inv}{Inc_{t=1} - C_{t=1}}$$

$Payback$ Payback period [yr]

Inv Total investment of BaaS deployment in the building [€]

$Inc_{t=1} - C_{t=1}$ Cash flow in the first year after the implementation of BaaS [€/yr]

Once the economic parameters are defined, is necessary to establish a period of time to calculate the NPV, IRR and RoI parameters in each pilot building. It is common to apply the project duration (length time) or the depreciation cost time of the ECM in a retrofitting project, but in the present case of BaaS project, length time is not long enough and depreciation cost time is uncertain because BaaS tool is not material. Three different periods of time are considering in this study: 5 years (short term period), 10 years (medium term period) and 15 years (long term period).

4.2.1 CARTIF building

The following table shows CAR building cash-flow from the investment/deployment year (YR 0) to the final year considered (YR 15):

CAR	YR 0	YR 1	YR 2	…	YR 15
Configuration	- 1,140.40 €				
Modelling	- 5,702.00 €				
Licence		- 33.20 €	- 33.20 €	- 33.20 €	- 33.20 €
Savings		166.00 €	166.00 €	166.00 €	166.00 €
TOTAL	**- 6,842.40 €**	**132.80 €**	**132.80 €**	**132.80 €**	**132.80 €**

Table 18: CAR Building cash-flow

CAR	5 yr	10 yr	15 yr
IRR	n.a.	n.a.	n.a.
RoI	-90%	-81%	-71%
NPV	-6,094.56 €	-5,538.74 €	-5,035.31 €
Payback	51.52 yr		

Table 19: CAR Building economic parameters

With these parameters, the first conclusion is that the required investment for BaaS System seems to be **not viable** in CARTIF building at first instance. In the next section the sensibility analysis shows in which conditions BaaS System is viable.

4.2.2 ZUB building

The following table shows the results for ZUB building cash-flow from the investment/deployment year (YR 0) to the final year considered (YR 15):

ZUB	YR 0	YR 1	YR 2	…	YR 15
Configuration	- 596,00 €				
Modelling	- 2.980,00 €				
Licence		- 86,80 €	- 86,80 €	- 86,80 €	- 86,80 €
Savings		434,00 €	434,00 €	434,00 €	434,00 €
TOTAL	**- 3.576,00 €**	**347,20 €**	**347,20 €**	**347,20 €**	**347,20 €**

Table 20: ZUB Building cash-flow

ZUB	5 yr	10 yr	15 yr
IRR	-20%	-1%	5%
RoI	-51%	-3%	46%
NPV	-1.901,46 €	-448,28 €	867,91 €
Payback	10,30 yr		

Table 21: ZUB Building economic parameters

With these parameters, the first conclusion is that BaaS System **is viable** in ZUB building in a long term period. In the next section, the sensibility analysis shows in which conditions BaaS System is fully viable.

4.2.3 SES building

The following table shows SES building cash-flow from the investment/deployment year (YR 0) to the final year considered (YR 15):

SES	YR 0	YR 1	YR 2	…	YR 15
Configuration	- 1.616,20 €				
Modelling	- 8.081,00 €				
Licence		- 279,00 €	- 279,00 €	- 279,00 €	- 279,00 €
Savings		1.395,00 €	1.395,00 €	1.395,00 €	1.395,00 €
TOTAL	**- 9.697,20 €**	**1.116,00 €**	**1.116,00 €**	**1.116,00 €**	**1.116,00 €**

Table 22: SES Building cash-flow

SES	5 yr	10 yr	15 yr
IRR	-16%	3%	8%
RoI	-42%	15%	73%
NPV	-4.349,98 €	320,95 €	4.551,55 €
Payback	8,69 yr		

Table 23: SES Building economic parameters

With these parameters, the first conclusion is that BaaS System **is viable** in SES building in a medium term period. In the next section the sensibility analysis shows in which conditions BaaS System is fully viable.

4.3 Sensibility analysis

In this section, a sensibility analysis has been developed considering two variables: Modelling costs and Energy Savings. All the economic parameters are evaluated in the different periods of time: short-term, medium-term and long-term.

4.3.1 CAR building

The first parameter to analyze is the payback period. In CAR building, payback depends mainly on the energy savings achieved:

		Modelling costs					
Payback	51,52 yr	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 4.000,00 €	- 5.000,00 €	- 5.702,00 €
Savings	166,00 €	9,04 yr	18,07 yr	27,11 yr	36,14 yr	45,18 yr	51,52 yr
	1.000,00 €	1,50 yr	3,00 yr	4,50 yr	6,00 yr	7,50 yr	8,55 yr
	2.000,00 €	0,75 yr	1,50 yr	2,25 yr	3,00 yr	3,75 yr	4,28 yr
	3.000,00 €	0,50 yr	1,00 yr	1,50 yr	2,00 yr	2,50 yr	2,85 yr
	4.000,00 €	0,38 yr	0,75 yr	1,13 yr	1,50 yr	1,88 yr	2,14 yr

Figure 4: CAR Building payback analysis

<u>Short-term: 5 years</u>

		Modelling costs					
NPV 5yr	-6.094,56 €	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 4.000,00 €	- 5.000,00 €	- 5.702,00 €
Savings	166,00 €	- 562,80 €	- 1.739,27 €	- 2.915,74 €	- 4.092,21 €	- 5.268,68 €	- 6.094,56 €
	1.000,00 €	2.520,36 €	1.343,89 €	167,42 €	- 1.009,05 €	- 2.185,52 €	- 3.011,40 €
	2.000,00 €	6.217,19 €	5.040,72 €	3.864,25 €	2.687,78 €	1.511,31 €	685,43 €
	3.000,00 €	9.914,02 €	8.737,55 €	7.561,08 €	6.384,61 €	5.208,14 €	4.382,26 €
	4.000,00 €	13.610,85 €	12.434,38 €	11.257,91 €	10.081,44 €	8.904,97 €	8.079,09 €

		Modelling costs					
IRR 5yr	#¡NUM!	- 1.000,00 €	- 1.100,00 €	- 1.200,00 €	- 1.300,00 €	- 1.400,00 €	- 1.500,00 €
Savings	166,00 €	-17%	-19%	-21%	-23%	-25%	-26%
	1.000,00 €	60%	53%	48%	43%	38%	34%
	2.000,00 €	131%	119%	108%	99%	92%	85%
	3.000,00 €	199%	181%	165%	152%	141%	131%
	4.000,00 €	266%	242%	222%	204%	190%	177%

		Modelling costs					
ROI 5yr	-90%	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 4.000,00 €	- 5.000,00 €	- 5.702,00 €
Savings	166,00 €	-45%	-72%	-82%	-86%	-89%	-90%
	1.000,00 €	233%	67%	11%	-17%	-33%	-42%
	2.000,00 €	567%	233%	122%	67%	33%	17%
	3.000,00 €	900%	400%	233%	150%	100%	75%
	4.000,00 €	1233%	567%	344%	233%	167%	134%

Figure 5: NPV, IRR and RoI short-term analysis for CAR Building

In the short-term, BaaS ECM is economically viable in CAR building when the energy savings are higher than 2,000 €/yr and is fully viable if these savings are higher than 3,000 €/yr.

Medium-term: 10 years

		Modelling costs					
NPV 10yr	-5.538,74 €	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 4.000,00 €	- 5.000,00 €	- 5.702,00 €
Savings	166,00 €	- 6,97 €	- 1.183,44 €	- 2.359,91 €	- 3.536,39 €	- 4.712,86 €	- 5.538,74 €
	1.000,00 €	5.868,69 €	4.692,22 €	3.515,75 €	2.339,28 €	1.162,81 €	336,93 €
	2.000,00 €	12.913,86 €	11.737,39 €	10.560,92 €	9.384,45 €	8.207,98 €	7.382,09 €
	3.000,00 €	19.959,02 €	18.782,55 €	17.606,08 €	16.429,61 €	15.253,14 €	14.427,26 €
	4.000,00 €	27.004,19 €	25.827,72 €	24.651,25 €	23.474,78 €	22.298,31 €	21.472,42 €

		Modelling costs					
IRR 10yr	#¡NUM!	- 1.000,00 €	- 1.500,00 €	- 2.000,00 €	- 2.300,00 €	- 2.600,00 €	- 3.000,00 €
Savings	166,00 €	2%	-5%	-10%	-11%	-13%	-15%
	1.000,00 €	66%	43%	31%	26%	22%	18%
	2.000,00 €	133%	89%	66%	57%	50%	43%
	3.000,00 €	200%	133%	100%	87%	77%	66%
	4.000,00 €	267%	178%	133%	116%	102%	89%

		Modelling costs					
ROI 10yr	-81%	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 4.000,00 €	- 5.000,00 €	- 5.702,00 €
Savings	166,00 €	11%	-45%	-63%	-72%	-78%	-81%
	1.000,00 €	567%	233%	122%	67%	33%	17%
	2.000,00 €	1233%	567%	344%	233%	167%	134%
	3.000,00 €	1900%	900%	567%	400%	300%	251%
	4.000,00 €	2567%	1233%	789%	567%	433%	368%

Figure 6: NPV, IRR and RoI medium-term analysis for CAR Building

In the medium-term, BaaS solution is viable in CAR building if the savings obtained are higher than 1,000 €/yr and is fully viable when the savings are higher than 2,000 €/yr.

Long-term: 15 years

		Modelling costs					
NPV 15yr	-5.035,31 €	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 4.000,00 €	- 5.000,00 €	- 5.702,00 €
Savings	166,00 €	496,45 €	- 680,02 €	- 1.856,49 €	- 3.032,96 €	- 4.209,43 €	- 5.035,31 €
	1.000,00 €	8.901,38 €	7.724,91 €	6.548,44 €	5.371,97 €	4.195,50 €	3.369,62 €
	2.000,00 €	18.979,24 €	17.802,77 €	16.626,30 €	15.449,83 €	14.273,35 €	13.447,47 €
	3.000,00 €	29.057,09 €	27.880,62 €	26.704,15 €	25.527,68 €	24.351,21 €	23.525,33 €
	4.000,00 €	39.134,94 €	37.958,47 €	36.782,00 €	35.605,53 €	34.429,06 €	33.603,18 €

		Modelling costs					
IRR 15yr	#¡NUM!	- 1.000,00 €	- 2.000,00 €	- 2.500,00 €	- 3.000,00 €	- 3.500,00 €	- 4.000,00 €
Savings	166,00 €	7%	-2%	-5%	-7%	-8%	-9%
	1.000,00 €	67%	33%	26%	21%	17%	14%
	2.000,00 €	133%	67%	53%	44%	38%	33%
	3.000,00 €	200%	100%	80%	67%	57%	50%
	4.000,00 €	267%	133%	107%	89%	76%	67%

		Modelling costs					
ROI 15yr	-71%	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 4.000,00 €	- 5.000,00 €	- 5.702,00 €
Savings	166,00 €	66%	-17%	-45%	-58%	-67%	-71%
	1.000,00 €	900%	400%	233%	150%	100%	75%
	2.000,00 €	1900%	900%	567%	400%	300%	251%
	3.000,00 €	2900%	1400%	900%	650%	500%	426%
	4.000,00 €	3900%	1900%	1233%	900%	700%	602%

Figure 7: NPV, IRR and RoI long-term analysis for CAR Building

In the long-term, BaaS System as ECM is fully viable in CAR building when the savings achieved are higher than 1,000 €/yr.

4.3.2 ZUB building

The first parameter to analyze is the payback. In ZUB building payback depends on modelling costs and energy savings:

		Modelling costs					
Payback	10,30 yr	- 1.000,00 €	- 1.250,00 €	- 1.500,00 €	- 2.000,00 €	- 2.500,00 €	- 2.980,00 €
Savings	434,00 €	3,46 yr	4,32 yr	5,18 yr	6,91 yr	8,64 yr	10,30 yr
	1.000,00 €	1,50 yr	1,88 yr	2,25 yr	3,00 yr	3,75 yr	4,47 yr
	2.000,00 €	0,75 yr	0,94 yr	1,13 yr	1,50 yr	1,88 yr	2,24 yr
	3.000,00 €	0,50 yr	0,63 yr	0,75 yr	1,00 yr	1,25 yr	1,49 yr
	4.000,00 €	0,38 yr	0,47 yr	0,56 yr	0,75 yr	0,94 yr	1,12 yr

Figure 8: ZUB Building payback analysis

Short-term: 5 years

		Modelling costs					
NPV 5yr	-1.901,46 €	- 1.000,00 €	- 1.250,00 €	- 1.500,00 €	- 2.000,00 €	- 2.500,00 €	- 2.980,00 €
Savings	434,00 €	427,95 €	133,84 €	- 160,28 €	- 748,52 €	- 1.336,75 €	- 1.901,46 €
	1.000,00 €	863,17 €	569,05 €	274,94 €	- 313,30 €	- 901,53 €	- 1.466,24 €
	2.000,00 €	1.632,11 €	1.337,99 €	1.043,87 €	455,64 €	- 132,60 €	- 697,31 €
	3.000,00 €	2.401,04 €	2.106,92 €	1.812,81 €	1.224,57 €	636,34 €	71,63 €
	4.000,00 €	3.169,98 €	2.875,86 €	2.581,74 €	1.993,51 €	1.405,27 €	840,56 €

		Modelling costs					
IRR 5yr	-20%	- 1.000,00 €	- 1.250,00 €	- 1.500,00 €	- 2.000,00 €	- 2.500,00 €	- 2.980,00 €
Savings	434,00 €	14%	5%	-1%	-10%	-16%	-20%
	1.000,00 €	30%	17%	8%	-3%	-11%	-16%
	2.000,00 €	70%	46%	30%	11%	0%	-8%
	3.000,00 €	123%	85%	60%	31%	14%	3%
	4.000,00 €	182%	130%	96%	55%	31%	16%

		Modelling costs					
ROI 5yr	-51%	- 1.000,00 €	- 1.250,00 €	- 1.500,00 €	- 2.000,00 €	- 2.500,00 €	- 2.980,00 €
Savings	434,00 €	45%	16%	-4%	-28%	-42%	-51%
	1.000,00 €	82%	46%	22%	-9%	-27%	-39%
	2.000,00 €	149%	99%	66%	25%	0%	-16%
	3.000,00 €	216%	153%	110%	58%	26%	6%
	4.000,00 €	282%	206%	155%	91%	53%	28%

Figure 9: NPV, IRR and RoI short-term analysis for ZUB Building

In the short-term BaaS System is viable in ZUB if savings are higher than 1,000€/yr and modelling costs are less than 1,500€ and is fully viable if savings are higher than 2,000€/yr and modelling costs are less than 1,500€.

Medium-term: 10 years

		Modelling costs					
NPV 10yr	-448,28 €	- 1.000,00 €	- 1.250,00 €	- 1.500,00 €	- 2.000,00 €	- 2.500,00 €	- 2.980,00 €
Savings	434,00 €	1.881,13 €	1.587,01 €	1.292,90 €	704,66 €	116,43 €	- 448,28 €
	1.000,00 €	2.316,35 €	2.022,23 €	1.728,11 €	1.139,88 €	551,64 €	- 13,06 €
	2.000,00 €	3.085,28 €	2.791,17 €	2.497,05 €	1.908,81 €	1.320,58 €	755,87 €
	3.000,00 €	3.854,22 €	3.560,10 €	3.265,98 €	2.677,75 €	2.089,51 €	1.524,81 €
	4.000,00 €	4.623,15 €	4.329,04 €	4.034,92 €	3.446,68 €	2.858,45 €	2.293,74 €

		Modelling costs					
IRR 10yr	-1%	- 1.000,00 €	- 1.250,00 €	- 1.500,00 €	- 2.000,00 €	- 2.500,00 €	- 2.980,00 €
Savings	434,00 €	26%	19%	14%	7%	3%	-1%
	1.000,00 €	38%	28%	21%	12%	6%	2%
	2.000,00 €	73%	51%	37%	22%	13%	7%
	3.000,00 €	123%	87%	63%	37%	23%	14%
	4.000,00 €	183%	131%	98%	58%	36%	24%

		Modelling costs					
ROI 10yr	-3%	- 1.000,00 €	- 1.250,00 €	- 1.500,00 €	- 2.000,00 €	- 2.500,00 €	- 2.980,00 €
Savings	434,00 €	189%	131%	93%	45%	16%	-3%
	1.000,00 €	227%	162%	118%	64%	31%	10%
	2.000,00 €	294%	215%	162%	97%	57%	32%
	3.000,00 €	360%	268%	207%	130%	84%	54%
	4.000,00 €	427%	322%	251%	164%	111%	77%

Figure 10: NPV, IRR and RoI medium-term analysis for ZUB Building

In the medium-term BaaS System is viable in ZUB if modelling costs are up to 2,500€ and is fully viable if savings are higher than 1,000€/yr and modelling costs are up to 2,500€.

Long-term: 15 years

		Modelling costs					
NPV 15yr	867,91 €	- 1.000,00 €	- 1.250,00 €	- 1.500,00 €	- 2.000,00 €	- 2.500,00 €	- 2.980,00 €
Savings	434,00 €	3.197,32 €	2.903,20 €	2.609,08 €	2.020,85 €	1.432,61 €	867,91 €
	1.000,00 €	3.632,54 €	3.338,42 €	3.044,30 €	2.456,06 €	1.867,83 €	1.303,12 €
	2.000,00 €	4.401,47 €	4.107,35 €	3.813,23 €	3.225,00 €	2.636,76 €	2.072,06 €
	3.000,00 €	5.170,41 €	4.876,29 €	4.582,17 €	3.993,93 €	3.405,70 €	2.840,99 €
	4.000,00 €	5.939,34 €	5.645,22 €	5.351,10 €	4.762,87 €	4.174,63 €	3.609,93 €

		Modelling costs					
IRR 15yr	5%	- 1.000,00 €	- 1.250,00 €	- 1.500,00 €	- 2.000,00 €	- 2.500,00 €	- 2.980,00 €
Savings	434,00 €	26%	19%	14%	7%	3%	-1%
	1.000,00 €	38%	26%	26%	26%	26%	26%
	2.000,00 €	73%	26%	26%	26%	26%	26%
	3.000,00 €	123%	26%	26%	26%	26%	26%
	4.000,00 €	183%	26%	26%	26%	26%	26%

		Modelling costs					
ROI 15yr	46%	- 1.000,00 €	- 1.250,00 €	- 1.500,00 €	- 2.000,00 €	- 2.500,00 €	- 2.980,00 €
Savings	434,00 €	334%	247%	189%	117%	74%	46%
	1.000,00 €	372%	277%	214%	136%	89%	58%
	2.000,00 €	438%	331%	259%	169%	115%	81%
	3.000,00 €	505%	384%	303%	203%	142%	103%
	4.000,00 €	572%	437%	348%	236%	169%	125%

Figure 11: NPV, IRR and RoI long-term analysis for ZUB Building

In the long-term BaaS System is fully viable in ZUB if modelling costs are up to 2,500€.

4.3.3 SES building

The first parameter to analyze is the payback. In SES building payback depends on modelling costs and energy savings:

		Modelling costs					
Payback	8,69 yr	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 5.000,00 €	- 7.000,00 €	- 8.081,00 €
Savings	1.395,00 €	1,08 yr	2,15 yr	3,23 yr	5,38 yr	7,53 yr	8,69 yr
	2.000,00 €	0,75 yr	1,50 yr	2,25 yr	3,75 yr	5,25 yr	6,06 yr
	3.000,00 €	0,50 yr	1,00 yr	1,50 yr	2,50 yr	3,50 yr	4,04 yr
	4.000,00 €	0,38 yr	0,75 yr	1,13 yr	1,88 yr	2,63 yr	3,03 yr
	5.000,00 €	0,30 yr	0,60 yr	0,90 yr	1,50 yr	2,10 yr	2,42 yr

Figure 12: SES Building payback analysis

Short-term: 5 years

		Modelling costs					
NPV 5yr	-4.349,98 €	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 5.000,00 €	- 7.000,00 €	- 8.081,00 €
Savings	1.395,00 €	3.980,61 €	2.804,14 €	1.627,67 €	- 725,27 €	- 3.078,21 €	- 4.349,98 €
	2.000,00 €	6.217,19 €	5.040,72 €	3.864,25 €	1.511,31 €	- 841,63 €	- 2.113,40 €
	3.000,00 €	9.914,02 €	8.737,55 €	7.561,08 €	5.208,14 €	2.855,20 €	1.583,43 €
	4.000,00 €	13.610,85 €	12.434,38 €	11.257,91 €	8.904,97 €	6.552,03 €	5.280,27 €
	5.000,00 €	17.307,68 €	16.131,21 €	14.954,74 €	12.601,80 €	10.248,86 €	8.977,10 €

		Modelling costs					
IRR 5yr	-16%	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 5.000,00 €	- 7.000,00 €	- 8.081,00 €
Savings	1.395,00 €	89%	37%	17%	-2%	-12%	-16%
	2.000,00 €	131%	60%	34%	10%	-2%	-6%
	3.000,00 €	199%	97%	60%	29%	13%	8%
	4.000,00 €	266%	131%	85%	45%	26%	19%
	5.000,00 €	333%	165%	108%	60%	38%	30%

		Modelling costs					
ROI 5yr	-42%	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 5.000,00 €	- 7.000,00 €	- 8.081,00 €
Savings	1.395,00 €	365%	133%	55%	-7%	-34%	-42%
	2.000,00 €	567%	233%	122%	33%	-5%	-18%
	3.000,00 €	900%	400%	233%	100%	43%	24%
	4.000,00 €	1233%	567%	344%	167%	90%	65%
	5.000,00 €	1567%	733%	456%	233%	138%	106%

Figure 13: NPV, IRR and RoI short-term analysis for SES Building

In the short-term BaaS System is viable in SES if savings are higher than 3,000€/yr and modelling costs are less than 5,000€ and is fully viable if savings are higher than 3,000€/yr and modelling costs are less than 3,000€.

<u>Medium-term: 10 years</u>

		Modelling costs					
NPV 10yr	320,95 €	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 5.000,00 €	- 7.000,00 €	- 8.081,00 €
Savings	1.395,00 €	8.651,53 €	7.475,06 €	6.298,59 €	3.945,65 €	1.592,71 €	320,95 €
	2.000,00 €	12.913,86 €	11.737,39 €	10.560,92 €	8.207,98 €	5.855,04 €	4.583,27 €
	3.000,00 €	19.959,02 €	18.782,55 €	17.606,08 €	15.253,14 €	12.900,20 €	11.628,44 €
	4.000,00 €	27.004,19 €	25.827,72 €	24.651,25 €	22.298,31 €	19.945,36 €	18.673,60 €
	5.000,00 €	34.049,35 €	32.872,88 €	31.696,41 €	29.343,47 €	26.990,53 €	25.718,76 €

		Modelling costs					
IRR 10yr	3%	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 5.000,00 €	- 7.000,00 €	- 8.081,00 €
Savings	1.395,00 €	93%	45%	28%	13%	6%	3%
	2.000,00 €	133%	66%	43%	23%	14%	10%
	3.000,00 €	200%	100%	66%	38%	26%	21%
	4.000,00 €	267%	133%	89%	53%	36%	31%
	5.000,00 €	333%	167%	111%	66%	47%	40%

		Modelling costs					
ROI 10yr	15%	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 5.000,00 €	- 7.000,00 €	- 8.081,00 €
Savings	1.395,00 €	830%	365%	210%	86%	33%	15%
	2.000,00 €	1233%	567%	344%	167%	90%	65%
	3.000,00 €	1900%	900%	567%	300%	186%	147%
	4.000,00 €	2567%	1233%	789%	433%	281%	230%
	5.000,00 €	3233%	1567%	1011%	567%	376%	312%

Figure 14: NPV, IRR and RoI medium-term analysis for SES Building

In the medium-term BaaS System is always viable in SES and is fully viable if savings are higher than 2,000€/yr and modelling costs are up to 5,000€.

Long-term: 15 years

		Modelling costs					
NPV 15yr	4.551,55 €	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 5.000,00 €	- 7.000,00 €	- 8.081,00 €
Savings	1.395,00 €	12.882,14 €	11.705,66 €	10.529,19 €	8.176,25 €	5.823,31 €	4.551,55 €
	2.000,00 €	18.979,24 €	17.802,77 €	16.626,30 €	14.273,35 €	11.920,41 €	10.648,65 €
	3.000,00 €	29.057,09 €	27.880,62 €	26.704,15 €	24.351,21 €	21.998,27 €	20.726,50 €
	4.000,00 €	39.134,94 €	37.958,47 €	36.782,00 €	34.429,06 €	32.076,12 €	30.804,36 €
	5.000,00 €	49.212,80 €	48.036,33 €	46.859,86 €	44.506,92 €	42.153,97 €	40.882,21 €

		Modelling costs					
IRR 15yr	8%	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 5.000,00 €	- 7.000,00 €	- 8.081,00 €
Savings	1.395,00 €	93%	46%	30%	17%	10%	8%
	2.000,00 €	133%	67%	44%	26%	17%	14%
	3.000,00 €	200%	100%	67%	40%	28%	24%
	4.000,00 €	267%	133%	89%	53%	38%	33%
	5.000,00 €	333%	167%	111%	67%	47%	41%

		Modelling costs					
ROI 15yr	73%	- 1.000,00 €	- 2.000,00 €	- 3.000,00 €	- 5.000,00 €	- 7.000,00 €	- 8.081,00 €
Savings	1.395,00 €	1295%	598%	365%	179%	99%	73%
	2.000,00 €	1900%	900%	567%	300%	186%	147%
	3.000,00 €	2900%	1400%	900%	500%	329%	271%
	4.000,00 €	3900%	1900%	1233%	700%	471%	395%
	5.000,00 €	4900%	2400%	1567%	900%	614%	519%

Figure 15: NPV, IRR and RoI long-term analysis for SES Building

In the long-term BaaS System is fully viable in SES if modelling costs are up to 5,000€.

4.4 Conclusions

Once the sensibility analysis is done, some conclusions appear taking into account the results in the pilot buildings:

1. Energy savings (%) potential is high.
2. Economic viability to apply BaaS system depends on modelling costs and economic savings:
    a. Nowadays modelling costs needs high skilled profiles, so need to be reduced to be applied.
    b. Economic savings depends on the energy consumption of the building and on the energy prices.
        i. Low energy consumption buildings are no BaaS System target.
        ii. Nowadays energy prices (gas or electricity) are very low, so need to be increased to make BaaS System more viable.

Considering this general conclusions, it is possible to have individual conclusions per pilot building:

- **CAR Building**: Economic savings is the main barrier to apply BaaS System in CARTIF in a viable way. Energy savings potential is acceptable, but CAR Building is a low-energy consumption building and energy prices in Spain in the current market are very low. CAR building is not in the target of BaaS System.
- **ZUB Building**: In this building exits a balance between economic savings and modelling costs as main barrier to apply BaaS System. Energy savings potential is acceptable, but is a low-energy building. Viability is possible because the energy price is a medium level and modelling cost is medium too. ZUB Building is probably not in the target of BaaS System.

- **SES Building**: BaaS System is viable in SES Building, with minor adjustments in the modelling costs, in all the situations.

5 Replication potential analysis

The typology of buildings considered in this project, according the Directive 2010/31/EU on energy performance of buildings, is the following:

- Offices
- Educational buildings
- Healthcare
- Hotels and restaurants
- Sport Facilities
- Wholesale and retail.

Considering the BPIE survey and the results of the study developed in Deliverable 6.1 "*Identification and definition of BaaS demonstration buildings*" the most representative buildings from the point of view of surface and energy consumption are:

1. Wholesale and Retail
2. Offices
3. Educational buildings.

In addition, all the results obtained with BaaS are deployed in Offices (CAR Building and ZUB Building) and in Educational Buildings (SES Building). From the replication point of view, the potential energy savings in this sectors applying BaaS are:

Building typology	Replication typology	Replication Savings
Offices	**Offices**	**15%-20%**
Educational buildings	**Educational buildings**	**18%**
Healthcare	Offices	15%
Hotels and restaurants	Offices	15%
Sport Facilities	Educational buildings	18%
Wholesale and retail	Offices	15%

Table 24: Potential energy savings

The criteria to assume the replication typology in those typologies where BaaS was not applied is the following one:

- Healthcare, Hotels and Wholesale buildings use HVAC systems at the same level to heating or cooling → "Offices" typology.
- Sport facilities buildings use HVAC system to produce heat or cool in different levels, usually one of them is the primary use → "Educational" typology.

Once the characterization is done, the next step is trying to obtain the energy average consumption and the floor area average per building typology.

Using the database from ENERDATA [11], the breakdown of non-residential floor areas by sub-sector is the following:

Unit 1,000 m2	Offices	Wholesale & trade	Hotel & restaurant	Health	Education	Other
Austria	36.515	14.051	36.347	4.570	13.610	9.228
Belgium	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bulgaria	28.000	11.700	1.200	4.040	9.700	9.203
Cyprus	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Czech Rep.	35.615	15.750	1.479	5.142	12.410	18.342
Denmark	55.125	13.899	5.321	3.667	18.247	26.236
Estonia	1.855	2.061	572	538	2.059	4.930
Finland	14.454	35.493	5.986	8.426	13.646	29.114
France	205.298	207.194	64.119	116.864	189.174	124.723
Germany	347.176	508.900	284.600	64.374	207.688	42.835
Greece	26.216	28.391	26.057	1.960	43.600	13.755
Hungary	5.013	25.861	28.463	11.236	15.995	12.184
Ireland	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Italy	56.674	151.539	41.389	31.038	73.255	73.418
Latvia	4.116	2.638	1.431	1.328	4.441	2.622
Lithuania	8.853	8.759	n.a.	2.793	10.746	n.a.
Luxembourg	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Malta	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Netherlands	37.382	88.877	13.352	5.416	14.028	135.764
Poland	88.510	95.853	42.693	10.248	101.637	46.439
Portugal	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Romania	7.814	18.300	5.170	9.250	17.430	1.375
Slovakia	6.769	299	5.605	6.730	13.841	4.906
Slovenia	7.256	6.934	3.005	1.243	3.652	5.433
Spain	83.588	78.815	36.218	19.056	54.524	77.796
Sweden	29.344	15.295	6.458	19.147	53.930	28.326
UK	135.665	279.486	67.399	23.268	94.175	136.105
Serbia	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Croatia	7.690	3.150	14.280	3.150	3.930	0

Table 25: Non-residential floor areas by sub-sector

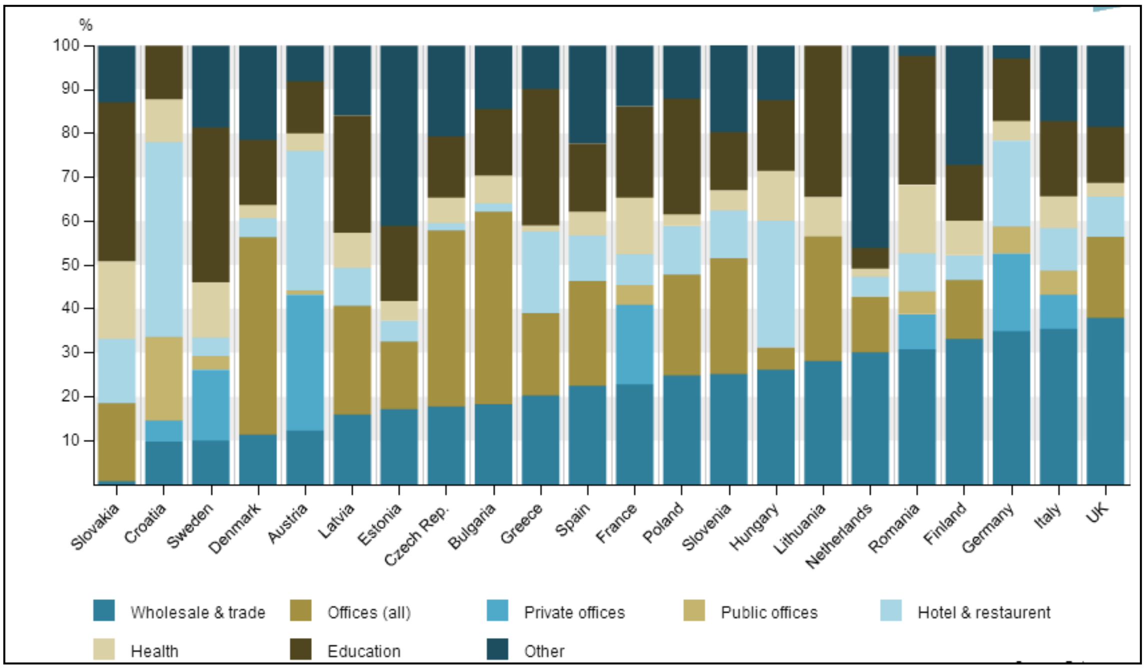

Figure 16: Percentage of non-residential floor areas by sub-sector [11]

Unit kWh/m²	Total	Gas	Electricity	Oil	District Heat	Biomass	Coal
Austria	**345,48**	67,33	124,73	51,66	89,85	11,26	0,66
Belgium	**553,90**	198,16	215,76	130,90	8,28	0,82	0,00
Bulgaria	**171,05**	15,04	113,29	11,14	20,62	9,84	1,11
Cyprus	**365,59**	0,00	259,15	91,01	0,00	15,43	0,00
Czech Rep.	**423,84**	181,53	163,64	2,19	59,28	6,28	10,93
Denmark	**195,67**	22,61	91,89	7,70	68,31	5,16	0,00
Estonia	**443,21**	38,45	222,62	35,42	120,42	23,27	3,04
Finland	**298,78**	3,21	164,45	27,57	96,23	7,09	0,22
France	**238,46**	78,11	103,86	40,00	16,51	n.a.	n.a.
Germany	**254,58**	103,29	77,05	41,18	28,86	3,83	0,37
Greece	**198,07**	11,53	151,32	34,86	0,00	0,36	0,00
Hungary	**347,54**	179,75	116,05	2,49	29,67	19,07	0,50
Ireland	**468,61**	100,36	214,84	142,70	0,00	3,92	6,80
Italy	**590,11**	336,05	231,04	22,67	0,00	0,36	0,00
Latvia	**444,77**	82,89	166,51	28,12	95,47	56,98	14,80
Lithuania	**244,17**	0,86	112,43	2,57	91,40	12,87	24,03
Luxembourg	**n.a.**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Malta	**209,81**	0,00	168,44	41,37	0,00	0,00	0,00

Netherlands	**326,35**	179,20	106,78	10,56	25,31	4,50	0,00
Poland	**229,99**	53,18	111,20	17,69	19,36	5,57	22,98
Portugal	**237,08**	14,98	138,39	48,30	1,38	34,04	0,00
Romania	**401,47**	191,04	130,99	1,89	55,56	21,99	0,00
Slovakia	**623,40**	289,69	186,00	8,29	62,85	3,51	73,06
Slovenia	**220,57**	5,54	114,12	92,83	6,81	1,28	0,00
Spain	**310,79**	23,06	213,74	69,94	0,00	3,95	0,10
Sweden	**304,13**	7,36	177,15	15,67	100,56	3,40	0,00
UK	**277,15**	115,44	137,04	16,63	6,27	1,50	0,27
Serbia	**n.a.**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Croatia	**263,30**	47,94	161,52	37,98	13,64	1,84	0,37

Table 26: Consumption per m² in non-residential building (at normal climate) [11]

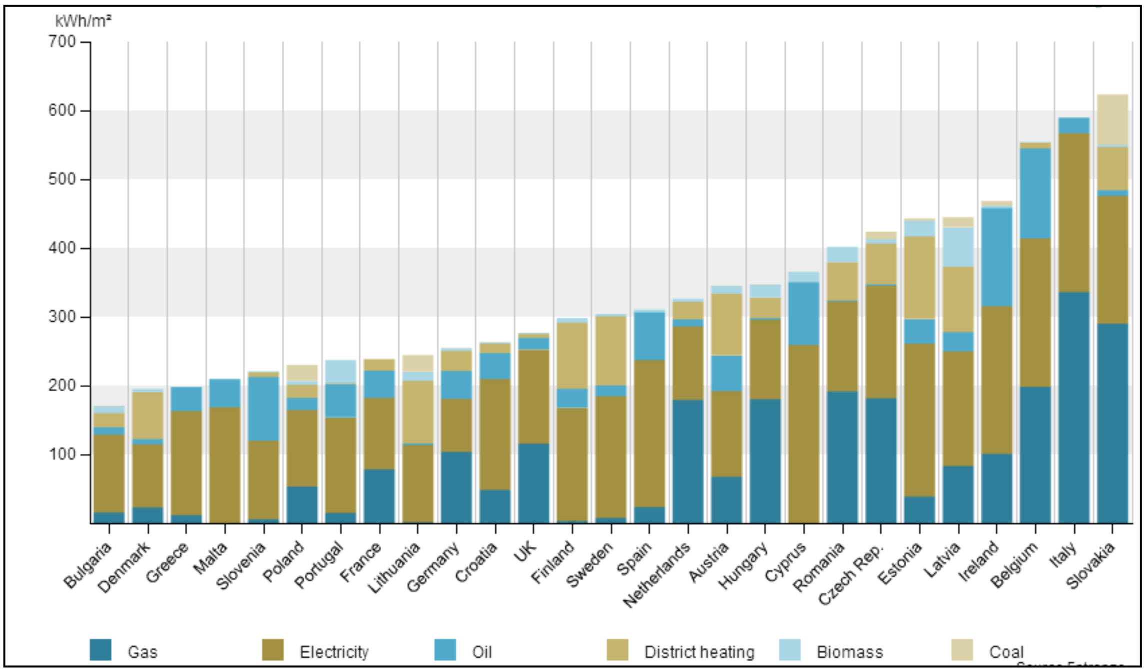

Figure 17: Consumption per m² in non-residential building (at normal climate) [11]]

As it can be observed in the previous tables and graph, there is a very high variability in the European countries, in terms of surface and energy consumption, but also in the energy prices.

After the previous considerations about the potential of energy savings from BaaS results as well as the data of energy consumption and building areas in Europe, the final step of this replication analysis is trying to determine minimum energy consumption from which the implementation of BaaS would be economically feasible, depending on the building typology and also depending on the range of conditioned area. Those buildings that meet these requirements would be a future target to deploy BaaS solution as ECM.

Next table includes the economic requirements to replicate BaaS in new buildings, which basically mean that the project should be viable at least for medium-term (T<10 yr), the net present value should cover the implementation costs and the minimum rate of return must be 5%.

Parameter	Criteria
Payback	< 10 yr
NPV	= Implementation costs
IRR	> 5%

Table 27: Economic criteria for BaaS replication

Three levels of building areas are distinguished, taking into account the reference ranges in the different European countries previously presented:

- S < 2,000 m^2
- S < 5,000 m^2
- S < 10,000 m^2

Applying these criteria, next tables summarize the results obtained regarding the minimum energy consumption (expressed in thousands of Euros per year) above which it can be considered that the deployment and use of BaaS is viable in that building (typology, surface).

Building typology	Replication Savings	Energy Consumption
Offices	15%-20%	6.5 k€/yr
Educational buildings	18%	5.4 k€/yr
Healthcare	15%	6.5 k€/yr
Hotels and restaurants	15%	6.5 k€/yr
Sport Facilities	18%	5.4k€/yr
Wholesale and retail	15%	6.5 k€/yr

Table 28: Minimum energy consumption in buildings < 2,000 m^2

Building typology	Replication Savings	Energy Consumption
Offices	15%-20%	13.1 k€/yr
Educational buildings	18%	10.8 k€/yr
Healthcare	15%	13.1 k€/yr
Hotels and restaurants	15%	13.1 k€/yr
Sport Facilities	18%	10.8 k€/yr
Wholesale and retail	15%	13.1 k€/yr

Table 29: Minimum energy consumption in buildings < 5,000 m^2

Building typology	Replication Savings	Energy Consumption
Offices	15%-20%	19.4 k€/yr
Educational buildings	18%	16.1 k€/yr
Healthcare	15%	19.4 k€/yr
Hotels and restaurants	15%	19.4 k€/yr
Sport Facilities	18%	16.1 k€/yr
Wholesale and retail	15%	19.4 k€/yr

Table 30: Minimum energy consumption in buildings < 10,000 m^2

Therefore, when evaluating if BaaS solution could be implemented or not on a new building as energy conservation measure, an ESCo could take the previous calculations for minimum values as reference for a preliminary analysis of viability of the project.

If the building characteristics (i.e. typology, conditioned area, range of energy consumption, energy system...) meet these requirements, the project is *a priori* feasible and further analyses should be undertaken in order to ensure that the potential of energy savings generated with BaaS solution is enough to amortize the investment (i.e. implementation and licence costs) at short or medium term and with an attractive rate of return for the business. Other strategic and business criteria, specific from each company, also have an influence on the final decision.

6 Conclusions

This document describes the end-user acceptance of the implementation and use of BaaS in the three pilot buildings, assessing the different technical and economic aspects from the end-user point of view in order to replicate BaaS in order potential buildings.

Regarding the **technical requirements**, the first conclusion that should be remarked is that CAR Building and ZUB Building cover all the requirements which highlight the needs of the end-user. It is only remarkable, within the non-functional requirements, that the performance is the only which is not fully achieved. This comment can be extrapolated to the rest of the pilots, although it is considerable in the CARTIF building. SES Building does not cover the modelling and simulation objective, but from end-user point of view cover the energy savings objective and also the fault detection.

All the partial requirements are aligned with the overall objectives of the end-users: energy savings, comfort improvement and fault detection. From this point of view BaaS is deployed successfully in each Pilot Building.

Considering the **end-users' perception**, the outcomes in the three pilot buildings are very successful in terms of energy savings achieved, operation and maintenance improved, comfort level increased, with the special attention to SES to the bad conditions and discomfort of the original situation previous to BaaS project. Different surveys were performed to gather the end-users opinion, considering operators, technical staff, client, workers, children...

A comprehensive **sensibility analysis** has been also here undertaken for the three pilot buildings of the project. From an economic point of view, the viability to implement BaaS system on a building depends on the modelling costs and the economic savings achieved as a result of the reduction of the energy consumption. On the one hand, modelling costs are very high nowadays due to the high-level skills needed for accurate and complex energy models. On the other hand, economic savings are not enough in low-energy consumption buildings, so that they would not be the first target for BaaS solution. Nevertheless, the results are quite promising in old buildings with high energy consumption and hence the economic viability indicates that they should be the main target for the use of BaaS system as ECM. In high-performance buildings, such as CAR and ZUB, BaaS solution is not feasible in the current status of the market. In the case of low-performance buildings, BaaS would be always fully-viable as ECM with minor adjustments in the modelling costs.

In addition, it should be remarked that the energy prices (both natural gas and electricity) in the current market are very low due to the global economic situation. A future increase on the energy prices, will entail that BaaS ECM will be viable in a wider range of buildings and more profitable in high-energy buildings.

Last but not least, in order to complete the present study within a global context of "end-users acceptance", a study of the **replication potential** of BaaS solution has been carried out as well. For this analysis, the different typologies of buildings initially considered in this project have been addressed (i.e. offices, educational, health-care, hotels and restaurants, sports facilities, and wholesale and retail). After that, the analogy between the typologies already addressed in BaaS pilot buildings (i.e. offices and educational) and the others buildings in order to obtain an estimation of the expected energy savings. The next step is to obtain an order of magnitude of energy consumptions and floor areas of the considered buildings categories in the different European countries, in order to calculate a reference ratio of kWh/m^2. The results show that a high variability appears regarding the energy prices, range of consumptions and building areas of the different countries.

The final step of the replication analysis establishes some minimum energy consumptions above which the implementation of BaaS would be economically feasible, depending on the building typology and the conditioned area. To that end, we use the potential energy savings previously considered by analogy and we distinguish three levels of building areas; in order to have more realistic results.

Applying these criteria, some relevant results are obtained regarding the minimum energy consumption (expressed in thousands of Euros per year) above which it can be considered that the deployment and use of BaaS is viable in that building (typology, surface).

Non-residential buildings have a high potential of energy savings (more than 15%), but it is necessary to do a previous assessment of the energy costs. The energy savings achieved with BaaS ECM need to be supported in a project viable at least for medium-term (T<10 yr), a net present value equal to the implementation costs and a 5% of return.

Those buildings that meet these requirements would be a future target to deploy BaaS solution as ECM. Therefore, when a building under study meets these requirements, the project is *a priori* feasible and further analyses should be undertaken.

Ensuring that the potential of energy savings generated with BaaS solution is enough to amortize the investment (i.e. implementation and licence costs) at short or medium term and with an attractive rate of return for the business, as well as other strategic and business criteria, specific from each ESCo, are factors to be taken into account.

7 References

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

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

[3] BaaS Consortium. "BaaS Deliverable 2.5: Prototype documentation, deployment, evaluation, monitoring and support". Technical Report. April 2016.

[4] BaaS Consortium. "BaaS Deliverable 5.4: Deployment, evaluation, monitoring and support of SO2 integrated services: Software components report". Technical Report. April 2016.

[5] BaaS Consortium. "BaaS Deliverable 4.4: Evaluation of the WP5 results under different KPIs: Report". Technical Report. April 2016.

[6] BaaS Consortium. "BaaS Deliverable 6.3.3: Reporting period in pilot buildings". Technical Report. April 2016.

[7] BIM Academy. http://bimacademy.es/en/

[8] Colegio Oficial de Ingenieros Industriales de Madrid. http://www.coiim.es/

[9] BPIE. "EUROPE'S BUILDINGS UNDER THE MICROSCOPE". 2011

[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.

[11] http://www.entranze.enerdata.eu/ September 2016