BaaS

BaaS

Buildings as a Service

http://www.baas-project.eu

SEVENTH FRAMEWORK PROGRAMME

European Commission

This project is funded by
7th Research Framework Programme

Project Overview

Objectives

The BaaS system aims to optimize energy performance in the application domain of non-residential buildings in operational stage. In the building operational life-cycle three significant tasks have to be continuously performed: collect information and assess the buildings current state; predict the effect that various decisions will have to Key Performance Indicators (KPIs) optimization.

A generic ICT-enabled system will be developed to provide integrated assess, predict, optimize services that guarantee harmonious and parsimonious use of available resources.

This major objective is also pursued within BaaS via a number of multifaceted actions and Scientific & Technological Objectives:

Scientific Objectives SO1

Development of building modelling and simulation for energy performance estimation and control design.

Scientific Objectives SO2

Development of integrated Automation and Control Services.

Technological Objective TO1

Development of data Management: Working on existing initiatives and ongoing projects results, integrating State of the Art of extended BIM, EEB Ontologies and Standards.

Technological Objective TO2

Development of middleware Platform: System Integration, Interoperability And Standards

Approach

The **BaaS system** comprises four components:

A **data management** component to collect, organize, store and aggregate data from various in- and out-of-building sources. An (IFC-based) BIM will act as a central repository for all static building data, and a data warehouse will be used for dynamic data.

A **service middleware platform** to abstract the building physical devices, support high level services on the cloud and facilitate secure two-way communication between the physical and ICT layers (building) with high level services (cloud).

Energy models for performance estimation and for control services, looking for a trade-off between prediction accuracy (performance estimation) and computational complexity (fast-model for control design).

Assessment, Prediction and Optimization Service such as:

- **Assessment and prediction services:** simulation models, acting as surrogates of the real building, incorporating sensor dynamic data, will be used to assess performance and comprehensively estimate the values of relevant KPIs as well as help perform sensitivity analyses;

- **Optimization service,** automatically will generate holistic nearly-optimal control strategies with the goal of achieving operational efficiencies as measured through relevant KPIs and will be imbued with adaptive and re-configurability properties to respond to faults and atypical scenarios.

Upon verification of component interoperability, and development of a measurement and verification plan, the BaaS system will be demonstrated in two buildings and will be validated as an Energy Conservation Measure with Energy-Services Companies as the end-user.

End-user acceptance will be accomplished by analysing the replication potential in tandem with the results of a sensibility study.

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Fundación Cartif

Fundación CARTIF is a leading Spanish Applied Research Centre in terms of R&D and technology transfer activities created in 1994. CARTIF is formed up by 9 technical divisions and 200 researchers specialised in several areas such as Energy, Environment, Food and Chemicals, Biomedical, Robotics, etc. In 2010 CARTIF carried out over 100 R&D and innovation projects, with a turnover of approximately 12M€.

Information and Communications Technologies (ICT) and Energy are two of the main research areas of CARTIF. Both together have created a multidisciplinary group focused on the application of ICT in the field of Energy, in particular Energy Efficiency, Energy Saving integration of Renewable Energy Systems, Electricity Market, Demand Response, Smart Grid, etc.

NEC Laboratories Europe

Empowered by Innovation

NEC Corporation is a leader in the integration of IT and network technologies that benefit businesses and people around the world. By providing a combination of products and solutions that cross utilise the company's experience and global resources, NEC's advanced technologies meet the complex and ever-changing needs of its customers. NEC brings more than 100 years of expertise in technological innovation to empower people, businesses and society. NEC Europe is a subsidiary of NEC Corporation based in the UK that builds upon its heritage and reputation for innovation and quality by providing its expertise, solutions and services to a broad range of customers, from telecom operators to enterprises and the public sector. NEC Laboratories Europe is a laboratory established by NEC Europe Ltd. and is located in Heidelberg, Germany. NEC Labs Europe conducts leading research and development across IT and communications, including Future Internet and OpenFlow, next generation fixed and mobile networks, M2M, context-aware platforms and services, the Internet-of-Things, multimedia, security, energy-saving services and green technology. Special emphasis is placed on solutions that meet the needs of NEC's European customers and as well as collaboration with industrial and academic partners within the European R&D Framework Programme (FP7, etc.).

Honeywell Prague Laboratory

Honeywell is a diversified technology and manufacturing leader, serving customers worldwide with aerospace products and services, control technologies for buildings, homes and industry, automotive products, turbochargers, and specialty materials. Advanced control products and energy management services for homes and buildings represent an important part of Honeywell Automation and Control Solutions (ACS).

Honeywell customers range from individual homeowners to larger commercial and governmental buildings, health care facilities, airports, schools, and military bases. Honeywell Prague Laboratory – part of Honeywell spol. s r.o. – is an R&D organization involved in development of new solutions for the process industries, homes and buildings, as well as in the fields of video surveillance and security.

Fraunhofer IBP

The Fraunhofer Institute for Building Physics (IBP) deals with research, development, testing, demonstration and consulting in the fields of building physics. This includes noise control, sound insulation measures in buildings, optimization of audibility conditions in audiences, energy saving measures, lighting technology, questions of indoor climate as well as aspects of moisture and weathering protection, the preservation of building structures and of historical monuments.

The fields of research that the Fraunhofer Institute cover include: research, development, testing, demonstration, and consultancy in the field of building physics: acoustics, sound insulation, lighting, energy conservation, indoor climate, durability, hygrothermics, building chemistry and building biology.

Technical University of Crete

The Technical University of Crete TUC is a research-oriented university with activities encompassing a number of engineering disciplines. The mission of TUC is to contribute to the advancement of the state-of-the-art in pertinent technological fields while establishing and maintaining close cooperation with the industrial- and production-sectors in Greece and abroad.

The TUC research group has significant experience in the area of ICT for Energy Efficiency. A non-exhaustive list of research activities in pertinent to the BaaS project research areas include: development of cloud-based building monitoring and control systems; integration technologies; development of building simulation software; development of algorithms to facilitate intelligent building operation. The TUC research group has significant experience in the area of ICT for Energy Efficiency and a computer cluster to support computational activities. In addition, a building on TUC campus has been fitted with an extensive sensing infrastructure and a web-based monitoring and control ICT system has been developed–this building will act as a test-bed for algorithm testing and ICT tool development in the BaaS Project.

University College of Cork

UCC is a state-owned University structured into four Colleges. UCC wil be involved in the project through IRUSE (Informatics Research unit for Sustainable Engineering) as UCC-IRU. UCC-IRU is committed to the research and development of Sustainable Built Infrastructure, Systems and Technologies. Current research areas are Information Technology in Architecture, Engineering, and Construction as well as Building Energy Systems, Buildings Operation and Facilities Management. UCC-IRU is member of the European Construction Technology Platform (ECTP-FA7), CITA (Irish Construction Information Technology Alliance).

UCC-IRU has extensive experience in the area of ICT for Energy Efficiency. UCC-IRU research agenda addresses the need for integration concepts, holistic monitoring and analysis methodologies, lifecycle oriented decision support and sophisticated control strategies through the seamless integration of people, IT devices and computational resources. UCC-IRU have already developed a data warehouse system for its ongoing national projects that will be subsequently customised to match the requirements of various application domains and deployed in BaaS project. The motivation of UCC-IRU in BaaS is to collect, consolidate and analyse data and standardise data models.

Veolia Environment

Around the globe, Veolia helps cities and industries to manage, optimize and make the most of their resources, improves the technical, financial and environmental performance of the facilities it manages on the behalf of local authorities and businesses.
From design and engineering to energy procurement and facility operation and maintenance, all of Veolia's services are performed with a focus on sustainable development. Its goal is to leverage local resources and minimize each facility's impact on the environment, while reducing both fossil fuel consumption and greenhouse gas emissions. Veolia provides cost-effective, eco-friendly energy efficiency services that include performance guarantees for the public-and private-sector customers around the world.

Work Package WP1
Theoretical Case Studies and End-user Acceptance

Objectives

WP1 is an end-user-driven work package. It continuously monitors the proper alignment of RTD outcomes with the application domain of "non-residential" buildings, in operational stage. The main objective of WP1 was to reach:

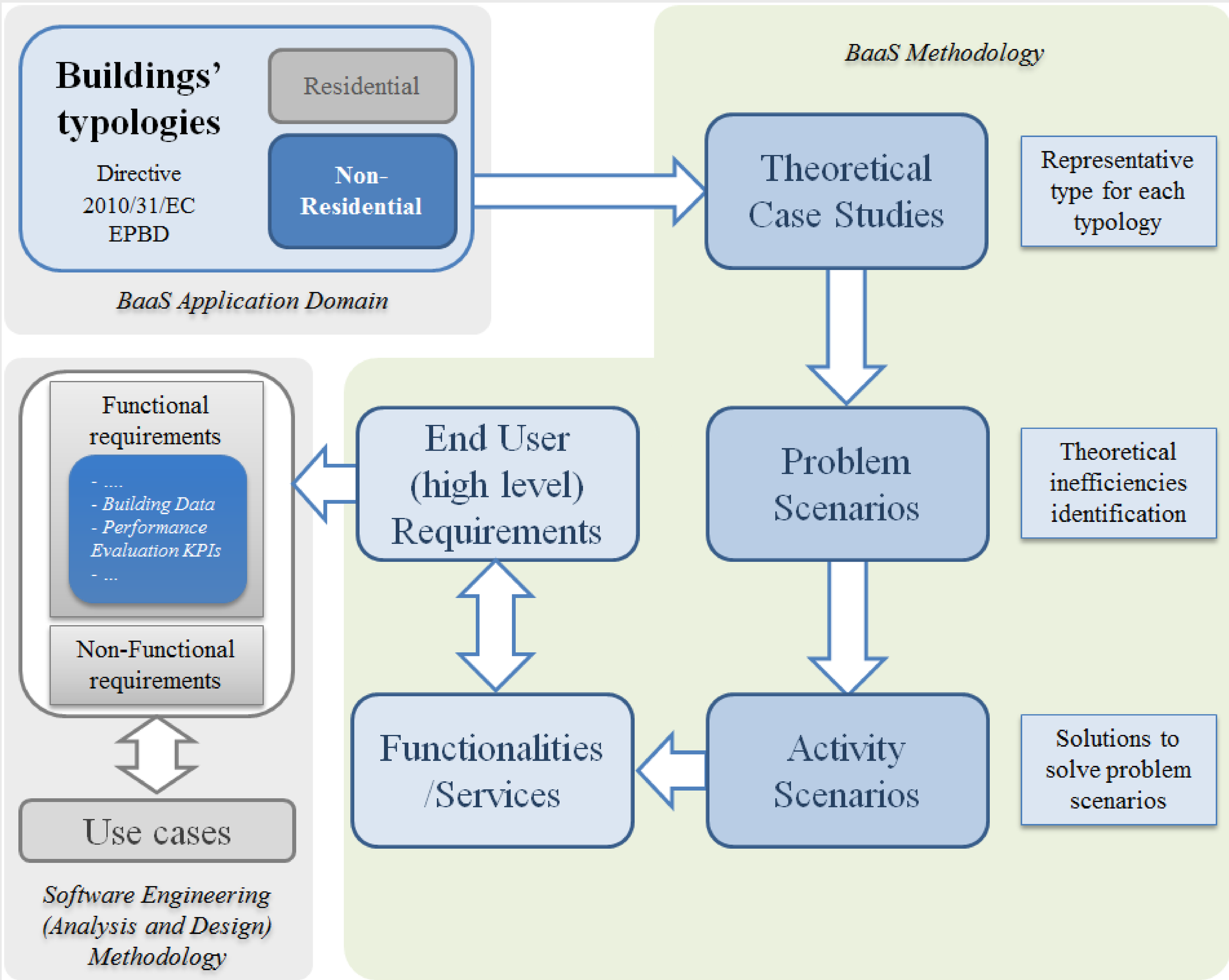
- A proper alignment with the application domain assuring replication of the BaaS solution on the whole typologies of buildings.
- A methodology of measurement and verification (M&V) of Energy Savings. BaaS aims on enhancing and using the results of on-going EC funded initiatives.
- A suitable end-user acceptance level by the end of the project.

Approach

These objectives are being achieved through:

- Six theoretical case studies have been developed to analyse each of the six typologies of buildings which completely characterize the BaaS application domain.
- A set of key performance indicators (KPIs) have been identified and defined for each case study.
- These theoretical case studies were assigned as starting point for the remaining tasks in WP1 and also for the scientific and technological Work Packages 2, 3, 4, and 5.
- After the validation in demonstration buildings, selected in WP6 (belonging 3 typologies: offices, hotel and educational) in this WP1 the replication potentials of the BaaS Solution were analysed over the remaining buildings typologies (hospital, sports facilities and wholesale) which have not been selected as pilots.
- End-user acceptance was accomplished by analysing the replication potential in tandem with the results of a sensibility study.
- To achieve the savings evidence (through which potential benefits were calculated in the sensibility study), this work package, in conjunction with the demonstration WP6, defined (in WP1) and implemented (in WP6) a methodology to validate the expected savings associated to the project outcomes. Data obtained from WP6 was used to develop the sensibility study corroborated with real evidence of savings.

Task 1.1: Theoretical Case Studies Definition
In this task, six theoretical case studies have been developed to analyse each of the eight typologies of buildings which characterize the BaaS application domain (offices, hotel, educational, hospital, sport facilities and wholesale and retail). For each of the six theoretical case studies, analysis developed identifies problem scenarios and functional and non-functional requirements for which the BaaS system has been designed to address.



Scheme of the methodology for the development of the BaaS System

Task 1.2: Methodology of Measurement and Verification of Energy Savings
A methodology to record evidence, in an accurate way, of energy savings and CO2 emissions reduction and to measure and certify energy-savings attributed directly to the BaaS system (as an isolated retrofit-measure) has been identified. This methodology is the International Performance Measurement and Verification Protocol (IPMVP). In the project, the retrofits or (Energy Conservation Measures) ECMs to isolate will be the implementation of the BaaS Solution.

Task 1.3: End-User Acceptance Assessment
The goal of this task is ensuring proper implementation of Task 1.1 requirements in WP4 and WP5 and end-user acceptance. This task was in charge of the necessary functional requirements, partial-results monitoring and validation, at the end of the project, to ascertain end-user acceptance.

Achievements

As planned, the Theoretical Case Studies were analysed from the point of view of the problem scenarios affecting them, and solutions to solve these problems, i.e. the activity scenarios. Thus, the functionalities and services that will implement these activity scenarios, were used to define all the requirements that the BaaS System should fulfil from the end-user point of view) that were used by the technological WPs of the project.

Besides, main existing measure and verification protocols have been reviewed, emphasizing on a comparative among their characteristics focusing on how them evaluate savings in the ICT context. As result of this study, the International Performance Measurement and Verification Protocol (IPMVP) was selected for measuring the savings due to the BaaS system.

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- Dalkia Energía y Servicios

Work Package WP2
Building Data: interoperability and standardization

Objectives

This work package aims on improving building data interoperability and standardization. Specifically, the work package objective was to collect, aggregate, integrate and use the existing buildings' product and process data and data models. It is concerned with interoperability and standardization of the data modeling (static and dynamic data). Therefore, in this work package we've specified and developed an extended data warehouse and a Building Information Model (BIM) based on standardized data model and functions.

The starting point was the current initiatives and on-going projects working on complementary topics and with aligned technological interests to exchange information and share experiences (BuildingSMART, HESMOS, CAMPUS-21) on developing and using an updated "Enhanced BIM with EE and FM extensions" (ISO/PAS 16739 and the newer version IFC2x4 which has a more comprehensive coverage in the data model of systems, sensors, controls).

These WP's activities were in charge of providing data (in the operation and maintenance building stage) supporting the requirements of energy models, simulations and algorithms addressed at the proposal (WP4 and WP5).

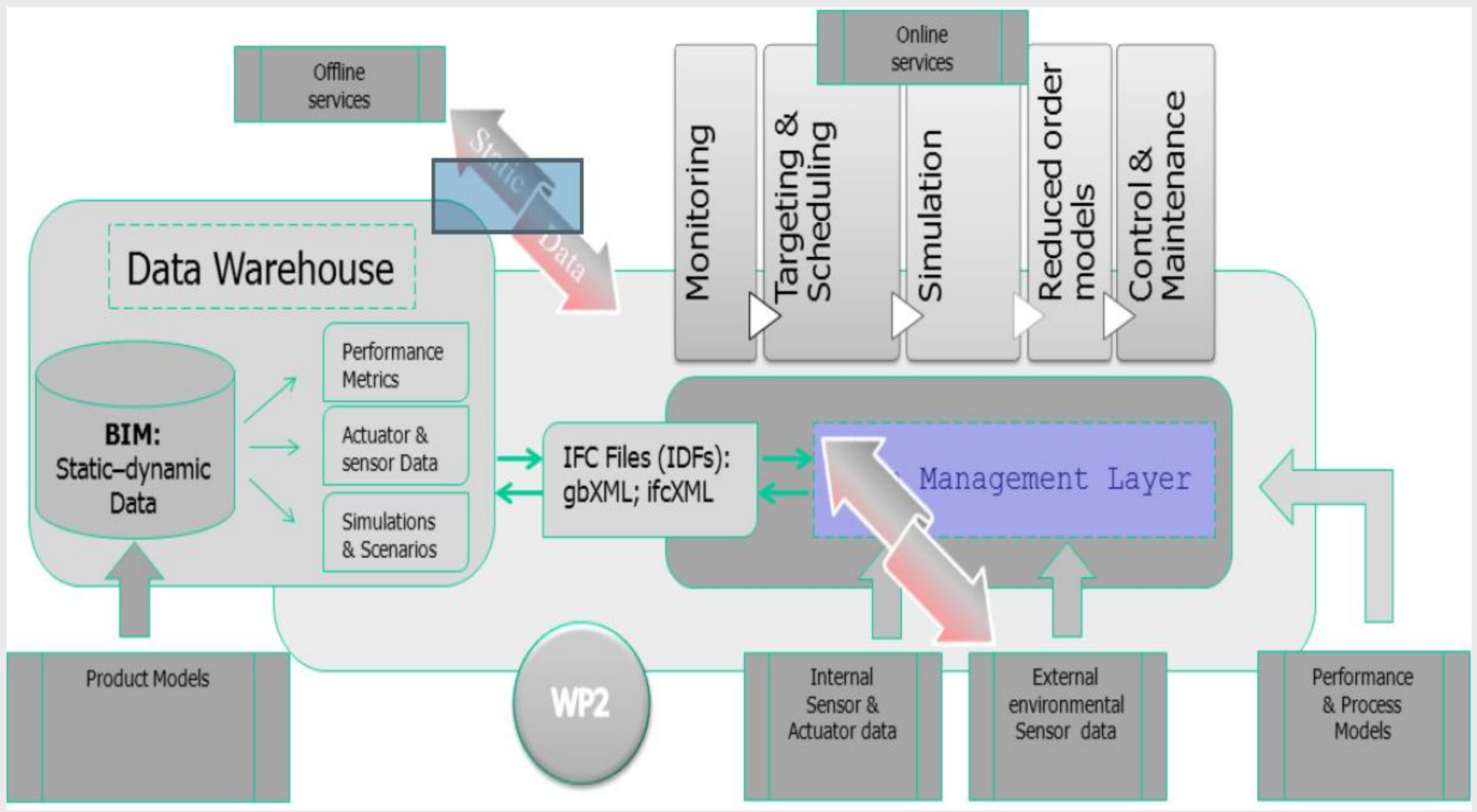
Approach

Information and data collected from multiple sources was consolidated, integrated, aggregated and pre-arranged for complex data-mining processes. The Extended Data Warehouse was the main consolidated data source of the BaaS network and contains all relevant product, process and performance data of the built artifacts being managed.

Task 2.1: Data Warehouse Requirements and extended BIM Specification
This task was in charge of developing a Building Information Model (BIM) specification utilizing formal standard definitions (data & functions) of engineering building components (e.g. pumps, valves), systems (e.g. Air handling units, heat pumps, solar panels) and sensors (temperature, relative humidity, CO2, VOC's) as specified by professional engineering institutions CIBSE and ASHRAE.

Task 2.2: Data Warehouse
In this task, using off-the shelf software tools, we've developed a data warehouse that aggregate the raw data from the BIM and monitoring system, including monitoring and targeting of environmental and energy resources for single and multiple building portfolios, to support facility management activities.

Task 2.3: Standardized information exchange protocols
This task was in charge of designing and implementing the BIM specification from Task 2.1 using an ISO standard data model to facilitate seamless interoperability of the BIM with upstream activities that include data warehousing. ICT Building Blocks and downstream activities.



Task 2.4: Data imputation, Uncertainty propagation and Data integrity
In this task a methodology to address the identified inconsistencies in data was developed.

Task 2.5: Prototype deployment and validation
This task was working on a DW connected to the Middleware Platform (WP3), using IFC and ifcXML files, with functional capacity to deal with uncertainty.

Achievements

We have designed a piece of software which could clean data for sensors and meters for any chosen building and for any type of sensor and meter data in that building. We have demonstrated that it is feasible to run the software over long time periods of up to one year. We have also demonstrated that there is a methodology for checking the data cleaned by the software. We have verified the hypothesis that we have a methodology to clean data over any time horizon, which acts directly on the database and cleans the data in automated way.
The choice of SQL to implement the software meant that we achieved our goal of cleaning the data automatically, whilst acting directly on the database, and without the need to involve other external tools.

As a result of the activities developed in the WP2, the data model IFC4 has been selected as the standard to exchange building information among the different software elements of the BaaS Project system, especially chosen for its openness, interoperability and capacity to cover all the phases of the building life cycle, as well as the possibility to define and implement Model View Definitions (MVD). Regarding the BIM repository, the required servers are implemented with the open solution BIMServer 1.2 by TNO, adapted to the standard IFC4 as part of the activities of the Task 2.3; whereas the clients, required to perform queries and extract the building's data from the server, have been completely programmed in JAVA as part of the same task.

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Work Package WP3
Middleware Platform

Objectives

In work package 3, the middleware platform (called communication logic layer CLL in BaaS) was specified, implemented, and evaluated. The middleware is an effective, holistic service and provides integrated communication among all entities of the BaaS system, e.g. the physical building, its Building Information Model, the data repositories, the APO (assess, predict, optimise) services, and the GUI. The CLL takes into account existing open standards frameworks, SOA architecture, and security and privacy needs.

While designing the CLL, essentials for data description (integrating the data modelling results from WP2) were taken into account. Moreover, the functional architecture and the integration components for control strategy and real-time building performance as well as the detailed interface specifications are defined. Additionally, WP3 builds a service platform prototype upon which the WP5 APO services is implemented. The aim was to provide a robust and flexible service middleware platform architecture that can be applied to the theoretical use cases defined in WP1.

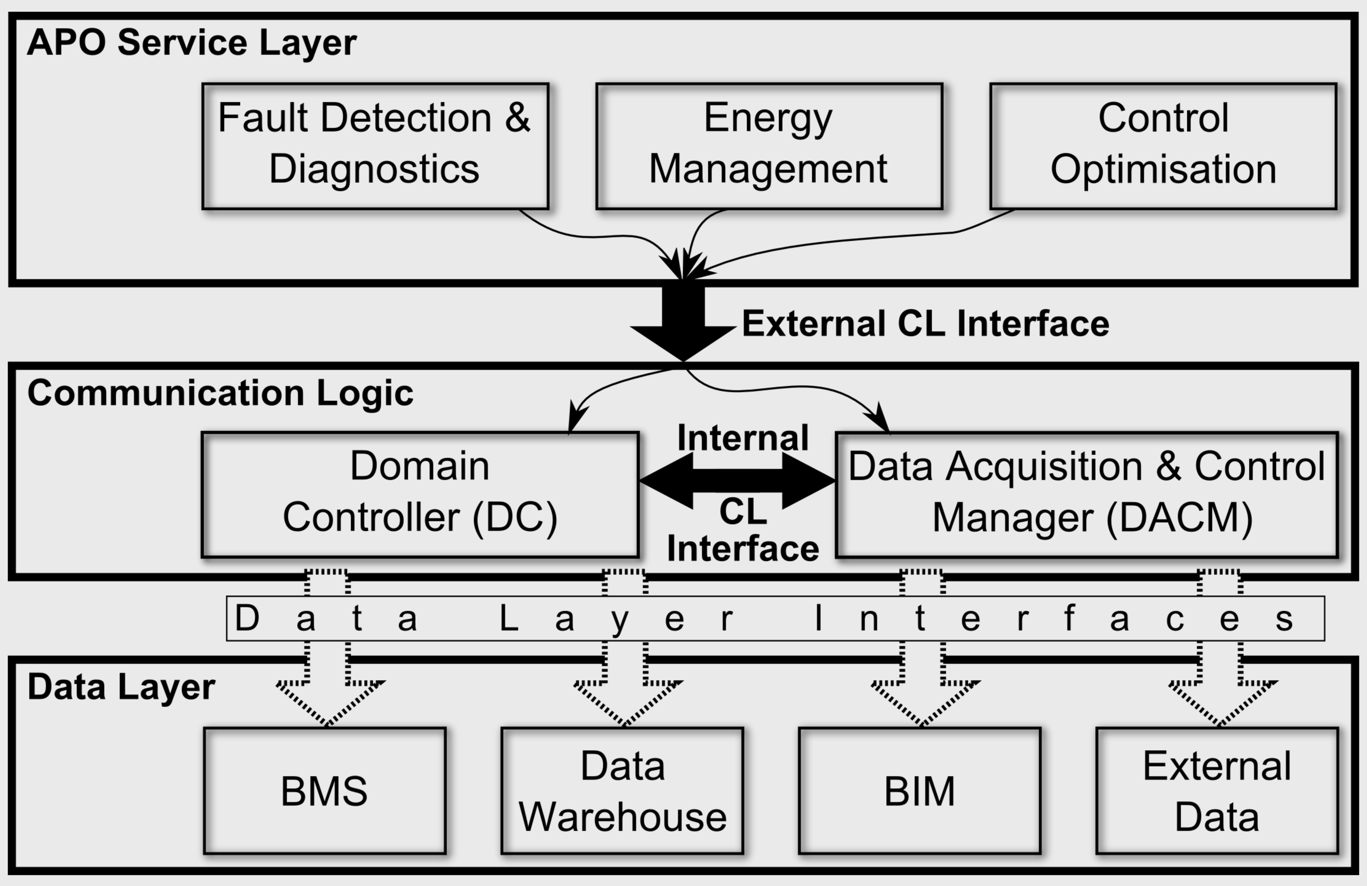
Approach

Task 3.1: Data Modelling Harmonisation
Task 3.1 provided an overview of the BaaS data modelling harmonisation efforts. Moreover, in line with the overall emphasis of work package 3 on the BaaS middleware, task 3.1 yielded the following results which form the basis for the remaining work in WP3 but also the entire project in general:

- The BaaS High-Level Architecture
- Data Model Extensions with emphasis on Industry Foundation Classes as defined under BuildingSmart release IFC 2x4 Release 3
- Data Model Security and Privacy Classification

Task 3.2: Functional Architecture
The BaaS system consists of three layers: the *Data Layer DL*, the *Communication Logic Layer CLL*, and the *APO Service Layer APO-S*. In Task 3.2, the functional architecture and their interconnections via interfaces were elaborated: The DL provides and stores data from various sources (BMS, data warehouse, BIM, etc.), the CLL reads and writes data from/to the DL and passes data on to the APO-SL, and the APO-SL provides intelligence for assessment, prediction, and optimisation as well as calculating KPIs and supporting decision-making. In order to achieve the system architecture, functional and non-functional requirements were collected. Together with the anticipated use cases, they were used to derive the functional components, functional blocks, and interfaces needed to design the functional architecture of the BaaS system and to deliver the desired functionality.

Task 3.3: Overall System Design
Task 3.3 result in four deliverables, each of them giving an in-depth description of a particular part of the BaaS system:
(1) Interfaces to external ICT systems
(2) Containers for service logic on performance and control strategies
(3) Detailed system design
(4) Development guide
Work on these deliverables is finished at the moment. Class diagrams, sequence diagrams, and interface specifications have been created. Class diagrams represent the relationship among the objects for implementing the functionalities of a specific component and provide the basis for the final implementation of the components and the communication among them.



Task 3.4: Prototype implementation
In task 3.4, the BaaS system which has been developed and defined in the previous tasks during the project, is actually implemented. The prototype system was deployed to several demo sites and tested thoroughly in order to prove the feasibility of the chosen approach and to demonstrate its viability in real-world environments.

Left: Schematic representation of the overall BaaS system design.

Achievements

During the BaaS project, WP3 made several fundamental decisions regarding the overall BaaS system design. Among others, a harmonised approach to the data models to be employed in the BaaS system has been presented, i.e. wherever possible an extended IFC model (based on 2x4 R3) and the BACnet protocol is used. Moreover, in order to allow the speedy and efficient implementation of a BaaS prototype to be deployed to several demo sites, the high-level system design has been introduced. This includes the description of use cases, scenarios, and functional requirements along with the distribution of data and functionality as well as the interfaces. Last, security and privacy considerations relating to the collection, storage, and processing of building data have been addressed.

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Work Package WP4
Building Energy Modelling and Simulations for Performance Estimation and Control

Objectives

The objectives of WP4 were to provide building modeling and simulation tools for energy performance (EP) estimation and control design integrating needed-simulation capabilities into the BaaS system.
In particular within WP4 the objectives are:

- to develop thermal simulation models capable of estimating performance (using both models and sensor measurements) so that it can be comprehensibly compared with actual measured performance;
- to create a simulation platform for testing and evaluating the control strategies developed in WP5 (advanced automation and control services for performance optimization of building operation);
- to develop simulation platforms for anomaly identification;
- to create simulation models amenable to control design;
- to integrate the simulation component in the BaaS framework.

Approach

Task 4.1: Simulation for energy estimation, interconnection to the BaaS system
For energy performance estimation zonal-type software is selected to perform the simulations.
There are several appropriate components developed to:

- Interface with the BIM and extract information about installed infrastructure in a building.
- Interface to the data warehouse to obtain dynamic data.
- Interface with external systems (e.g. weather service to obtain weather data).
- Interconnect the various components to permit the use of dynamic data.
- Experimental testing and verification of interoperability in the development test-bed (buildings).

Task 4.2: Simulation models for the pilot buildings
This task activity was diverted on creating a simulation models of varying complexity and accuracy ("just enough accurate") for the BaaS pilot buildings.
Subtask 4.2.1: Develop the thermal simulation models, for energy performance estimation.

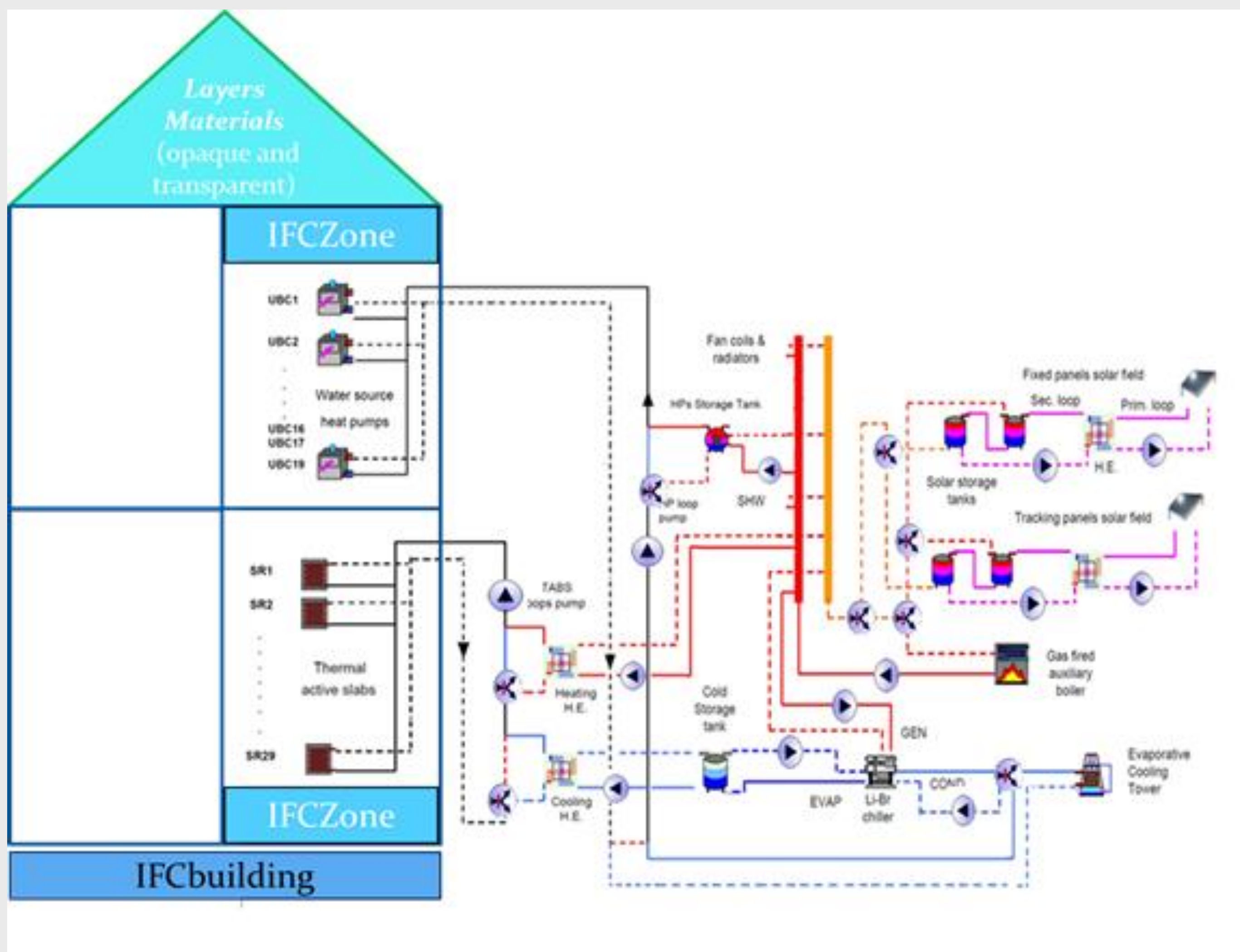
- Develop the simulation models for the zonal-type software selected in Task 4.1.
- Validate models under standard building operation.
- Verify that the components developed in T4.1 are of sufficient generality to interface with BIM & DW
- Evaluate KPIs defined in WP1. Suggest additional KPIs if deemed necessary.

Subtask 4.2.2: Model-reduction for control and monitoring

- Specify the computational complexity and accuracy requirements for each of the operations that the models will support (control design, monitoring and anomaly detection, etc.)
- Select a hierarchy of modeling and simulation approaches that could serve the requirements imposed
- Identify the structured model for pilots from available data, contextual information and EP models
- Verify against measurement data and compute deviations in KPI value predictions.

Task 4.3: Evaluation of control strategies on the pilot buildings

- To use EP models to assess control strategies developed in WP5 and compute relevant KPIs
- To evaluate the performance improvement and select KPIs to be optimized
- To test WP4 and WP5 algorithm integration before installing into real building, minimizing deployment impact. BaaS will be applied firstly in non critical zones increasing the complexity until a complete implementation.
- To compute energy performance and energy-efficiency comparing the control with the "no-control" strategies.



The schematic on the left represents the interconnection between the systems installed inside buildings to generate, distribute and deliver energy into the conditioned zones with building and its occupants. Utilization of the IFC types included into BIM's in combination with the online measurements obtained from the buildings permits the creation of simulation environments that accurately reproduce the real environments.

The simulation structures created are used by the APO's to evaluate different cases as Fault detection or to estimate the behavior of the set Building/equipment operated under new evolved control strategies development in WP5.

Achievements

During the BaaS project, WP4 developed the interfaces connected to the BIM servers, through the WP5, responsible of extracting the information needed to create the simulation environments. Furthermore, this information was used by other BaaS components to evaluate KPI's, control strategies, abnormal strategies of the building equipment.
It was defined the data characteristics that should present the components described with the IFC files for simulation purposes as well as the external values needed as can be the connection with weather station, weather forecasts, scheduled facts no present in the building definition and collecting of occupants votes in matters as climate and illumination comfort.

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Work Package WP5
Advanced Automation and Control Services for Performance Optimization of Building Operation

Objectives

The work in Work Package 5 concerned the design and development of advanced automation and control services for performance optimization during building operation. This includes development of proper analytics (Assess, Predict, and Optimize – APO services) and also a hosting platform (APO Kernel). The APO platform is an integration layer to support data access and communication needs of the APO Services. Together, the Kernel and the APOs comprise the business logic of BaaS; in general, there are three major types of inefficiencies were addressed by the APO services:

- **Hardware faults detection and diagnostics**. ***"You need a hammer to fix it."***
  Detect and possibly find a root cause (diagnose) of various equipment malfunctions and faults. Such faults may either prevent the system to operate and maintain required level of comfort or may lead to abnormal energy consumption caused by compensating a fault.
- **Control faults and inefficiencies monitoring and optimization.** ***"You need a keyboard to fix it."***
  Even properly working HVAC equipment may result in inefficient operation when not properly controlled. Control-related analytics monitor the applied control sequence to identify inefficiencies and, if needed, develop optimized strategies.
- **Equipment performance degradation and monitoring.** ***"Just looking what's going on"***
  Any equipment degrades over time and operating degraded equipment is more expensive. Various analytics can monitor equipment degradation and should a critical level for effective operation be reached, maintenance is scheduled.

Approach

Work was divided in four tasks:

Task 5.1: APO Services Functional and Interoperability Requirements
Understanding the data and functional requirements along with the interoperability constraints is critical for developing and deploying the BaaS APO service layer components. Within this Task these requirements were collected to drive the development of the required software components. The APO services kernel was introduced, a middleware service, supporting the interoperability and data access requirements of the APO layer. Also the APO Services to be supported (Fault Detection and Diagnostics, Energy Management, Control Design and Optimization) were defined.

Task 5.2: Anomaly and Event Identification and Diagnosis Services based on Energy Performance Estimation
Work within this task was focused on the development of the analytics components within BaaS. Starting from simple rule-based fault detection, to the more elaborate symptomatic treatment of anomalies, to model-based approaches, analytics components are being developed to form part of the BaaS business intelligence.

Task 5.3: Building Automation and Control (BAC) Algorithms Development
Within this task Building Automation and Control analytics are being developed. The focus was on developing supervisory control strategies; special emphasis is given to the implementation and testing of model-based control design strategies that optimize and automatically tune the control system parameters so that good performance with respect to energetic and comfort parameters can be obtained.

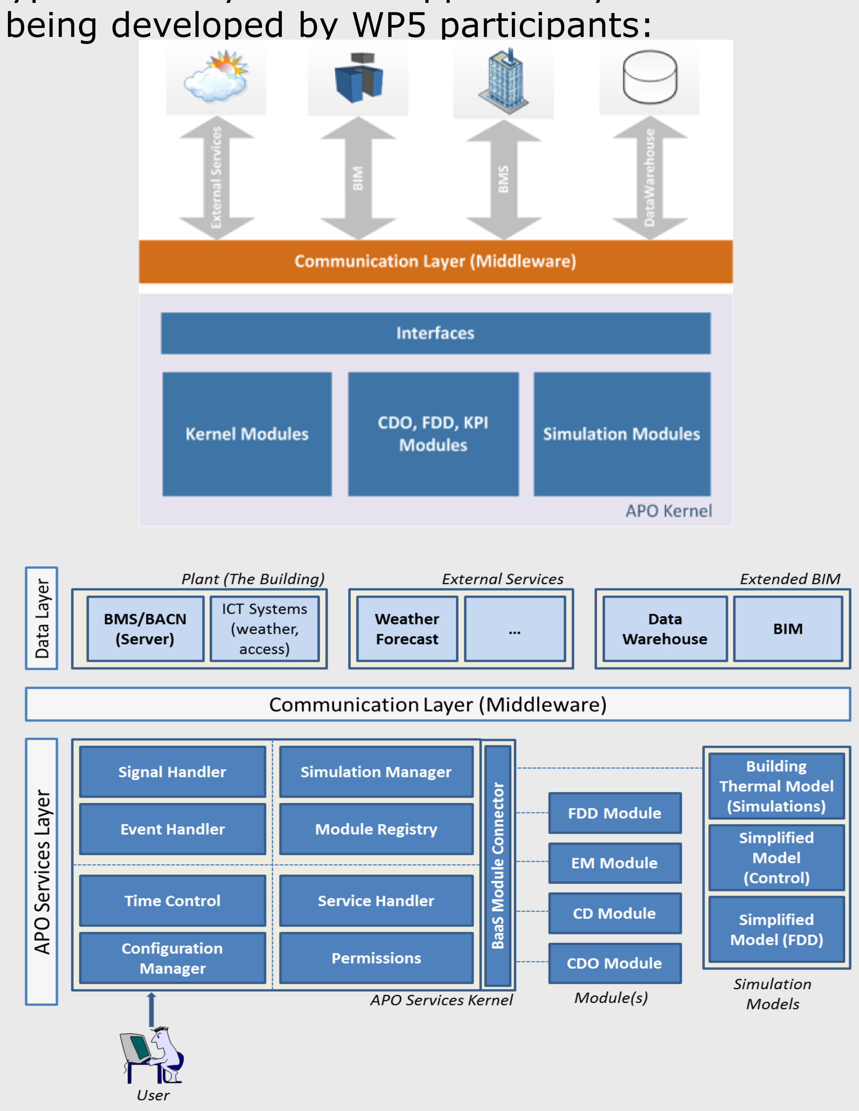
Task 5.4: Integration of BaaS APO Services
Integration of the APO Kernel with the middleware developed in WP3, so that the BaaS system can be realized. Deployment of the analytics modules developed in the previous tasks to the BaaS demonstration buildings.

Achievements

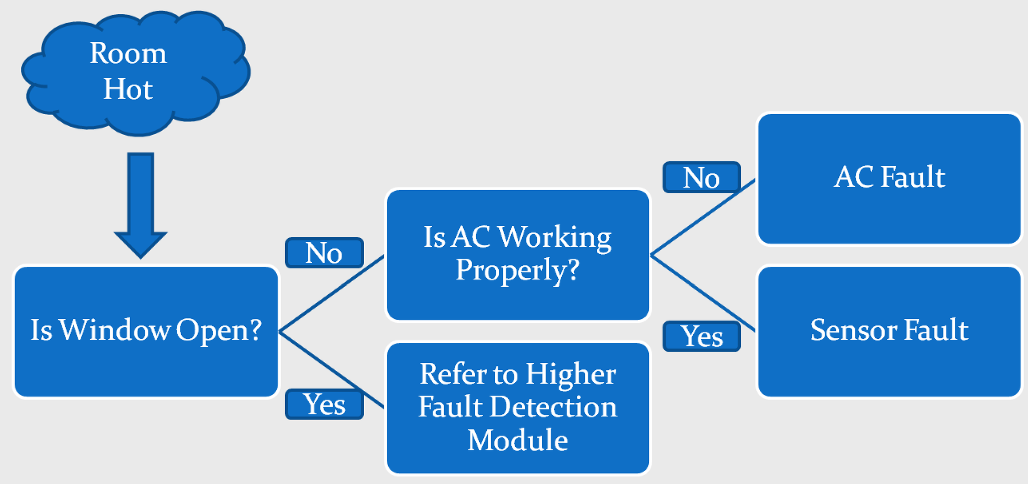
The activities undertaken during the BaaS project proceeded along two axes:

- Design and implementation of the platform (APO Kernel) to host APO analytics services and address data management, scheduling and simulation needs, and;
- Development of analytics components that provide the functional services outlined above.

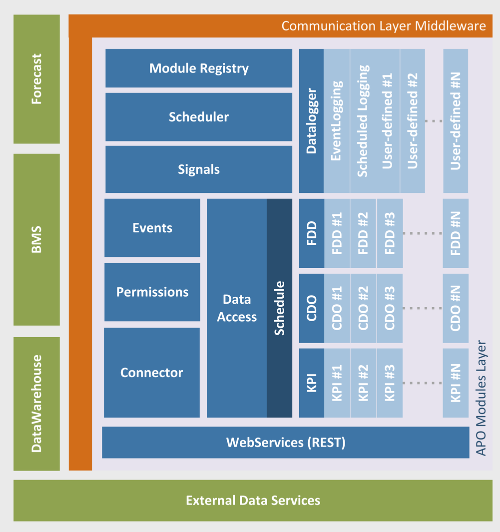
APO Services
Different types of analytics are supported by the APO Services Layer these are being developed by WP5 participants:



Example of fault detection analytic
One fairly simple illustration of situations to be detected by APOs is illustrated in the following picture:



APO Kernel:



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Work Package WP6
Demonstration of the Baas System

Objectives

The following activities were performed:

1. Using the theoretical case studies defined in WP1, in WP6 representative Demonstration Buildings have been selected as demonstration sites covering at least three of the six typologies of the Application Domain.
2. Implement in the Demonstration Buildings along with the measurement and verification methodology (developed in WP1).
3. Implement the measurement and verification methodology defined in WP1 for evaluating energy-savings.
4. A comprehensive validation procedure to ensure correct functionality, usability and interoperability of the BaaS system, recording and calculation of savings will be performed.
5. The implementation of this WP is in charge of providing feedback to the RTD work packages (WP2, WP3, WP4, and WP5), identifying potential inconsistencies and/or providing real value.

Approach

Task 6.1: Selection of pilot buildings
Five Demonstration Buildings have been initially selected for implementation of the BaaS solution. Thus, three typologies are represented: offices, hotels and educational buildings. Therefore, due to various circumstances, there are three buildings only used as the test-bed to completely integrate the BaaS results (https://www.baas-project.eu/index.php/public/home/demosites).

Task 6.2: Preparation of Pilots for the implementation and evaluation of the BaaS system
All planning, subcontracting and monitoring retrofitting actions are performed, necessary for adapting the pilots according to the BaaS implementation requirements and for implementing the M&V methodology.

Task 6.3: Implementation of measurement and verification M&V methodology in each Pilot: M&V Plan, Baselining and Reporting
Each Measurement and Verification Plan include: Energy Conservation Measures (ECM) intent, measurement boundary, Baseline (Period, energy and conditions), reporting period, basis of adjustment, analysis procedure, energy prices, meter specifications, monitoring responsibilities, expected accuracy, budget, quality assurance.

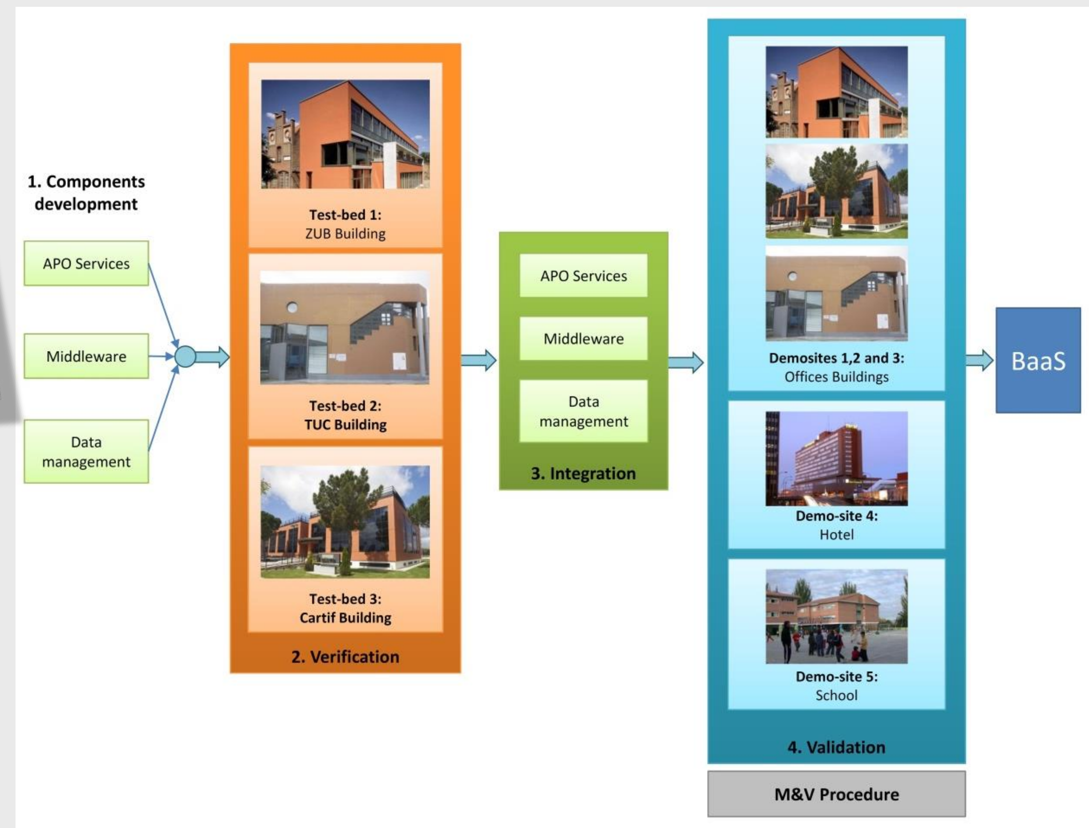
Task 6.4: Deployment of the BaaS ECM in the pilots
This task is developed the effective implementation of the complete BaaS System on each pilot. This task Have been started after the monitoring systems were commissioned and after the baseline period required by the M&V plan (a year at most) has completed.

Selected buildings must fulfil the conditions and requirements that have been set in the project framework, regarding the scope of its activities and objectives. In this sense, considering the portfolio provided by the ESCO, all buildings have been analysed from these requirements point of view, selecting the most suitable for the BaaS solution verification in order to move from the research and technological development to the demonstration and validation process. This selection is closely related to the theoretical case studies and the analysis of the end-user acceptance, activities carried out in WP1.

BaaS demonstrators

Three of the demonstration buildings, are also used as test-bed, in order to validate on them each component of the BaaS system separately.

As the validation of the whole system is based in a M&V Protocol implementation, the demonstration buildings selection is followed by the preparation of pilots to baseline period (MS3), the solution installation (MS5) and reporting of savings to final user validation (MS6).



Scheme of BaaS demonstration process

Achievements

During the BaaS project, the demonstration buildings have been selected, defined (building general information, installed energy systems, existing monitoring and control systems) and analysed in order to adapt the buildings to implement the BaaS solution and the M&V protocol selected (IPMVP) in WP1. Finally, the application potential of BaaS and its feasibility in other case studies was proved as very useful and innovative. These BaaS innovative solution could complement the existing methodologies and technical solutions, providing buildings with an added value in comparison with other utilities due to the improvements in energy efficiency and cost-effectiveness.

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