eTEACHER

Requirements for BACS add-on services

WP 2 Empower Tools I - BACS add-on services

T2.1 Requirements specification for BACS add-on services

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Abbreviation and Acronyms

AHU	Air handling unit
API	Application Programming Interface
BACS	Building Automation and Control System
BEMS	Building Energy Management System
BIM	Building Information Model/Modelling
CfPB	Center for People and Buildings
COP	Coefficient of Performance
ECM	Energy Conservation Measure
EER	Energy Efficiency Rating
EPA	Environmental Protection Agency
FM	Facility Manager/Management
HVAC	Heating, Ventilating and Air Conditioning
ICT	Information and Communication Technologies
IEQ	Indoor Environment Quality
IP	Internet Protocol
KPI	Key Performance Indicator
LED	Light-emitting diode
OR	Overall Requirements
SoA	Service-oriented architecture
SR	Solar Radiation
UBCI	Universal BACS Communication Interface
WiA	What-if Analysis
WP	Work Package

1 Abstract

The eTEACHER project aims to empower energy end-users to achieve energy savings and improve comfort and health conditions within buildings through enabling behavioural change. The behavioural change is addressed by means of ICT solutions that connect building energy and control systems with end-users, providing tailored recommendations designed with engagement methods and gamification concepts based on the results of social studies. In this way, end-users (householders, facility managers, staff, teachers…) are able to identify energy and comfort improvements that they can undertake by themselves and integrate in their usual activities.

As part of the project and to develop the ICT solutions to achieve an effective energy behavioural change, this report aims at defining the functional and technical requirements for the BACS (building automation and control systems) add-on services that eTEACHER encompasses. BACS add-ons are hardware (devices) and software solutions that extend the functionalities of the existing BACS or BEMS (building energy management systems) in order to empower building occupants to achieve better energy efficiency and comfort levels.

Buildings and their facilities are complex systems with a wide variety of parameters related to energy consumption and comfort (building envelop, heating and cooling systems, ventilation, lighting, control devices, etc.). For this reason, functional and technical requirements have been aggregated as use cases to facilitate its understanding from a social and technical point of view.

In addition, this document includes the preliminary system architecture to connect vendor-independent BACS add-on services to existing ones as well as the specification of data points, information requirements and data schema/model to perform data analysis for end-user engagement.

Therefore, this document has been structured in the following chapters:

- Functional and technical requirements (description of overall requirements and use cases). Use cases have been classified in energy conservation measures (mainly related to energy savings), building performance (energy efficiency) and indoor environmental quality (comfort).
- Data requirements with information requirements for each BACS add-on and data processing requirements (building automation, alarms, performance optimization, facilities, indoor conditions, commercial compatibility…)
- Overall system architecture and technology description of each BACS add-on.
- Monitoring requirements for eTEACHER pilot buildings.

2 Functional and Technical Requirements

The eTEACHER project aims at developing and integrating cost-effective add-ons services in the existing BACS (building automation and control systems) of the twelve pilot buildings located in Spain, United Kingdom and Romania. The objective of these add-on services is to deploy an ICT environment to provide energy analysis and informed decisions to empower building users towards energy efficiency behaviour. The add-on services consist of a data processing module for system performance and indoor environmental quality (IEQ); what-if analysis for energy efficiency; comfort and health control advices; data processing for end-user engagement; and universal BACS communication interface. The BACS add-ons will connect to the existing BACS through the universal BACS communication interface that must provide functionalities to satisfy building, system and users' requirements as well as the tools and solutions to ensure end-users' engagement.

Therefore, BACS add-ons have to deal with different types of requirements, which have been classified in functional and technical requirements. Functional requirements aim at describing the expected functionalities (i.e. what), configurations and interactions between building systems and users: what users can do with the system, what users expect to obtain, how the systems have to respond in different situations, etc. On the other hand, technical requirements are related to the technologies and restrictions needed to satisfy functional requirements (i.e. how): communication protocols, data points, position and type of sensors, thresholds, sample frequency, etc.

Moreover, the technical goal of the project is to develop a common ICT platform for the pilot buildings (residential, offices, academic and health centres). Due to the variety of combinations of buildings, climate conditions, energy systems, automation and control systems and user profiles, pilot buildings have been audited in order to characterise them and produce a comprehensive list of requirements. The audit template designed for this reason is included in Annex A. Furthermore, to generate a feasible list of requirements, functional requirements have been compiled as 'use cases', which reflect real situations that will be found in target buildings when eTEACHER tools are running and which describe users, building facilities involved and technical requirements to save energy and improve IEQ through behavioural change. This approach has allowed defining four groups of functional requirements: overall requirements (OR), energy conservation measures (ECM), building performance (BP) and indoor environmental quality (IEQ).

Use cases (except overall requirements) are described according to the following fields:

- ID (index to identify and refer to)
- Use case title
- Description
- Users involved
- Level (building, zone, room…)
- Technical requirements:
    - Data points (measurements)
    - BACS add-on configuration (static data)
    - Minimal pre-conditions (mandatory specifications)
    - Optional pre-conditions (previous recommendations)

2.1 Overall Functional Requirements

Overall functional requirements are related to the eTEACHER design to achieve project goals. This kind of requirements aims at defining the minimum functionalities, technologies and information needed to make it possible the energy behaviour change in pilot buildings, and to estimate its economic, social and environmental impact. In this regard, the project distinguishes between two objectives for the BACS add-ons: firstly, the BACS add-ons must settle and host the eTEACHER solution to motivate the behaviour change of building users, thus system specifications like communication systems, energy systems (HVAC, lighting, equipment, devices, appliances…) and building space distribution (floors, surfaces, envelope…) have to be collected. Second, BACS add-ons must provide the means to monitor the impact and effectiveness of the engagement methods to achieve energy savings and improve IEQ, thus the interoperability and compatibility with existing monitoring systems/devices must be assured.

Overall functional requirements are listed as follows:

Table 1. Overall Requirements

ID	Overall functional Requirements	Rationale
OR1	**Available building information**: construction, building uses (school, office, residential…), facilities (HVAC, lighting, BACS, monitoring…), internal distribution (zonification), climate conditions, type and number of occupants.	Information to characterise product/solution in order to predict and evaluate building energy conditions. Potential integration with building information models (BIM).
OR2	**ICT infrastructure (network)** to collect, store and exchange information with building systems and users.	eTEACHER solution requires monitoring of building facilities, environmental and users' parameters to improve the energy efficiency and indoor environmental quality. In addition, the information has to be collected, managed in the universal BACS interface and exchanged through the ICT network in order to get the users' feedback (e.g. gadgets) and assess the project (solution) impact.
OR3	**Establish communication between add-on services**	The universal interface provides necessary technologies to connect add-ons from different vendors, using standard communication protocols and databases allowing for data flows.
OR4	**Evaluation of savings** (energy, CO_2 emissions and costs) by means of behaviour change	WiA add-on takes care of estimating potential savings evaluating different behaviour scenarios and interaction of end-users with building facilities.

ID	Overall functional Requirements	Rationale
OR5	**Evaluation of indoor environmental quality (IEQ)**	Especially important in non-residential buildings since the productivity and well-being of occupants is totally related to indoor conditions. The system should be able to access the necessary information from monitoring system to evaluate, assess and advice
OR6	**Prioritise energy conservation measures (ECM)**	WiA add-on takes care of selecting the best scenario to perform the target savings, identifying and avoiding situations that can counter effect the potential savings (synergies)
OR7	**Creation of advice based on engagement methods and getting users' feedback**	Advices aim to change the energy behaviour of users to get better energy efficiency, indoor conditions and building performance. These have to be based on engagement methods to motivate end-users to participate in the experience and be aware frequently how their behaviour impacts in the building performance. Users' feedback is mandatory to assess the effectiveness of advices and the level of engagement obtained.
OR8	**Identification of under-performance building conditions and proposal of potential interventions**	Building under-performance conditions entail higher energy consumption and reduce the lifespan of facilities. In order to detect this type of situations, the operation status of facilities (characterized by different parameters like the Energy Efficiency Ratio) must be monitored to calculate the gap with respect to design or manufacturing stage.

2.2 Definition of Use Cases (Functional and Technical Requirements)

In software and systems engineering, the definition of use cases is a common practice that allows defining and capturing functional requirements in an understanding manner (Jacobson Ivar, 1992). A use case is a list of actions (work flow) and functionalities that defines the interaction between end-users and target systems with clear objectives. Therefore, this approach requires knowing the context of functionalities and objectives, what means basically **5 information groups** in the case of eTEACHER: building construction, energy systems, control systems, user profiling and environmental conditions:

- **Building construction** is the static information related to the building configuration, distribution, construction materials and passive systems (doors, windows, blinds…) that characterise the energy performance of the building. Volume, surface and distribution of spaces are examples of parameters that are necessary to estimate the energy demand of the building, areas and rooms.

- **Energy systems** are the collection of facilities or appliances that building occupants require staying in the building under comfort conditions: heating, cooling and lighting are typical examples.
- **Control systems** are relating to the automation and monitoring devices to manage the operation of building facilities (as known as BACS or BEMS). These systems are composed of electronic devices that allow communicating with different facilities (heating, cooling, ventilating, pumping, lighting…) and controlling them according to predefined set-points and schedules. Therefore, the functionalities of this group are related to ICT concepts, graphical user interfaces, communication devices, etc. However, buildings usually do not include this type of control devices for different reasons (e.g. facilities include their own local control systems) and potential requirements become specifications to install the corresponding eTEACHER solutions with the universal BACS interface working as unique control system.
- The **user profiling** is the cornerstone of the eTEACHER project since through behavioural change we aim at saving energy and improving comfort conditions and thus the productivity and wellbeing of building occupants. People are responsible of wasting energy in buildings, especially when electric appliances, devices and HVAC system are working unnecessarily or out of sensible limits. The behaviour (Andrew Reeves, 2018) depends on culture, educational level and mainly the objective of occupancy (worker, facility manager, student, householders…), and one single building can aggregate different user profiles, making more complex defining strategies for detecting wrong behaviours regarding energy efficiency criteria. For the definition of functional and technical requirements, the user profile is focused on why people occupy buildings and if they are potential users of eTEACHER: doctors, teachers, students, householders, etc.
- Last but not the least, **environmental and external conditions** have to be collected and characterized in order to model the energy and specifically the thermal behaviour of buildings and their systems. This information is in general described through parameters like the outdoor maximum and minimum temperature, average humidity, solar radiation, etc., which provide useful information to estimate building energy demand at different conditions.

Once the building information is collected and classified according previous four groups, it is necessary to analyse users' interaction with energy systems to foresee the possibilities of reducing energy consumption and increasing comfort levels in return. This analysis has been possible through the questionnaire of Annex A. , detecting the users' interactions common to the 12 building pilots and with a significant effect in comfort and energy consumption levels. For example, heating is a common energy consumption that users can vary and although the specific technology is different (gas boilers, heat pumps, air handling units, chillers…) the strategy and energy calculations behind are very similar to be considered a single use case.

In addition, the definition of use cases includes two additional terms: level and preconditions. Level is related to the area covered by the use case actions or experiment objectives. Hence, it is targeted room or apartment level, area (e.g. floor) and building level (e.g. whole energy consumptions). Preconditions are the preliminary requirements that are necessary to deploy BACS add-ons in order to roll-out the use cases in the different pilots. These have been classified into mandatory and optional to highlight the priority of activities relating to additional monitoring systems that should be prepared in target buildings.

Finally, and following this approach, the eTEACHER's specific use cases have described according to the three groups described: energy conservation measures (ECM) as the set of actions aiming at saving energy with user interaction, building performance (BP) as the whole energy efficiency and indoor environmental quality (IEQ) that aims at evaluating the level of indoor comfort conditions.

2.2.1 Energy Conservation Measures

The term "energy conservation measures" (ECM) was highlighted in the International Performance Measurement and Verification Protocol (EVO - Efficiency Valuation Organization, 2012) that comprises *the set of activities designed to increase the energy efficiency of a facility, system or piece of equipment*. ECM may involve one or more interventions as modifications of equipment, new procedures for maintenance and operation, implementation of new control hardware/software or training end-users to change their behaviour, i.e. the main focus of eTEACHER. Therefore, the first activity to define the functional and technical requirements to define ECM has been identifying the energy systems of target buildings.

Considering the pilot buildings (health centres, educational, administrative and residential) of the project, the systems that interact with end-users relating with energy consumption are the following (Table 2):

Table 2. List of energy systems and building pilots in eTEACHER

Energy system	Building	Building type	Building users	Country
Lighting	NCC	Administrative	FM, staff	UK
	Djanogly	High school	FM, teachers, staff	UK
	Villafranca	Health Care Centre	Staff	Spain
	Guareña	Health Care Centre	Staff	Spain
	Torrente	High school	Staff	Spain
	Arcoiris	School	Staff	Spain
	OAR	Administrative	Security and cleaning staff	Spain
	Badajoz	Residential	Householders	Spain
	Bucharest	Residential	Householders, FM (common areas)	Romania
Fuel/gas boilers	Djanogly	High school	FM	UK
	Torrente	High school	FM	Spain
	Badajoz	Residential	FM	Spain
	Bucharest	Residential	FM	Romania

Chillers	Djanogly	High school	FM	UK
Heat pumps	Villafranca	Health Care Centre	FM	Spain
	Guareña	Health Care Centre	Staff	Spain
	OAR	Administrative	FM	Spain
Splits	Torrente	High school	Staff	Spain
	Arcoiris	School	Staff	Spain
	OAR	Administrative	Managers	Spain
	Badajoz	Residential	Householders	Spain
	Bucharest	Residential	Householders	Romania
District heating	NCC	Administrative	FM	UK
	Bucharest	Residential	FM	Romania
Radiators	Djanogly	High school	FM	UK
	NCC	Administrative	FM	UK
	Badajoz	Residential	Householders	Spain
	Torrente	High School	FM	Spain
	Arcoiris	School	FM	Spain
	Bucharest	Residential	Householders	Romania
Convectors/Fancoils	NCC	Administrative	FM	UK
	Villafranca	Health Care Centre	FM, Staff	Spain
	OAR	Administrative	FM	Spain
Air-handling unit (AHU)	Djanogly	High School	FM	UK
	NCC	Administrative	FM	UK
	OAR	Administrative	FM	Spain
	Villafranca	Health Care Centre	FM	Spain
	Guareña	Health Care Centre	Staff	Spain
Windows	All	All	FM, staff	All

Solar protector (e.g. blinds)	Djanogly	High school	Staff	UK
	Bucharest	Residential	Householders	Romania
	Badajoz	Residential	Householders	Spain
	Torrente	High school	Staff, students	Spain
	Arcoiris	School	Staff	Spain
	OAR	Administrative	Staff	Spain
Electric appliances, devices and equipment	All	All	All	All

With the identification of systems related to the energy consumption, it has been defined a total of four use cases relating to potential energy conservation measures that can be applied by building users in order to obtain effective energy savings:

- **ECM1**: Save cooling energy using HVAC control, windows and blinds
- **ECM2**: Save heating energy using HVAC control, windows and blinds
- **ECM3**: Save lighting energy using natural lighting or power-off when there are not people using it
- **ECM4**: Save electric energy power-off unnecessary appliances, devices or equipment

These definitions have been based on a holistic approach, taking into account the thermal behaviour, comfort conditions and lighting levels to get effective energy savings, since some interventions can reduce the energy consumption in some energy systems but requires increasing the energy consumption in others. For example, cooling consumption can be reduced by closing blinds if solar radiation is increasing the room temperature but such action entails in turn increasing the lighting consumption, thus both effects must be evaluated to propose the most suitable action to obtain an effective whole energy saving. In addition, there are two types of interventions based on the system: passive and active. Passive interventions are related with those systems that do not consume energy by themselves, but their configurations are essential to control the room temperature, solar radiation, etc., like windows that allows recycling indoor air or blinds that protect against solar radiation in summer. Active interventions are related directly to the energy consumption of appliances, devices and equipment, using control systems to change set-points towards better thresholds or just connecting or disconnecting them (switches).

The four ECM use cases with a detailed list of requirements are shown in the following tables:

Table 3. Energy Conservation Measure 1 use case (Save cooling energy)

ID	ECM1

ID	ECM1
Title	**Save cooling energy using HVAC control, windows and blinds**
Description	End-users can save energy controlling HVAC consumption, by means of temperature set-point and fan speed as well as external energy factors (external gains due to solar radiation) by opening/closing windows and blinds. In summer conditions, solar radiation has a negative effect (increase building, zone or room temperature) that should be mitigated closing blinds when it is necessary; indoor temperature and humidity (wet climates) can be also controlled by closing windows (dry effect of cooling systems).
Users	All end-users (room level) and facility manager (any building level)
Level	Room/Zone/Building
Technical Requirements	
Data Points	Energy meter (cooling), pyranometer (or weather information if available), shading percentage (manual/auto), occupancy (e.g. presence sensors), indoor temperature sensor, outdoor temperature sensor (or weather information if available), cooling production status (AHU, heat-pump, chillers...), date/time.
BACS add-on configuration (static data)	Shading system type, cooling system type, specifications (COP/EER, rated power, monitoring & control system…), building/zone/area location or position, HVAC system (heating/cooling distribution system: fan-coils, radiators…)
Pre-conditions (mandatory)	AC system existing, cooling control at room, zone or building level; monitoring system (temperatures, heat, water flow, power…) available and accessible.
Pre-conditions (optional)	Monitoring available; central blind control available (otherwise, users' feedback); central cooling control accessible; blinds (if exist) with gradual positions.

Table 4. Energy Conservation Measure 2 use case (Save heating energy)

ID	ECM2
Title	**Save heating energy using HVAC control, windows and blinds**
Description	End-users can save energy controlling the HVAC consumption by means of temperature set-point and fan speed as well as external energy factors (external gains due to solar radiation) by opening/closing windows and their blinds. In winter conditions, solar radiation has a positive effect (reduce heating demand) that should be taken advantage of by opening blinds when it is necessary; closing windows also helps to reduce heating losses.

ID	ECM2
Users	All end-users (room level) and facility manager (any building level)
Level	Room/Zone/Building
Technical Requirements	
Data Points	Heat meter, pyranometer (or weather information if available), shading percentage (manual/auto), occupancy (e.g. presence sensors), indoor temperature sensor, outdoor temperature sensor (or weather information if available), cooling production status (AHU, heat-pump, chillers...), date/time.
BACS add-on configuration (static data)	Shading system type, heating system type, specifications (COP/EER, rated power, monitoring & control system…), building/zone/area location or position, HVAC system (heating/cooling distribution system: fan-coils, radiators…)
Pre-conditions (mandatory)	Heating control at room, zone or building level; monitoring system (temperatures, heat, water flow, power…) available and accessible.
Pre-conditions (optional)	Monitoring available; central blind control available (otherwise, users' feedback); central cooling control accessible; blinds (if exist) with gradual positions.

Table 5. Energy Conservation Measure 3 use case (Save lighting energy)

ID	ECM3
Title	Save lighting energy using natural lighting or power-off when there are not people using it
Description	Lighting energy consumption can be reduced taking advantage of natural lighting by opening blinds and power-off when there are no people in the room or building
Users	End-users and facility managers
Level	Room/Zone/Building
Technical Requirements	
Data Points	Indoor light sensor, pyranometer (or weather information if available), shading percentage (manual/auto), occupancy (e.g. presence sensors)
BACS add-on configuration (static data)	Type of lighting system (fluorescent, LED…), rated power (kW), type of shading system, building/zone/area location or position

ID	ECM3
Pre-conditions (mandatory)	Monitoring system available and accessible (energy consumption or status)
Pre-conditions (optional)	Central control system. In case of presence detector switches, lighting must be controlled manually as well.

Table 6. Energy Conservation Measure 4 use case (Save electric device/appliance energy)

ID	ECM4
Title	Save electric energy power-off unnecessary appliances, devices or equipment
Description	Electric devices (computers, printers…), home appliances (TV, laptops…) when they aren't used is a common practice to save general electric energy.
Users	end-users (offices, high-school, health-centres, householders…)
Level	Room
Technical Requirements	
Data Points	Occupancy (e.g. presence sensors), device/appliance electric meter (e.g. smart-plugs)
BACS add-on configuration (static data)	Type of device or appliance
Pre-conditions (mandatory)	Electric plug or device/appliance status available and accessible
Pre-conditions (optional)	N/A

2.2.2 Building Performance

HVAC systems are one of the more demanding facilities regarding energy, which represent the 50% of European annual energy consumption and accounting for 79% of total final energy use in households only for the heating and hot water (European Commission, 2016). Besides, taking into account the variety of technologies and energy sources available to provide heating and cooling energy (gas boilers, biomass, heat pumps, chillers…), it is necessary to define specific maintenance plans to guarantee the expected building energy performance (i.e. as designed).

HVAC systems are composed mainly of three components: production system, distribution system and control system. The production system is composed of technologies that transform specific energy sources to increase or reduce the temperature of fluids. Distribution systems are those facilities that transport the heating and cooling to all the rooms and areas of the building in order to get the desired comfort level (temperature, humidity and air quality). Finally, the control system, which can be centralised or distributed, is responsible for regulating the energy flows from production to distribution in order to satisfy specific or general comfort conditions according to the building's schedules.

In general, facility or energy managers must operate HVAC systems to achieve indoor comfort levels and guarantee performance is close to rated values provided by manufacturers and building designers. However, there are cases where buildings have more than one type of production system to provide cooling and heating separately, what requires a better coordination and higher control of the building performance.

For this case, one use case has been defined to advice facility managers about underperformance conditions, when some of the three HVAC components are working out of expected conditions, and advice about possible procedure to take the system back to normal operation. Underperformance conditions are difficult to detect if BACS software is not prepared to offer such information. For this reason, this use case complements the potential energy behaviours that entail positive effects in energy savings in buildings.

Table 7. Building performance use case (underperformance conditions)

ID	BP1
Title	Detection of building underperformance conditions
Description	Sometimes building facilities, devices and appliances can work simultaneously due to wrong management or potential anomalies. For example, heating working together with cooling, heating/cooling working with the ventilation distribution system powered-off, lower efficiency levels (COP/EER) in production units, pump failures, etc.
Users	Facility/Energy Manager
Level	Building
Technical Requirements	
Data Points	Energy meter (heating/cooling), indoor temperature sensor, outdoor temperature sensor (or weather information if available), cooling production status (AHU, heat-pump, chillers...), date/time, pressure sensors.
BACS add-on configuration (static data)	HVAC system type (COP/EER, rated power, monitoring & control system…), building/zone/area location or position, HVAC system (cooling distribution: gas, water…)
Pre-conditions (mandatory)	Existing BACS / BEMS / Monitoring system with the following HVAC measurements: temperatures, pressures, energy consumption. Building information (e.g. BIM) available.

Pre-conditions (optional)	Existing building Information model (BIM)

2.2.3 Indoor Environmental Quality (IEQ)

The term indoor environmental quality relates to air quality, thermal conditions, daylight and acoustics. These parameters impact in the comfort conditions of building occupants, especially regarding the productivity of office workers, what is very relevant for non-residential buildings. Thus, air quality is related to the indoor level of CO2 that have to be balanced with the outside airflow, the thermal conditions with the temperature and humidity set points in the different HVAC controls, the daylight with the balance between sunlight and artificial lighting and acoustics with the level of noise. In eTEACHER the focus is on the air quality, thermal conditions and daylight, since acoustics depends on other specific factors of buildings and their surroundings that have to be fixed with punctual interventions or solutions.

Regulations and standards about air quality refer usually to the renovation of the total air volume in buildings or by occupant. For example, according to ASHRAE's recommendations, the outside air flow (considering this as clean) must be higher than 8.5 m3/h per worker to keep CO2 levels below 2500 ppm. On the other hand, optimal thermal conditions must be between 21-26º C and 40-60% of humidity. Finally, several studies (N. Shishegar, 2016) have demonstrated the health improvement (e.g. psychologically) on building occupants regarding the exposition to natural lighting.

For these reasons, the IEQ is defined as use case, since all the energy conservation measures and interventions regarding improvement of building performance must guarantee default comfort conditions. In other words, the following use case checks the feasibility of proposed behaviour change interventions regarding comfort conditions.

Table 8. Indoor environmental quality use case (comfort condition advisor)

ID	IEQ1
Title	Monitoring and advisor of indoor environmental quality to improve the wellness and productivity
Description	The system will check the indoor environmental quality (when the room/zone/building is occupied) based on temperature, humidity, CO2 level, lighting level and users' feedback in order to evaluate the whole level of wellness and advice to improve the current conditions
Users	End-users and building manager or householders
Level	Room/Zone/Building
Technical Requirements	
Data Points	Indoor temperature, humidity, CO2 level, lighting level and users' feedback

BACS add-on configuration (static data)	Building zonification, lighting requirements per zone
Pre-conditions (mandatory)	Monitoring system available and accessible for indoor temperature, humidity, CO_2 and lighting. Occupancy or presence system.
Pre-conditions (optional)	Existing building Information model (BIM)

3 Data Requirements

Data requirements specify the information needed and agreed by different stakeholders in order to satisfy the use cases presented in the previous chapter. Data requirements are specified based on the capabilities of different BACS add-on services, mainly focused in energy conservation measures, indoor conditions monitoring and system performance optimisation. Due to the diversity of the pilot projects and the data requirements in the project, data requirements are presented in a general form. As the project progresses and the information about the pilots is more accessible and specific, data requirements will be specified in more detail depending on the pilot buildings and their potential. Nevertheless, data requirements are not represented as a fixed list in a document, but rather as an initial guideline for data gathering and collection.

3.1 Information Requirements

For achieving the requirements described in chapter 2, different information sources are necessary. On the one hand, information has to be handled by the BACS add-ons so that they can realise the functional requirements and provide useful features to an end-user in order to increase his energy literacy and engagement. On the other hand, this information has to be accessed from and managed through the universal BACS communication interface. With regard to the requirements defined in the previous chapter, the whole information that has to be engaged within eTEACHER solution can be subdivided into the following categories:

- **Building Performance:** this kind of information relates to the technical and energy behaviour of buildings during their operation. In principle, such information is gathered by the monitoring system. Main examples are the measured energy consumption in terms of heat, cooling or electric energy, indoor temperature and humidity in the different areas of the building, indoor light levels, efficiency of the energy system, malfunctions, etc. Main related information sources are the different meters and sensors installed in the building. Alternative information sources could be building users and technical staff who can report about actual building indoor conditions and operating states.

- **User Behaviour:** user behaviour information encompasses all data that reflect the users' actions on building facilities as well as their effect on building indoor conditions and energy performance. Typical examples are energy system control settings like set points, thermostat positions, but also positions of openings and shading components (windows, blinds…), lights status as well as the use of devices and appliances. This information represents the main factors that eTEACHER solution aims at optimizing for guarantying more energy-efficient building operation, preserved comfort and enhanced building performance. As for building performance information, user behaviour information shall be primarily gathered by the eTEACHER monitoring system collecting for instance sensor and actuator parameters, BEMS settings and records.

- **Building Information:** In order for BACS add-ons to provide outcomes for a specific use case, it is fundamental to obtain information about the built elements of the currently analysed building including its architectural and technical characteristics. Every building has a different structure and is equipped with different types of systems which have specific effects on energy use and overall performance. For example, main singularities are building shape, areas, height, number of storeys, rooms, as well as technical characteristics like energy sources, rated power, used energy system technologies (district heating, boiler, heat pump, air handling units…), the presence or not of air-conditioning, heat recovery system, etc. All this information has a determinant influence on energy performance. On one side, this information is used by the BACS add-ons to perform their analyses. On the other side, this information has to be used for locating in the building the different data points and issues identified by the add-ons. Furthermore, this location capability will be used by the eTEACHER user-friendly interface to provide targeted advices and results, which can then be spatially allocated to rooms, zones or technical components.

- **Environment information:** this information encompasses all data about the environment of the building. More specifically, this information concerns phenomena and variables which can be considered as building boundary conditions and that are not controllable. They primarily include weather conditions like outdoor temperature, solar radiation, sunshine duration, etc. As for the user behaviour, they have a major impact on building energy use, performance and indoor environmental quality. But contrary to user behaviour, these variables cannot be optimised and act as dynamic boundary conditions. As for building performance and user behaviour, this information is provided at first by the monitoring system.

- **User perception:** this kind of information is directly provided by building users through a specific input interface. It mainly concerns the users' feedbacks which reflect comfort dissatisfaction or describe problems related to indoor environmental quality. Furthermore, user perception inputs can also relate to technical issues or malfunctions that can be identified by users or technical staff.

- **Knowledge:** knowledge information is characterised in eTEACHER as reference information which is used by BACS add-ons to enable logical interpretation of the actual building operation and to derive potential corrective measures. This knowledge is composed of expert knowledge which can be formalised as rules. These rules can for example represent which ECM to undertake by certain environmental conditions or operating states in order to save energy. They can also define what kind of underperformance or malfunction is associated to specific building behaviours. This knowledge represents the fundamental information for generating advices.

- **BACS add-ons results:** This last category of information represents the outputs of BACS add-ons which will be further used by the user-friendly graphical user interface developed in the project. Main outputs are for a part characterised by advices and messages which shall guide the end-user behaviour with regard to e.g. energy conservation measures as well as performance and comfort optimisations. They shall also provide him a better understanding about the building operational state and his own influence on it. Another part of BACS add-ons outputs is characterised by different quantitative values and metrics (e.g. KPI), which shall provide for performance literacy and visibility. These metrics will also play a role in the gamification concept to be elaborated in the project by defining e.g. scores and bonus, and by providing means of comparisons between reference or targets values and actual values.

To summarise, the information can be sorted in two main categories:

- Static information: building information, knowledge, reference values and KPI targets.
- Dynamic information: building performance, user behaviour, environmental conditions, user perception, evaluated and measured metrics or KPIs.

3.1.1 Building Performance

Monitoring and controlling building performance is a broad and complex activity because of the variety of many technical systems operating. The eTEACHER project emphasises the technical systems that influence energy performance the most, such as air handling units.

Metrix focuses on system energy performance monitoring as one of the methods to reduce energy consumption and carbon emissions. However, in contrast to the energy performance metrics that focused on energy measures, Metrix measures factors that affect energy use in buildings. The reason for selecting a different perspective to energy performance is to find a way to use more efficiently the information collected by building automation systems that currently focus on displayed energy use figures but not providing information of the causes of energy use anomalies. There are several reasons for anomalies in building energy use but energy savings are usually gained by correcting operational and control deficiencies in HVAC systems, such as adjusting set points and changing time schedules and parameter settings. By measuring these factors that affect energy use in buildings, tools users would receive more detailed information than an ordinary energy use display.

The main feature of Metrix is that it transforms building automation data into performance metrics by comparing actual measurements with predetermined targets. Each performance target is based on either of the following principles (Ihasalo, 2012). Target values are generally seen as representing good performance, such as targets derived from building standards or guides. Targets can also be achieved according to the equipment manufacturer.

The comparison of actual measurements with target values enables performance metrics to be presented in 0-100 percent scale where 100 percent means the best performance level. The method used in transforming building automation data into performance metrics is shown in Figure 1

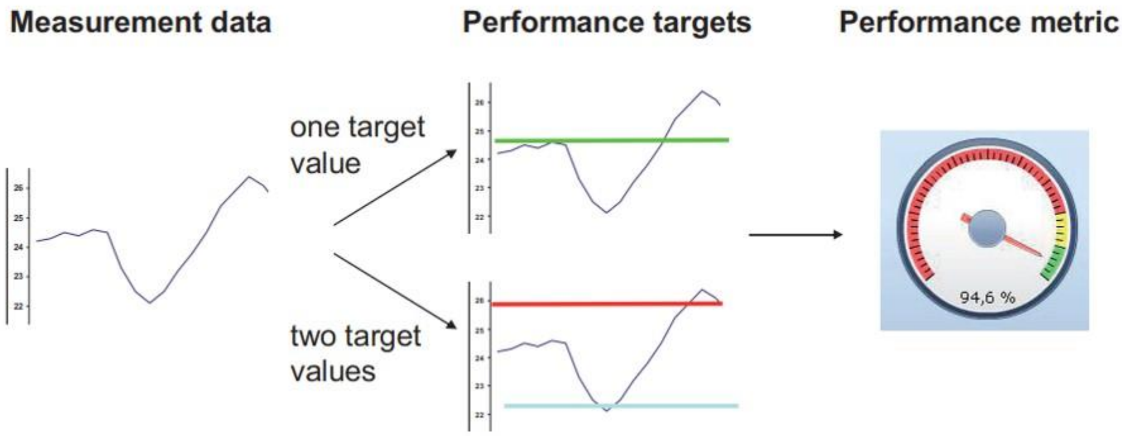

Figure 1. Transformation of BAS data into a performance metric

Time Schedule efficiency

The importance of air handling units (AHU) time schedule efficiency is to control that such facilities are operated only when needed. In many situations air handling units are changed to meet special needs in the building and if the schedules are forgotten in this setting and never changed back to original settings then problems may occur. To prevent such situations the sub-measure compares the actual AHU time schedule to a so-called optimal time schedule. Optimal time schedule for each AHU is determined together with the users and operators of the building. The AHU time schedule efficiency sub-measure has two target values, starting time and ending time. The sub-measure is calculated by counting the time during which the actual time schedule exceeds the optimal time schedule and dividing this by the total measurement time.

3.1.2 Indoor Environmental Quality

Monitoring and controlling indoor environment quality (IEQ) is one of the most important activities for improving productivity, well-being and satisfaction for the building users. The Environmental Protection Agency (EPA) states that on average people spend 87% of their time indoors. The impact of indoor air quality is huge for productivity, wellness and satisfaction of employees. Several studies have established the relationship between indoor air quality and productivity. For instance, adverse warm or cold temperatures can have a negative effect on employee productivity especially when performing tasks lasting longer than one hour (Lan, 2009). In elevated indoor temperatures productivity can be decreased by 5-7% (Niemelä, 2002). (Seppänen, 2002) stated that there is 2% decrease in work performance per degree ºC temperature rise, when the temperature is above 25º C. Consequently, increasing fresh air to dilute pollutants may rise productivity of employees by up to 3%, while productivity may drop up to 6% when users are relocated from natural ventilation to air-conditioned environments (Thompson, 2011). IEQ is also important for physical and psychological health and well-being; however the influences may vary depending on the different people (Valbjorn, 2000). Typical health problems that may be related to poor IEQ are irritation of eyes, nose, throat; reddening and dryness of the skin due to allergic reactions, headaches or feelings of heaviness in the head, unnatural tiredness or problems with concentration, nausea and dizziness. The probability that these symptoms can be caused by poor IEQ increases when a large group of people in the building show identical symptoms and these ones disappear for many people when they are outside the building for shorter or longer time. Legionnaire's disease is specifically related to buildings and facilities. Usually the infection is spread from building installation like hot water and air-conditioning system. In Denmark there are on average approximately one hundred cases of Legionnaire's disease recorded annually, of which 10% to 20% are fatal (Valbjorn, 2000). Poor IEQ can aggravate other diseases such as bronchial infections, asthma, bronchitis and sinusitis (Valbjorn, 2000). Some of IEQ problems are caused by lack of maintenance, thus it is important to monitor these parameters related to air temperatures, air velocity, air humidity, content of pollutants such dust, air humidity, gases, vapours and uncomfortable smells. Ultimately, satisfaction related to the IEQ is ranked of high importance by employees but the satisfaction level is usually low. The Center for People and Buildings (CfPB) database contains 105 case studies conducted between 2007 and 2013 to a total of 14,980 employees. Two out of three employees are satisfied with the organization, their work, accessibility to the office and spatial support of communications. However, one out of three is satisfied with the indoor climate (temperature control and air quality) even though the level importance of indoor climate is ranked as top three by the employees. (Brunia, 2016) shows that IEQ has a strong impact in people's productivity, well-being and satisfaction related to the building and facilities thereof; however IEQ is not always given the level of importance or has adequate methods to monitor and control IEQ levels. Low IEQ levels can also trigger actions towards maintenance issues or malfunctioning equipment.

3.1.3 Energy Conservation Measures

Because of the lack of energy awareness and knowledge, the building users and facility managers may need guidance to change their behaviour towards energy efficiency. In last decades, much research efforts have been spent to optimise the efficiency of energy systems. New technologies have been introduced that increase the use of renewable energies and existing technologies have been optimised to avoid or reuse wasted energy. Even if technology has been enhanced, there was not much attention about the building users themselves who represent a major factor of energy inefficiency and wasted energy due to energy unaware behaviour. The energy conservation measures shall fix this energy unawareness and support users in enhancing their energy literacy and behaviour. ECMs are presented through the eTEACHER user-friendly interface in the form of tailored suggestions and advices which are preliminary generated by the What-if-Analysis. On the basis of different types of information inputs, the WiA aims at finding out the potential energy conservation measures that can be carried out by end-users to increase the energy efficiency without compromising indoor environmental quality (IEQ). The potential conservation measures of users can be of different kinds such as modifying set points or operating schedules, acting with windows and blinds, changes in the use of appliances and light, etc. The main kinds of ECM eTEACHER focuses on are mentioned in chapter 2 and were chosen because of their high energy saving potential. When ECMs are prioritised and computed by the WiA, an estimation of their energy saving potential is also calculated. Because of the need for a solution which can provide rapid answers, which is applicable to any building and which can be easily embedded in the eTEACHER software, the WiA relies on a data-driven analysis that can engage low computational cost. Similar analysis approaches are introduced by (Foucquier, 2013). Figure 2 below shows the main information inputs and outputs of the WiA. It takes as input both static and dynamic information. According to the information categories mentioned previously, the dynamic information is mainly characterised by building performance, user behaviour and environment information while static information are related to building information and knowledge. This latter category of information is used to describe and provide the ECMs which are contained in a specific knowledge base.

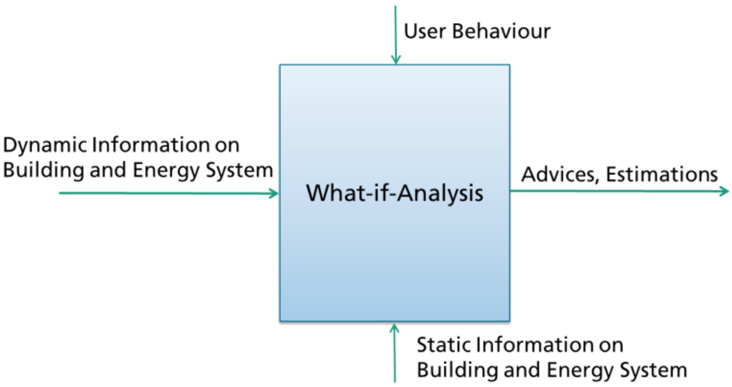

Figure 2. Information inputs and outputs of the What-if-Analysis

As shown in Figure 2, the WiA provides two functions which are closely related and that are based on information provided by the universal BACS interface. This information is managed in a common data layer which is further described in chapter 4. The first and main function of the WiA is to generate ECMs according to the current building operational state and its existing equipment. Concrete ECMs are defined as best-practice control handlings, which are formalised and structured into a knowledge base. In practice, ECMs are configured on the basis of expert knowledge which is preliminary available as static information. The second complementary function provides an estimation of the targeted savings by applying the ECM. Both WiA functions are referred to respectively as prescriptive and predictive functions.

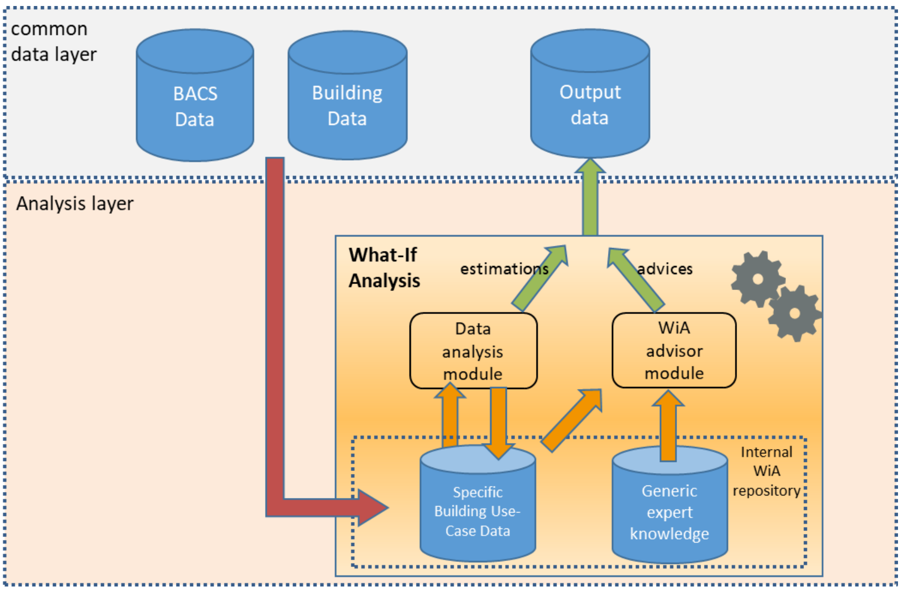

Figure 3. Internal components and information flow of WiA

The ECMs and resulting advices can be expressed at different levels, namely:

- Building level: global set points, central lighting, central ventilation control, central shading control, heat recovery control...
- Zone level: control heating or cooling in specific zones, zone-based lighting control, façade-specific blind control…
- At room level: room temperature thermostats, windows and blinds local control, switches…

Furthermore, ECMs can also consist of enhancing building performance by correcting building systems anomalies or wrong system settings. They can for example consist of corrective actions in terms of energy system control or maintenance that shall restore energy efficiency and enable resource savings. In view of that, the dependencies between building performance and ECMs have to be taken into account by the WiA.

3.2 Data Processing Requirements

Building Automation / Monitoring System

Figure 4 shows a common data transfer procedure for measured sensor data of a BAS system through the UBCI into monitoring of the energy related system performance management. The UBCI is further explained in next chapter. However, the following figure explains the procedure within Metrix module. The procedure starts by obtaining measurements of different parameters such as temperature, humidity, CO2 levels etc. from technical systems in various location points in a building. Afterwards, the sensor data is stored into the BAS server and later transferred to different modules in Granlund Metrix for validation. In many cases, data is exported with file extensions such as xls, csv or txt. After the data is processed and validated it is stored in a central Granlund Manager database. The results are later reproduced by the Performance Optimization Server for monitoring and reporting purposes. For the What-If-Analysis, the data processing approach is similar to Metrix. It relies also on the UBCI which is used as interface with the BAS server and provides a common data layer. The WiA uses then same types of data formats and disposes itself of an add-on specific internal database for collecting sensor data and performing data analysis as previously described in Figure 3.

Commonly all the physical and programmable points in building automation are stored in the historical database of the BAS system. For measurements, the used sampling period is 10 minutes. The database is automatically cleared of the old measurements data in order to prevent the building automation central PC's storage unavailability. The measured data is stored in an open database of files (text or csv). Below there are examples for the uses of BAS data for the performance monitoring.

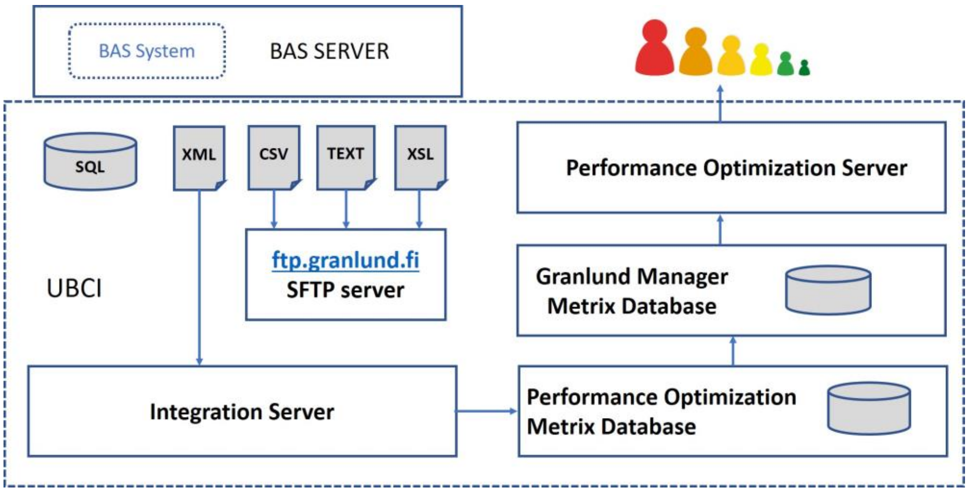

Figure 4. Internal flow and components of Metrix

Alarms

Alarms usually report anomalies in the correct functioning of the technical equipment.

Attributes saved regarding **alarm** events:

- Time & Data
- Priority; Can be as an example “Level A”, “B”, “C” or as in numbers as “Level 1”, “2”, “3”. Can also be as “Service” or i.e “Critical”.
- Point ID
- Alarm Description
- Alarm State, i.e.: active, inactive and acknowledged
- If the measurement data is used for storing files that are stored in a single file, one trend the measured values for the last 7 per day. The file name is the name of a trend point. The contents of files should be separated, for example, in such a way that the separator semicolon, such as: Date;Time;301TE16.01;16.06.2012;14:02:54;22,7
- If the measurement data is stored in an open database, oBIX (Open Building Information Xchange) standard can be used.

Performance Optimization (most likely heat recovery will only be applied to one building)

- For possible heat recovery and heating & cooling network efficiency calculations:
- Outdoor temperature (°C)
- Supply air temperature after the heat recovery (°C)
- Extract air temperature (°C)

Depending on the heat recovery type one of the following:

- Heat recovery valve position (%)
- Heat recovery damper position (%)
- Rotation speed of the heat recovery wheel (%)
- Temperature measurements from all heating / cooling networks (°C)
- Valve positions from all heating / cooling networks (%)

Air handling unit (AHU) time schedule efficiency:

- Status (on/off) or the rotation speed of the supply air fan (Hz)
- Night ventilation and time lag switch status if available

Indoor conditions:

- Indoor temperature measurements (°C)
- Indoor humidity measurements (Rh)
- Pressure measurements (Pa)
- Carbon Dioxide measurements (CO2)
- Volatile organic compound measurements (VOC)

Consumption Data Transfer

Granlund Manager supports tens of different formats for consumption data transfer. Transfer method follows the same with building performance monitoring however there are only three needed information types from source system.

Needed measurement points for Consumption Data Transfer

- Time & Date
- Reading
- Unique meter identifier

Unique meter identifier can be formed in many ways. It can be Meter ID or name that can be found from source system. It can also be combination of different fields, for example client and meter ID.

Remote connection specifications:

- Minimum of DSL2 / ADS2L+ connection
- Access right to Windows admin and the BMS system admin
- Firewall ports opened for ftp data transfer

4 Overall System Architecture

One of the technical objectives of eTEACHER project is the development and the integration of cost-effective BACS add-ons services in vendor-independent building automation and control systems to empower users' behaviour towards energy efficiency. The new empower services provide energy analysis of different scenarios supporting end-users (e.g. building manager, occupants) taking informed decisions.

The overall system architecture needs to be adaptable to different buildings, easy to set up and updatable. As the pilot buildings/demonstrators are spread across Europe, it is necessary for the architecture to be distributed on different systems and connected via Internet. To achieve this goal eTEACHER seeks to combine different software components, developed by the key technological partners as BACS add-on services. The approach of combining the software components allows the overall architecture to grow and shift during the project, as each partner contributes and improves their software component.

4.1 System Architecture. Data flow Description

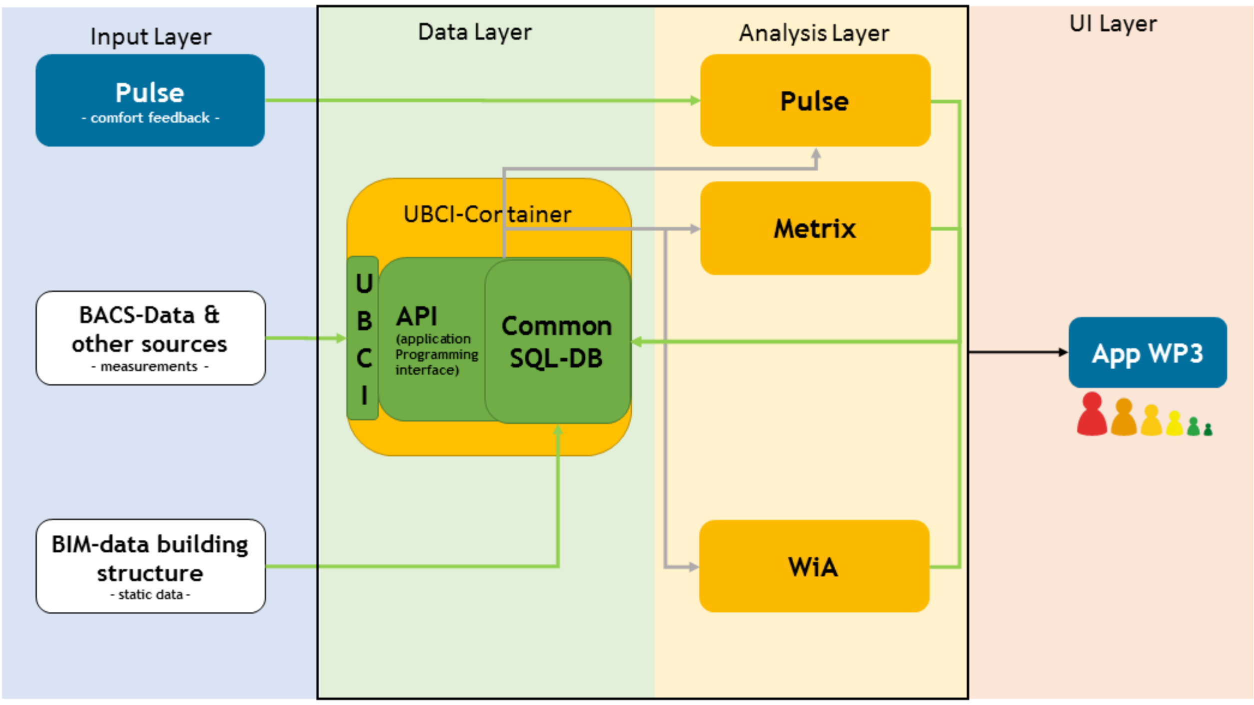

Figure 5. eTEACHER system architecture (data flow description between BACS add-ons)

The architecture of the eTEACHER system subordinates the planned data flow. There is an input layer, in which the data from the local BACS will be collected. If available, the BIM-data building structure will also be collected.

In order to collect data from the BACS, a matching software interface is necessary. Since there is a multitude of BACS and therefore unique software interfaces, one task of eTEACHER will be the development of a universal BACS communication interface UBCI.

The BACS data will be collected and stored in the UBCI container. The processed data then can be provided towards the analysis layer either via a common database, as well as an API that will be developed within the eTEACHER project.

Within the analysis layer the data will be processed by two major software components. The indoor environment quality (IEQ) system matches the sensor data with the building information model (BIM) data. This so processed data can be easily used by the software component itself, as well as the App developed for end-user engagement, to provide information and graphs for end users such as occupants. It furthermore matches sensor data with the suggested behavioural changes and with provided data.

The second software component which is part of the data analysis layer is the What–if-Analysis (WiA). The WiA processes the sensor data and matches it with the BIM in a way, that it can propose energy conservation measures and describe how much energy could potentially be saved by applying them e.g. when turning off consuming facilities or reducing their energy consumption (e.g. by closing the blinds and lowering the cooling). This data shall also be provided for end-user application developed in the project.

4.2 Technology Description

As mentioned in chapter 3 and chapter 3.1, the system architecture of eTEACHER consist of four core components: UBCI-Container, Metrix System, Pulse and What-if-Analysis.

4.2.1 UBCI-Container

Based on the knowledge and the software-products of ACX GmbH, the UBCI-Container provides the data layer for the eTEACHER system. The container consists of three components, the UBCI, BACS software developed by ACX GmbH and an interface to the data analysis layer.

UBCI: Currently, there is a multitude of interfaces and building automation and control systems available. Therefore the aim of the UBCI is to unify these interfaces into a single universal one. In order to achieve this, three prime criteria – media, protocol, data-frames – have to be defined. By integrating it into the BACS of ACX GmbH, it will serve as an API in return and can be used by the different manufacturers of BACS.

To connect the pilot sites which feature different levels of Automation as well as different BACS, it is planned to use many different open protocols, binary signals (switch on/switch off) and proprietary protocols from other manufacturers created and made available for integration.

ACX' BACS: The BACS is running as a service on a computer. Using a graphical programming tool developed by ACX GmbH, one can create the configurations that are executed by the service. In the project the configuration will connect to the pilot buildings, using the available interfaces in order to collect data. The data collected can be pre-processed as necessary. It is possible to use mathematical operations, convert datatypes and de-/construct strings.

Analysis Layer Interface: In order to connect the software components of the analysis layer with the stored data, the UBCI-Container will provide a common database as well as necessary API. The database will store and manage the collected building data and can provide the communication interface for the analysis layer. One API that is already agreed upon in an OPC UA interface, which is described in section 4.2.4.

4.2.2 Metrix System

Metrix system through a developed web service requests BAS data from the UBCI-container. The BAS data can contain parameters such as temperature, humidity, CO2 levels data or equipment component performance data. The data usually provided in different file formats (csv, text, xls) is converted into XML format for integration. To guarantee this functionality a XML converter runs within Metrix integration server. The integrated data is stored in the performance optimization Metrix database and later to the performance optimization server for analysis and subsequent storage in the UBCI container. The UBCI server provides memory space to store analysis outputs from Metrix.

4.2.3 Pulse

Pulse collects continuous user feedback on buildings and connects it to building services. The idea behind pulse it to provide a large amount of new information for building maintenance, enabling improvements to conditions, technical functionality and energy efficiency while boosting the well-being of people and buildings.

Pulse also offers up the feedback collected from the property to the building's users. As such, people are able to see how the owners and managers have reacted to feedback and what the conditions are like in the building.

Feedback can be provided using a mobile device, a traditional website, user feedback buttons located on properties or by clicking on the signature of an email.

4.2.4 WiA - What-if-Analysis service

To execute a What-if-Analysis, the WiA service requires monitoring data (the actual sensor values) and BIM data provided by the UBCI-Container. As a result, the WiA service delivers recommendations in text form. The WiA service will use to communicate with the UBCI-Container the OPC Unified Architecture (OPC UA) protocol. OPC UA is a machine to machine communication protocol originally developed for industrial automation, but fits with its characteristics also for the eTEACHER project. OPC UA provides a standardized, open, cross platform and service-oriented architecture (SoA) protocol which is designed as a server/client architecture. The Server (UBCI-Container) includes an integral information model to provide information over the available data. A client (WiA Service) can browse this information model and read information like actual and historical sensor values (monitoring data). OPC UA provides also the possibility to transfer files between server and client (BIM data *.ifc files). Furthermore, the server (UBCI-Container) provides memory space in its information model where the client (WiA Service) can store analysis outputs like recommendation results produced by the What-if-Analysis.

5 eTEACHER Pilots: Monitoring Requirements

The concept of eTEACHER (i.e. ICT solution for buildings to motivate the energy behavioural change) is thought to be fast deployed in most of existing buildings considering the level of monitoring systems (BEMS/BACS features), the building architecture and the energy systems (HVAC, lighting, etc.), which are mainly related to the location and climate conditions. In this project, 4 types of buildings in three different climate zones (Spain, UK and Romania) are considered: two health care centres, three academic ones (one school and two high schools), two administrative buildings and five residential buildings (see Figure 6).

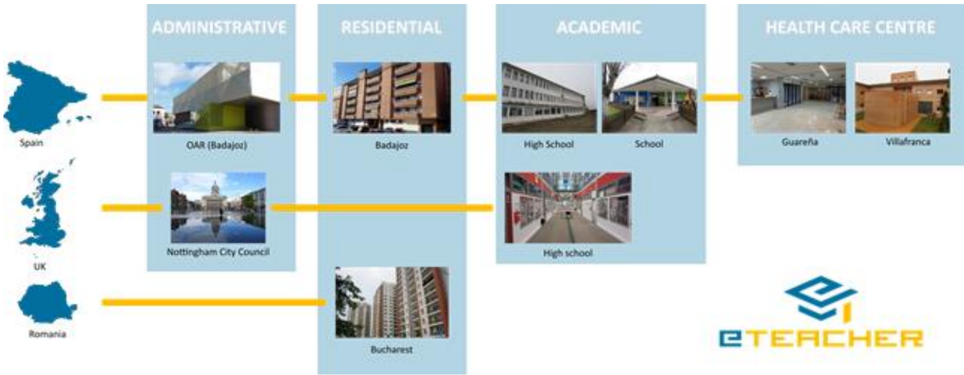

Figure 6. eTEACHER building pilots

However, taking into account this framework, the definition of monitoring requirements becomes a complex issue since building types, building configurations (architecture), energy systems (boilers, chillers…) and the existing monitor and control system result in many different potential combinations. Therefore, the definition of monitoring requirements to carry out the project research and integrating the eTEACHER solution is based on the common and basic specifications that allow designing and installing in short-term additional sensors and communications systems to capture and change the energy behaviour of building occupants:

- Internet connection: the system architecture and the UBCI are to receive information and monitoring information through external servers.
- Small PC to host ViciOne (core software of eTEACHER).
- Meters following MBus standard and gateways to translate MBus to IP.
- Additional Sensors for among others room climate and state of lighting with API and IP/Ethernet connection (e.g. Netatmo weather sensors)

In addition, given aforementioned conditions of buildings and the different use cases, a preliminary selection of most suitable use cases for the different buildings is shown as follows:

Table 9. Preselection of use cases for eTEACHER building pilots

Building	Type	Pre-selection of use cases
OAR	Administrative	ECM1, ECM2, ECM3, BP1, IEQ1

Building	Type	Pre-selection of use cases
NCC	Administrative	ECM2, ECM3, ECM4, BP1, IEQ1
Badajoz	Residential	ECM1, ECM2, ECM3, ECM4, IEQ1
InCity	Residential	ECM1, ECM2, ECM3, ECM4, BP1, IEQ1
High school (Spain)	Academic	ECM2, ECM3, IEQ1
School	Academic	ECM1, ECM2, ECM3, ECM4, IEQ1
High School (UK)	Academic	ECM1, ECM2, ECM3, ECM4, BP1, IEQ1
Guareña	Health Care Centre	ECM1, ECM2, ECM3, ECM4, IEQ1
Villafranca	Health Care Centre	ECM1, ECM2, ECM3, ECM4, BP1, IEQ1

These use cases are demonstrated and evaluated with the corresponding requirements in the different pilots.

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Annex A. Templates to Collect Pilot Information

1 BUILDING NAME

1.1 General Information

Building Type	[high school, office, etc.]
Surface (m^2)	
Address	
Year of construction	
Refurbishing (year / name / short description)	[Roof insulation (2010): …] [New boiler (2015): …]
Number of users	

1.2 Geometry

1.2.1 Summary

Non-Residential

Room Type	Floor 1	Floor 2	…	Floor n
[Room Type 1]	[nº rooms; nº users; m^2]			
[Room Type 2]				
…				
[Room Type n]				

Residential

Flat Type	Description
[Flat Type 1]	[m^2; orientation; nº users; type/number rooms]
[Flat Type 2]	[150 m^2; south; nº users; 2 bedrooms, 1 kitchen, 2 toilets, 1 livingroom, corridor]
…	
[Flat Type n]	

Flat Type	Floor 1	Floor 2	…	Floor n
[Flat Type 1]	[nº flats, nº users, m^2]			
[Flat Type 2]	[nº flats, nº users, m^2]			
…				
[Flat Type n]				

1.2.2 Plans

ID	Name	Description
[G.01]	[Distribution Floor 1]	[It includes … (2013)]

1.3 Construction Materials

Construction Type	Surface (m^2)	Layers[1]
Exterior wall		[Mortar Cement 1.5cm / Brick 12cm / Mineral Fiber Rock 4cm / Walls Air Gap / Brick 9cm / Gypsum 1.5cm]
Interior wall		
Floor/ceiling		
Roof		
Doors		
Windows		

[1] If no data about the layers, it is also possible to provide U(W/m^2K)

1.4 Building components

1.4.1 Windows

DESCRIPTION

Type/number	Glass	Frame	Shadings	Control	User interaction

OTHER INFORMATION

Problems	
Potential eTEACHER interventions	
Comments	

1.4.2 Doors

DESCRIPTION

Type/number	Glass	Frame	Shadings	Control	User interaction

OTHER INFORMATION

Problems	

Potential eTEACHER interventions	
Comments	

1.5 Energy Systems

1.5.1 HVAC

HEATING

GENERAL DESCRIPTION

Energy source	[Natural gas]
Production system	[3 gas boiler for heating and 1 for DHW]
Distribution (secondary)	[circuits, pipes, pumps, fan, …]
Terminal units	[Radiators in all the rooms of the building]
Control	[Central control] [Boilers automatically regulated according to $T_{water,return}$] [Radiators can be manually adjusted]
Interaction (user + how is the interaction)	FM can regulate setpoint for $T_{water,return}$ Teachers & students can manually regulate radiators
Problems	
Potential eTEACHER interventions	
Comments	

SYSTEM CONFIGURATION

Summary

Circuit name	Description
	[Components connection & location in every circuit for primary & secondary]
Cold circuit 1	[Chiller 1 connected to pumps 3,4; collector 1, and fancoils 1-4 in floor 1 (corridor & administrative area)]

Design Plans/Blueprint

ID	Plan Name	Description
[P.01]	[Production roof]	[It includes … (2013)]

COMPONENTS DESCRIPTION

[Include boilers, fancoils, chillers, AHU, pumps, fans, etc]

Production

number/type / vendor model[2]	Control	User interaction	Location / ID

Terminal units

number/type / vendor model	Control	User interaction	Location / ID

Distribution

Number/type / vendor model	Control	User interaction	Location / ID

[2] If no vendor model, introduce main features: Cooling Capacity, COP, etc.

COOLING

GENERAL DESCRIPTION

Energy source	
Production system	
Distribution (secondary)	
Terminal units	
Control	
Interaction (user + how is the interaction)	
Problems	
Potential eTEACHER interventions	
Other comments	

SYSTEM CONFIGURATION

Summary

Circuit name	Description
	[Components connection & location in every circuit for primary & secondary]

Design Plans

ID	Plan Name	Description
[P.01]	[Production roof]	[It includes … (2013)]

COMPONENTS DESCRIPTION

[Include boilers, fancoils, chillers, AHU, pumps, fans, etc]

Production

number/type / vendor model	Control	User interaction	Location / ID

Terminal units

number/type / vendor model	Control	User interaction	Location / ID

Distribution

Number/type / vendor model	Control	User interaction	Location / ID

VENTILATION

GENERAL DESCRIPTION

Energy source	
Production system	
Distribution (secondary)	
Terminal units	
Control	
Interaction (user + how is the interaction)	
Problems	
Potential eTEACHER interventions	
Comments	

SYSTEM CONFIGURATION

Summary

Circuit name	Description
	[Components connection & location in every circuit for primary & secondary]

Design Plans

ID	Plan Name	Description
[P.01]	[Production roof]	[It includes … (2013)]

COMPONENTS DESCRIPTION

[Include boilers, fancoils, chillers, AHU, pumps, fans, etc]

Production

number/type / vendor model	Control	User interaction	Location / ID

Terminal units

number/type / vendor model	Control	User interaction	Location / ID

Distribution

Number/type / vendor model	Control	User interaction	Location / ID

1.5.2 Domestic Hot Water

GENERAL DESCRIPTION

Energy source	
Production type	
Power installed	
Control	

Users interaction	
Problems	
Potential eTEACHER interventions	
Comments	

COMPONENTS DESCRIPTION

Number/type / vendor model	Control	User interaction	Location / ID

1.5.3 Lighting

GENERAL DESCRIPTION

Lighting type	
Power installed	
Control	[central/manual; schedule, etc]
Users interaction	
Problems	
Potential eTEACHER interventions	
Comments	

COMPONENTS DESCRIPTION

Number/type / vendor model	Control	User interaction	Location / ID

1.5.4 Other equipment

[Include computers, washing machines, printers, etc.]

DEVICES DESCRIPTION

Number/type / vendor model	Control	User interaction	Location / ID

OTHER INFORMATION

Problems	
Potential eTEACHER interventions	
Comments	

1.5.5 Electric cabinet

CABINETS DESCRIPTION

[Include 1 table per cabinet]

Name / location	
Description	
Picture	
Single Line Diagram	
Main electric meter type	[digital, analogic, smart meter, etc.]

OTHER INFORMATION

Problems	
Potential eTEACHER interventions	
Comments	

1.6 Monitoring system

Variables (measurements / sample time)	

Network configuration	[description & diagram/squema]
Sensors type (vendor model)	
Communication protocol(s)	
Monitoring software	
Other components description (pcs, router, modem, gateways, etc.)	
Interoperability / reuse in eTEACHER	
Other comments	

1.7 Control system: BACS / BEMS

Variables (measurements / frequency)	
Controlled variables	
Setpoints	
Network configuration	[description & diagram/squema]
Sensors type (vendor model)	
Actuators type (vendor model)	
Communication protocol	
BEMS/BACS software	
Other components description (pcs, router, modem, gateways, etc.)	
Interoperability / reuse in eTEACHER	
Other comments	

1.8 Historical monitoring & energy consumption data

[Registered data from previous years, invoices, etc.]

Name	File type /format	Data type /frequency

1.9 Energy Audits

Date	Objective	ECMs applied	Report name

1.10 Summary of building problems related to energy efficiency according to users

Building problems	
Potential eTEACHER interventions	

1.11 Additional information