D4.1–INBETWEEN METHODOLOGY FOR IMPLEMENTATION

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ICT enabled BEhavioral change
ToWards Energy EfficieNt lifestyles

LEADER:

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DISCLAIMER

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EXECUTIVE SUMMARY

InBETWEEN project aims to create more energy efficient lifestyles assisting users to identify energy wastes, learn how they can conserve energy and motivate them to act, through the collaborative InBETWEEN cloud based platform offering advanced energy services. It allows users to integrate their building's connected devices and systems with advanced energy analytics and optimisation services to create a comprehensive recommendation and feed-back solution, which will facilitate further the behaviour change towards more energy and cost efficient daily routines.

The inBETWEEN methodology for implementation aims to establish a common framework for carrying out the demonstration activities of the project in a wide range of real life pilot locations in two EU countries, France and Austria. The pilot location in France consists of 42 apartments, while the pilot location in Austria encompasses 8 single family houses and 6 non-residential buildings: 2 hotels (guest houses), a kindergarten, a school, and two community office buildings. Even if the demo sites addressed have many differences in term of size, typology, climate, and usage patterns, it is recommended to define a set of common guidelines directing the implementation process in order to ensure a successful deployment and guarantee at the same time the future replicability of the process in other locations.

Any deployment activity must be preceded by a deep analysis of the site targeted, which shall encompass both the building(s) of the site, and all related stakeholders, including both those that will directly use inBETWEEN technology, as well as those that have some kind of influence in the implementation process. The building(s) analysis shall include the study of the location and climate, constructive features and typology, all the related energy systems (inputs from energy grids, building-integrated energy generation and storage, HVAC equipment appliances, etc.), any potential already existing monitoring and building automation systems, and available communications infrastructure. Whenever possible, a preliminary study of the general energy use profiles in the building(s) shall also be included in the analysis. The stakeholder analysis shall try to identify and classify all relevant stakeholders in the implementation process, map different stakeholder profiles in terms of knowledge, interest and expectations in relation to the planned deployment, and potential engagement strategies for ensuring a successful implementation.

The analysis of the site will provide a set of requirements and goals that will help to identify how the inBETWEEN platform needs to be customized for each specific deployment. This customization shall be applied to the different layers of the platform architecture. At the sensor and actuator layer it will be necessary to define the most optimal devices for measuring energy consumption, indoor comfort, building usage patterns, and smart controls. At the gateway layer it has to be defined which communication protocols shall be integrated for communicating with sensors and actuators, how the building data will be locally processed, and what type of internet connection will be used for communication with the cloud layer, and how this communication will be done. Guidelines shall also be provided for any customization needed at the cloud layer, and for the applications that will deliver services to inBETWEEN users.

Once the deployment has been characterized at all levels, it is the turn to accomplish the detailed planning of the deployment, which shall start in first place with a global planning of the deployment phases, that may include a preliminary period for elaborating a detailed baseline, and then continue with the elaboration of the installation blueprints, the list of hardware and software components to be supplied and their cost, the planning of hardware and software installation task and their cost, and the preparatory activities like purchases and permit processing.

This detailed planning will allow carrying out the actual installation in the demo sites in the most efficient fashion, which shall be followed by a previously well-defined commissioning process, verification procedures for ensuring the correct operation of all the components, and implementation of adequate stakeholder training strategies for correct use of inBETWEEN platform.

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1 INTRODUCTION

This report aims to provide a common methodology for implementing the inBETWEEN platform in each of the project demo sites. The implementation is divided into different stages that shall be completed, and for which general guidelines are provided, in order to achieve a successful deployment.

This methodology is a practical document for the INBETWEEN project team, as it will drive the actual implementation that will be done in the demo sites, but at the same time it provides a base knowledge that can be reused for future replication of inBETWEEN in other buildings after the finalization of the project. These guidelines can even be useful for the implementation of other platforms different to inBETWEEN, but with similar objectives and approaches, i.e. collection of energy efficiency-related data in public residential and non-residential buildings, processing of these data in the cloud, and provision of intelligent feedback to users through apps, web interfaces, etc., with potential application of optimized automated control functions in the building.

The deliverable is an output from task 4.1 "Specification of the inBETWEEN platform deployment in the project demo sites", which is the first within WP4 "Demonstration site deployment and monitoring". The methodology will then be used as basis for producing the detailed specification of the inBETWEEN platform implementation in the demo sites (D4.2), that will be the reference document for the different phases of the actual deployment (D4.3, which corresponds to the 1st phase of the deployment, and D4.4, which corresponds to the 2nd phase).

The main inputs for producing the methodology come from WP1, where a deep characterization of the demo site buildings (task 1.1) and of their users' behaviour (task 1.2) are being carried out. Other important inputs to consider are related to the general architectural design of the INBETWEEN platform, which are being developed within task 1.3 (INBETWEEN platform requirements specification), task 1.4 (Definition of Key Performance Indicators) and task 2.1 (inBETWEEN Integration Approach/Architecture/Development). Besides, the work that is being carried out within WP3 for developing a methodology for achieving user engagement and behaviour change is also considered whenever it has direct implications for the implementation. The figure below depicts the interrelations of the Methodology with other project tasks and deliverables as they have been described.

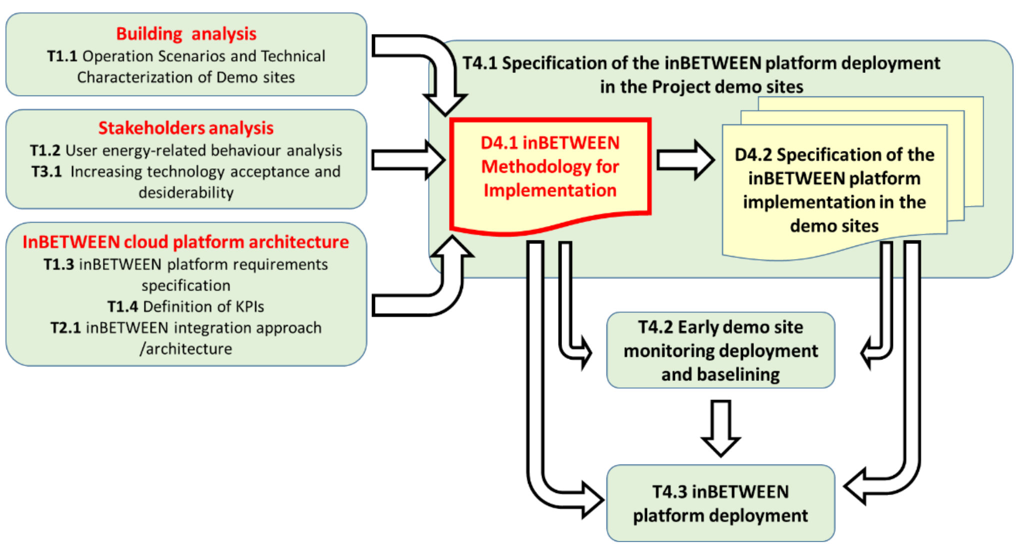


Figure 1 Interrelations between D4.1 and inBETWEEN tasks

Section 2 of the report provides guidelines for analysing each of the demo sites, both from the point of view of the building features and of the stakeholders involved. By stakeholders we mean not only the direct end users

of the INBETWEEN platform, but also other stakeholders that shall be considered for the implementation, even if they are not going to use the platform.
Section 3 provide guidelines on how to develop the specific (customized) implementation of the INBETWEEN platform in each demo site, by matching the results obtained from the previous analysis of buildings and stakeholders with the global architectural features of the INBETWEEN platform.
Section 4 deals with the detailed planning of the deployment based on the specification produced in the previous step. This planning shall produce the blueprints for the installations, a detailed list of hardware/software components that need to be supplied, an estimation of the costs of these components, a detailed planning of installation activities needed for deploying the platform and estimation of their associated costs, and preparatory activities needed prior to the installation activities (purchasing process, permits processing, etc.).
Section 5 provides the guidelines for carrying out the actual deployment in the demo sites, which includes in first place the installation of the software and hardware components, followed by the commissioning of the inBETWEEN platform, the verification of the correct operation of all components and services, and the training of all stakeholders, including those that will use the platform services
Section 6 presents the conclusions of the document and next steps to be followed within WP4 of inBETWEEN

2 GUIDELINES FOR DEPLOYMENT SITE ANALYSIS

2.1 BUILDING ANALYSIS

A deep and detailed characterization of each targeted building is essential in order to ensure a successful implementation of the inBETWEEN platform. Different features of the building such as location and constructive features, existing energy consuming and producing equipment, available ICT infrastructure and systems (including potential pre-existing monitoring and automation systems), and energy use profiles, will determine several requirements and constraints that shall be considered for the implementation.

The analysis of the buildings will require the collection of all available technical documentation about the building and of the systems and subsystems installed within it, and will normally require as well one or more field visits in order to retrieve information that may not be included in the documentation, or when the latter is incomplete.

Building typology (e.g. residential vs. non-residential buildings) is a key feature that is reflected in most of the rest of features, e.g. constructive features, building layout, types of energy installations, energy use profiles, etc., therefore, it will be considered as a cross topic in the following subsections that address each group of building features.

2.1.1 Location and constructive features

The first group of features to be analysed are related to the general architectural properties of the building, with special focus on the ones that may have a more direct impact on energy consumption and energy efficiency, namely:

Building location and orientation

Analysis of the location of the building will in first place determine the climate conditions to which it is exposed and thus get a first picture of the demand for heating and/or cooling that can be expected in the building.

Another important aspect of the location is the interaction/interference with surrounding elements of the neighbourhood, such as other buildings. This can have an impact for instance on indoor comfort conditions (e.g. rooms that get scarce natural light due to a nearby building that blocks it) and also on energy consumption (for the same case of a nearby building that blocks natural light, this will normally cause a higher demand for heating in cold periods). Besides, potential renewable energy systems integrated within the building will also be influenced by both climate conditions and interference of surrounding neighbourhood elements.

Finally, orientation of the building will also have an impact on its demand for heating and cooling, e.g. demand for cooling in hot periods will be higher in buildings with West and South orientation, lower with East orientation, and the lowest with North orientation, on the other hand, demand for heating in cold periods will be lower in buildings with South and East orientation, higher with West orientation, and the highest for North orientation. Therefore, global orientation of the building will also give some hints about the expected demand for heating and cooling, as well as potential comfort issues due to too cold or too hot indoor temperatures. Nevertheless, orientation shall also be analysed at room/dwelling level within the building as explained in the next section about building layout.

Building layout

The layout of the building will impact directly on the selection of the number and location of monitoring/control devices that will be deployed and connected to the inBETWEEN platform.

The analysis of the layout shall provide information about the main building areas, the different building rooms and common areas, and geometrical properties of each of them: dimensions, orientation, distribution of doors and windows, functions/uses of the areas and rooms, etc. It is useful trying to identify and group areas and rooms with similar properties, e.g. rooms with the same type of use.

All this information will help to decide on which areas/rooms of the building shall be prioritized in terms of monitoring and control depending on different factors. Budget constraints may force to select only a subset of the rooms/areas for deployment of sensors, meters and actuators, and this selection can be based on information obtained from the building layout analysis.

For instance, it is desirable to pick up a sample of rooms and areas representative of the majority of functions and uses of the building, with special focus on the areas with potentially more intense use and higher energy demand. The latter will be influenced by factors such as orientation of the room and building floor where it is located.

If there is a group of similar rooms, and it is necessary to select the most representative ones, a good approach is to identify a subset of rooms with potentially more extreme energy demand, as well as a subset with potentially average energy use, e.g. for a set of rooms distributed in different floors of the building, the selection could consist of a room in the ground floor (potential higher demand for heating in cold periods), another room in an intermediate floor (average heating/cooling demand throughout the year), and a room in the top floor (potential higher demand for heating in cold periods and for cooling in hot periods).

Dimensions of each room will have to be considered especially for buildings with particularly large spaces (which will be probably more the case of public buildings than social housing buildings), as there can be significant local variations of indoor parameters such as temperature. Therefore, large rooms and open spaces (e.g. surface larger than 50 m^2) may require monitoring of indoor comfort conditions in more than one point.

Building constructive features

Analysis of constructive features of the building, e.g. thermal insulation properties of walls and glazing, acoustic insulation and conditioning, existence of sun control and shading devices, and others, together with the previous analysed information about location, orientation, layout, etc., will provide further insight into the expected energy demand of the building for heating and cooling, as well as to identify potential indoor comfort issues. All these aspects can have in the end an impact on the deployment of the inBetween platform, both from the point of view of the selection of the location of sensors, as it may be more interesting to place them in areas with potential higher comfort issues, and from the point of view of the feedback that will be provided to the end users through the inBetween services, as this feedback shall help them to deal with (or at least be aware of) the energy consumption and indoor comfort issues that may be derived from the inherent properties of their building/dwelling.

2.1.2 Energy systems

Once the general properties of the building envelope have been analysed, the next step will be to study the building installations, starting with all the equipment related to energy consumption, production, and storage, as one of the main targets of inBetween will be to help end users to achieve an optimal use of all this equipment, and for that it will be needed to determine which are the most suitable sensors/meters for measuring the energy consumption/production of each system, and which actuators can be implemented in order to control them in the most efficient way.

Firstly, it will be needed to determine which are the main energy inputs to the building, which can belong to one or more energy carriers.

- **Electricity:** in some cases (e.g. the French pilot in In Between) this will be the only energy carrier that feeds a building, if this has electric HVAC systems. The analysis of the electricity installation of the building shall render the following data:
    - Utility supplying electricity to the building. In case of an apartment building, each dwelling may have its own contract with a different energy retailer. Analysis of contracts and pricing structure will help to determine potential opportunities for optimization of electric tariff choice and adaptation of electricity consumption to it.
    - Existing electricity meters. In the case of a building of public use, there may be a meter for the whole building or there may be different supply points if the building accommodates different uses. In the case of an apartment building, there will normally be a meter per dwelling plus a meter for the common areas. It shall be checked whether it is possible to extract data from existing meters.
    - Structure of circuits and existing electricity cabinets: Analysis of the layout of electric circuits will help to determine the possibilities that the building offers in terms of submetering. In buildings of public use the electric installation may allow to allocate the consumption to different areas of the building: e.g. consumption of each floor of the building, consumption of a specific room, etc. In these buildings it will also be interesting trying to differentiate the circuits for lighting from the circuits for other uses. In the case of apartment buildings, each dwelling will also normally have the electricity split in different partial circuits, e.g. for lighting, for the washing machine, the fridge, and other main electrical appliances. On the other hand, for all types of buildings it is essential to analyse the electricity cabinets in order to locate the points where submetering can be applied to the previously identified partial circuits. It shall be checked the availability of space within these cabinets for installation of submeters.
- **Gas:** natural gas is another of the main energy carriers used for providing heating and DHW (Domestic Hot Water) to the building. The approach for analysing the installation will be similar as for electricity: analysis of the supplying utilities and existing contracts and tariffs, analysis of existing meters, and analysis of circuits to identify options for submetering.
- **District heating:** certain regions of Europe make intensive use of this type of heating systems. The analysis will be similar to the previous ones: analysis of supplier and tariffs, existing meters, and opportunities for submetering within the building.

- **Biomass and fossil fuels/coal:** although biomass and fossil fuels/coal differ completely from the environmental point of view, they have in common the fact that they are supplied in batches, i.e. it has a discontinuous supply, and therefore continuous metering cannot be applied. There may be registries at the building of the consumption of these energy carriers, but real time metering will have to be done at the points of energy transformation (e.g. boilers).

Buildings of recent construction increasingly integrate energy generation technologies for covering part of their energy demand. In such cases, it will be interesting to try to monitor these systems within the inBETWEEN platform in order to enable a comprehensive analysis of all energy flows. Most frequently integrated energy generation technologies are:

- **Solar thermal:** this kind of systems are one of the most widespread renewable energy generation technologies integrated within buildings, and they are normally used to support the production of DHW and, in some cases, the heating system as well. The general features of this system (number, type, nominal capacity and orientation of panels) shall be analysed together with possibly existing metering systems for measurement of the energy produced, their interoperability options or, if there is no available metering, the options for installing such a system.
- **Solar PV:** these systems produce electricity, which can be either directly consumed by the building, injected into the power grid, or stored locally in the building if there is a system installed for that purpose. Therefore, in addition to the analysis of the general specifications of the installed equipment (which is similar to the one described for solar thermal: number, type, nominal power and orientation of the panels), and of the available or potential metering equipment, it is important to analyse the available options in terms of direct consumption, injection of electricity to the grid, and storage, as these will determine the opportunities for optimized management of this kind of systems.
- **Other:** Other types of renewable energies (e.g. micro wind turbines) are less frequent in buildings, but nevertheless the approach for analysing them would be similar as for solar thermal and PV: analysis of the technical features (focused on generation nominal capacity), and in case that the energy source produces electricity, it shall be analysed its potential direct use in the building, and potential flows to the energy grid and to any storage system. In some cases, renewables can directly assist an HVAC system (e.g. a ground source heat pump), and therefore the analysis will be focused on the HVAC installation itself, as explained below.

Once that the main energy carriers have been characterized, the next step will be to analyse the main points where this energy is either transformed into a different energy carrier (e.g. a boiler where natural gas is transformed into heat and DHW), or directly consumed (e.g. an electric domestic appliance).

Gas, biomass and fossil fuels are not usually consumed directly in the building (with some exceptions, such as gas stoves), and need therefore to be transformed into other forms of energy that are analysed below:

- **Boilers:** this equipment will take as input natural gas, biomass or fossil fuel, and produce heating and/or DHW. There are as well boilers that use electricity. It will be interesting to obtain information about the boiler model and its nominal parameters (power, efficiency). From the metering point of view, measuring the output flow of the boiler (volume and temperature) will allow determining its actual performance and detect possible malfunctions. Residential buildings may have a central heating system. In these cases it will be necessary to differentiate between the older systems, which do not have and do not allow for individual energy consumption metering of each dwelling, and more recent systems that have or can incorporate individual metering. For central heating systems it will be also useful to obtain information about the currently implemented management strategies (e.g. scheduling of on/off periods). For residential buildings with individual heating system, it is important to check whether all dwellings have the same model or there are differences among dwellings.

- **Micro-CHP:** this is a more advanced system which in addition to heating and DWH, produces as well electricity. The approach for analysing them will be similar as with boilers, with the only additional consideration of the existing or potential metering of electricity production.
- **Heat pumps, air conditioning:** under this category, different types of equipment powered by electricity can be identified. The most usual will be air conditioning units that are used for producing cool air in hot periods. Most of this kind of units can also work in reverse mode and produce hot air, although if the system coexists with a heating system with boiler, the heating function of the air conditioning will seldom be used. On the other hand, heat pump systems are meant to be used mainly as heating systems, although they will most frequently integrate as well the cooling function. Other types of heat pumps transfer the thermal energy to water instead of air, and thus are able to produce heating, cooling, and DHW. In these cases, the heat pump unit may be connected to radiator units, to a radiant floor, etc. As it has been mentioned previously, there are heat pumps that transfer heat to or from the ground (Ground Source Heat Pump, or GSHP), in order to achieve higher efficiencies. The way of analysing these systems does not differ much from the previous ones, and it will be necessary to check the nominal heating/cooling power of the unit, the performance parameters (COP – Coefficient of Performance), the existing or potential metering equipment for measuring electricity consumption, and for the case of units heat water, the existing or potential metering equipment for measuring the volume and temperature of the output flows.

For the distribution of heating through the building, there are different possible systems. For instance, within residential building the two most frequent will be:

- **Radiators:** it will be useful to characterize them in order to analyse opportunities for individual metering and control. This will be particularly useful for one of the cases that have been described above, central heating systems with no individual metering per dwelling. In these cases it is even more useful trying to monitor the consumption per radiator unit (in fact this is something enforced by EU's Energy Efficiency Directive). The same approach shall be followed for dwelling where the heating system is composed of individual electric radiators (as it is the case for instance in the inBETWEEN pilot in France).
- **Radiant floor:** this heating distribution system is more typical of high-end buildings/dwellings and is characterized by its higher efficiency and usually higher level of controllability (e.g. control per room). If this system is present, it will be useful to determine the interoperability options of its control unit.

Lastly, it will be necessary to characterize the main electrical loads of the building, namely:

- **Lighting:** this is one of the main uses that the inBETWEEN system shall be able to differentiate from the others. In many cases, there is a specific partial circuit in buildings/dwellings dedicated to this use, so it is generally feasible to measure its consumption separately, provided that the electrical layout of the building is available. It will be useful to determine the types of light bulbs present in the building (incandescent, fluorescent, LED, etc.). Knowing the types of light bulbs, the most relevant approach to saving energy is to change any light source that is not LED to an LED. With LED lighting the energy used for lighting will become little relevant compared to other consumption types.
- If we are to consider monitoring groups from the electricity cabinet, we need electrical layouts of the buildings – which may or may not be hard to acquire for this buildings,
- **Lifts:** lifts represent a significant fraction of the electricity consumption of a building, therefore it will be also useful to analyse them, their nominal consumption, performance, etc.

- **Home appliances:** in residential buildings it is especially interesting to identify the main electric appliances that are present: stove, oven, fridge, washing machine, dishwasher, drier…Most frequently each large appliance will be connected to a dedicated partial electric circuit, which will allow easy individual submetering from the electric cabinet of the dwelling.
- **Office equipment:** in buildings of public use, the main use of electricity, apart from lighting and lifts, will normally correspond to office equipment like PCs, printers, coffee machines, etc.

If the layout of the electric installation does not allow monitoring the consumption of two or more main appliances separately, then plug meters can be a solution. The risk is that this kind of equipment can be more easily moved, and therefore can end up measuring the consumption of an appliance different of what was initially expected. Another alternative is the use of cable mounted metering and control unit, which will not be as easily moved as a smart plug – it will limit the risk the same as a mounting clamp on meters. Nevertheless, the use of Non-Intrusive Load Monitoring (NILM) within inBETWEEN can help to overcome this type of issues.

2.1.3 ICT, monitoring and automation systems

Once that the characterization of the energy systems is completed, the next step in the building analysis will be to study the existing ICT-related infrastructure. Firstly, the analysis shall address existing or potentially deployable communications infrastructure to be used by inBETWEEN, both for transmission of data between the local monitoring/control devices and the inBETWEEN cloud, and for the use of inBETWEEN applications by final users. Afterwards, if the building has any pre-existing energy management solution (BMS, BEMS or HEMS), this shall be analysed in order to assess its potential interoperability with inBETWEEN system, as the approach will always be to minimize the deployment of new equipment and take as much advantage as possible from the already available systems.

Regarding the communications infrastructure, the following points shall be checked:

- **Availability of Internet connection:** this is a key point, as this will enable communication between locally deployed devices and inBETWEEN cloud platform, and will enable as well access to inBETWEEN applications by end users. In this point, there is a difference depending on whether the addressed building is residential or not. For non-residential public buildings there will probably be a Local Area Network (LAN) or Wireless Local Area Network (WLAN) that could be used for the connection of some of the field devices (mainly the gateway), but it shall be checked whether this connection will be possible, as the network could be subject to some security restrictions. Therefore, the network administrator shall be contacted to find out about this issue. For residential buildings, the most usual situation will be that each dwelling will have its own Internet connection (ADSL, Optical Fibre, etc.), and possibly a WiFi network. In this case, the only condition for connecting the gateway or any other device to this network will be to obtain the permission from the dwelling owner/tenant. However, it shall be noted that any change in the configuration of the home router could have an impact on the communications with inBETWEEN cloud. There may be situations where no internet connection is available, for which some proposals for addressing each case are listed below:
    - **Non-residential building with no internet connection:** in a situation like this, it could be studied whether the implementation of the inBETWEEN system could be an opportunity for deploying a LAN/WLAN infrastructure. If this is not feasible, then the simplest solution can be to use a gateway with integrated mobile Internet connection (3G, 4G, etc.). It shall be checked the coverage provided by the local mobile network operators to ensure that there will be a robust link between the gateway and inBETWEEN cloud.

   - **Dwelling with no internet connection:** for this case, if the dwelling owner/tenant is not willing to contract an internet connection, the most recommended solution is similar to the previous point: provision of a gateway with integrated mobile internet connection.
   - **Residential building with no internet connection (common areas):** it shall be noted that in residential buildings it can be interesting to monitor common areas in addition to the dwellings. In most cases, there will be no communal internet connection, and therefore it shall be decided either to contract an ADSL/optical fiber connection for this purpose, or use a similar solution based on mobile internet connection.
- **Existing monitoring/control infrastructure:** buildings as a whole or individual dwellings may already have some kind of energy monitoring/control solution already deployed, and therefore the most cost-efficient approach would usually be to take advantage of this infrastructure and just complement it with additional sensors, meters or actuators that may be needed, and connect it with the inBETWEEN platform. Nevertheless, trying to integrate such system has also its drawbacks, so for each site it will be needed to perform a careful analysis of the pros and cons of each alternative. The main advantages of reusing available infrastructure are: lower investment needed in equipment, users/staff of the building are already familiar with the existing system, there will normally be a base knowledge about how the system is performing and its potential technical problems, and historical data may be available to elaborate a baseline. On the other hand, potential disadvantages of infrastructure reuse are: possible lack of detailed technical documentation about the system, interoperability issues that may arise when trying to integrate new devices with the legacy ones, and objections from part of the building stakeholders to implementing modifications in the existing system. If the result of the assessment is trying to reuse existing systems, the following aspects shall be analysed:
   - **General features of the system:** depending on the building typology, different types of systems could be present. In the case of apartment buildings, there could be some kind of HEMS deployed. Unless this system was integrated in the construction phase of the project (which is normally the case of only high-end dwellings) then it is has been up to the dwelling owners/tenants to install or not the solution that they prefer. In those cases, it can be too challenging trying to integrate HEMS from different vendors, so most probably the most efficient option will be to deploy inBETWEEN as a separate solution. Previous HEMS could be used just to extract historical data, or maybe some sensors could be reused if they communicate through standard protocols. For non-residential buildings there could be a BMS or BEMS. These systems usually represent an important investment, and are centralized for the whole building, so it will normally be worth to integrate it with inBETWEEN. General features such as supplier of the system, management software, equipment where this is executed, current global management strategies, etc., shall be collected, and then proceed with the analysis of the rest of features listed below.
   - **Detailed list of components:** this analysis shall provide a list of the devices that are integrated within the system (sensors, actuators, communication equipment, etc.), and of the building parameters that are monitored/controlled. This analysis is an opportunity to check the actual working status of the system components. There could be malfunctioning devices that need to be replaced, or maybe a recalibration of sensors/meters is needed.
   - **Analysis of communication aspects:** In many cases, BMS/BEMS have their own communications network. It will be needed to determine the communication protocols currently used and others that can be supported, and analyse as well the layout of existing cabling and communication equipment (e.g. gateways), to assess the feasibility of mounting additional devices, not only from

the interoperability point of view, but also from the a point of view of practical aspects of the installation (e.g. available space for deploying new cabling).

2.1.4 Energy profile

After the gathering of data/documentation and analysis of all the building features following the steps described in previous sections, there shall be already enough information available to perform a preliminary characterization of the energy use profile of the building. This information shall be complemented with the profiling of building stakeholders as described later in section 2.2.2. Data that could be included within this preliminary analysis are:

- **General building features:** general constructive features and theoretical energy labelling. Dimensions of the building. Identification of main areas/uses.
- **Energy consumption:** identification of main primary energy sources (natural gas, electricity, district heating, etc. and integrated energy generation) and quantification of total consumption in previous years, trying to identify main trends (e.g. seasonal variations). Identification of main loads of the building and quantification if possible of their consumption in previous years, and of the share that they represent in the total building consumption.
- **Global use patterns:** perform a global identification of main use patterns of the building: e.g. scheduling of central heating systems, lighting systems, etc. Identification of tariffs/price structure used for the different energy supplies.

2.2 STAKEHOLDERS ANALYSIS

This section aims to provide guidelines for analysing the stakeholders targeted by InBetween project. These guidelines will provide support to:

- assess which are the stakeholders than need to be involved,
- define which information need to be collected in order to be able to profile them and evaluate their interest towards the inBETWEEN energy efficiency solution
- define strategies in order to get their engagement and commitment to reach the global project aims

2.2.1 Stakeholder identification and classification

In first place, we need to identify all the stakeholders that shall be considered for the InBetween platform implementation. Based on the aims addressed by the project, the stakeholders that should be involved belong to the following main categories:

- Operative end users on field stakeholders:
  - Building owners - these can be either single owners (single apartment or single-family home) or whole building owners (multi-apartment or non-residential building owners) such as Social housing associations / Municipalities.
  - Facility managers
  - Dwelling tenants. By extension, this category could include as well commercial tenants, i.e. businesses or other organizations to which the owner of a public non-residential building rents a space within the building.
- Operative technology and services provider on field stakeholders
  - Energy supplier companies

    - Technology providers of ICT solution from hardware and software point of view

- Strategic stakeholders:
    - Governments / Policy Makers
    - Energy Service Companies (ESCOs)

In a demonstration project, like InBetween is, it is convenient, in order to maximize the achievable outcomes, the involvement of operative end users on field stakeholders since they may have direct influence in the process.

Operative technology and services provider on field stakeholders are necessary to customize the EE solution that can be proposed.

The strategic stakeholders finally are needed to study how to cost effectively replicate what has been proposed.

2.2.2 Stakeholder profiling

Once the stakeholders is identified, it becomes useful to briefly describe who they are and what they represent in relation to the project. Then it is useful to identify some preliminary core aspects of the project and assess their position with respect to each of them. In our project, based on the objectives targeted, the assessment has been done rating "low", "medium" or "high" their position in relation to:

- EE and ICT knowledge
- EE and ICT interest
- EE and ICT expectations

Stakeholder profiling:

Operative end users on field stakeholders:

- Building owner - in our cases represented by Social housing associations VIL and SON. However, in a general context they can be both single owners (single apartment and single-family home owners) or whole building owners (multi-apartment and non-residential building owners) such as SoHo, cooperatives, Municipalities etc.
    - Multi owner - As customers, social housing associations and municipalities own large amount of social housing and buildings of different size and purpose and, as public entities, they are particularly keen to minimize the normally scarce resources they have to allocate and make economic savings in return. As policy makers, they are entitled to create and use different regulations and standards for use within their jurisdiction that will improve energy efficiency.
    - Single owner - they need to have clear information on benefits that can be achieved and on the return of investment, otherwise is difficult to have capabilities to sustain interventions not strictly mandatory for maintenance.
- Facility managers - they take care of building maintenance.
- Dwellings' tenants - The assessment of tenants behaviour will be performed in inBETWEEN project and guidelines for them to have conscious actions will be provided based on inBETWEEN deployed solution.

Operative technology and services provider on field stakeholders:

- Energy supplier companies. They daily deliver energy to their customers. The possibility of analysing data coming from field and provide customized services to their users is a plus. Thanks to InBetween platform they can identify best offers, services and values to be applied in specific contexts.

- Technology providers of ICT solution in terms of HW and SW:
  - HW smart home devices, home automation systems, EMS/BMS/SCADA systems, etc. In this context, InBetween platform extends the functionalities of their products or allows the effective integration of their products with other vendors'.
  - SW- they are providing on cloud services and customized apps to reach people needs. There will be the possibility to provide service for big data management.

Strategic stakeholders:

- Governments / Policy Makers: The results coming from InBetween project can have great impact on energy consumption and emissions reduction. Particularly, EU governments and policy makers will have a great deal of interest in maximizing the penetration of the InBetween results to achieve the highly ambitious EU2020 and even 2050 goals for energy consumption and emissions reduction.
- Energy Service Companies (ESCOs): Many ESCOs companies provide energy services to residential sector. They are mainly interested in methodologies and solutions to better manage the energy consumption and associated contracts. The proposed InBetween solution contributes to demand reductions (i.e. flattening the load profile), owing to the better energy management of customers, and lower costs of customer efficiency programs.

Stakeholders rating: From general project partners know-how the current position of the different stakeholders in terms of knowledge, Interest and expectations from energy efficiency solutions and ICT can be summarized as follow on a scale High, Medium and Low.

	EE and ICT Knowledge	EE and ICT interest	EE and ICT expectation s
Building owner	M	M	H
Facility managers	M	M	H
Dwellings tenants	L	L	M
Energy supplier companies	M	M	H
Technology providers of smart home devices.	H	H	H
Governments / Policy Makers	M	M	H
Energy Service Companies (ESCOs)	H	H	H

Table 1 Stakeholder rating

2.2.3 Stakeholder engagement strategies

Once the stakeholders have been identified and profiled it is necessary to define a procedure to get their active engagement in the project. Having an active engagement can be beneficial to the project. The possibility to clearly and easily define what these benefits for each category are should be the driver to proceed.

- Building owner - they will get a benefit based on the fact that sensors will be deployed increasing the value of their own apartments/family-homes or buildings.
- Facility manager- can benefit from the project since they can have a solution to be proposed to reduce energy costs to other buildings they are managing.

- Dwellings tenants can directly benefit from the project with indication on how to save energy only by taking some action on their normal behaviour.
- Energy supplier companies – can study new services to be provided.
- Technology providers of smart home devices – Can propose their innovative technology and test the real savings that can be achieved.
- Governments / Policy Makers - can have access to data coming from field and identify new strategies and policies to achieve global energy reduction aims.
- Energy Service Companies (ESCOs) - can have access to data coming from field and identify other Business models to operate.

3 GUIDELINES FOR INBETWEEN PLATFORM CUSTOMIZATION

3.1 GLOBAL FEATURES

InBetween platform has been designed to be highly modular and adaptable to different setups according to technological and budgetary constraints. Based on the needs of specific user and the building type, a general framework has been devised. The mapping of building and stakeholder analysis to the particular InBetween layer has been shown in Table 2.

Building type	Sensor and actuator layer	Gateway layer	Cloud platform	Applications
Residential building without smart meters/actuators	Smart meters, environmental and occupancy sensors.	Gateway supporting widespread communication protocols	No specific customization	• Mobile app • WiTMo dashboard • Energy service selection depends on the stakeholder needs (only recommendations or automatic actions)
Residential building with legacy equipment for metering	Additional smart meters and sensors depending on preinstalled legacy equipment	Gateway supporting widespread communication protocols and legacy equipment	No specific customization	• Mobile app • WiTMo dashboard • Energy service selection depends on the stakeholder needs (only recommendations or automatic actions)

Non-residential building without smart meters/actuators	Smart meters, environmental and occupancy sensors.	Gateway supporting widespread communication protocols	Platform customization regarding available resources depending on the deployment size	• Mobile app • WiTMo dashboard • energy service selection depends on the stakeholder needs (only recommendations or automatic actions)
Non-residential building with legacy equipment for metering	Additional smart meters and sensors depending on preinstalled legacy equipment	Gateway supporting widespread communication protocols and legacy equipment	Platform customization regarding available resources depending on the deployment size	• Mobile app • WiTMo dashboard • energy service selection depends on the stakeholder needs (only recommendations or automatic actions)

Table 2 Building and stakeholder analysis mapping to InBetween platform

3.2 SENSOR AND ACTUATOR LAYER

The project's pilot sites are located in Austria and France and consist of residential buildings; 8 family houses in Austria and 42 small apartments in France. Although they are very different, they are all residential units with metered energy consumption. In Austria, there are also 6 non-residential buildings, including 2 hotels (guest houses), a kindergarten, a school, and two community office buildings.

Common to both the residential and non-residential buildings is the need to monitor the total energy consumption e.g. reading electricity and gas meters - and if possible water.

When selecting sensors/meters and actuators, it is recommended to use a limited number of different communication protocols, in order to enhance simplicity and to enable the devices to utilize the network capabilities of each other. Therefore, when choosing the devices, it makes sense to use those with the same communication technology as already used by other devices. In this project, we will focus on selecting devices with Zigbee. If some device types are not available for that protocol, devices with BLE or Z-Wave can also be applied.

3.2.1 Energy consumption

3.2.1.1 Measuring total premise consumption

Some European regions have requirements for their smart meter roll-outs stating that the meters need to offer the consumer local access to the meters data for integration into the consumers own smart home system. Some use various one- or two-wire interfaces, others use WMBus, and again others use Zigbee e.g. France (Linky) and

UK (SMETS2). Common to all is that they are not harmonized, and the roll-outs are not completed, and there are few, if any, commercially available interfaces for these.

As the state is today, we need to attach external readers to each meter to be able to get live monitoring. Typical power/electricity meters installed today have an LED that gives a flash/pulse with a frequency proportional to the energy consumed, typ. 1000 or 10000 imp/kWh. This is commonly used to monitor the instantaneous power usage, and there are probes commercially available from various vendors that can be attached to this interface, count the LED flashes, and convert them into different communication protocols. These interfaces, however, need to be configured to the specific meter regarding the number of pulses per kWh and the current total count value.

Many meters, both electrical and gas, have an infrared optical port that is also accessible. With this interface, access to both the instantaneous and total consumption registers can be possible. Many electricity meters use Dlms on this port while others, including some gas meters, use Mbus. The experience shows that there are small differences that apply to the IR interface as only the physical form factor is actually standardized. The interface is intended to be a service technician interface, where the service technician has tools that take into account the different types of meters.

Although the LED pulse counter probe does have installation challenges, they are workable, and it is therefore the recommendation to use this interface when possible.

The EMI from Develco Products to be used in inBETWEEN have probe options to support different types of interfaces. Ref [1]

Meter values from meters with wireless MBus, transmitting consumption values, can potentially be directly collected by the gateway. This does, however, require the key for the particular meters and is therefore typically reserved for the utility owning the meter. For larger roll-outs, this option should be considered as a requirement from building owners when e.g. new water meters are installed.

3.2.1.2 Measuring premise consumption when premise is also producing (PV)

When energy (electricity) is both produced locally and consumed from the grid, there can be a gap in the metering of energy consumed while producing. Typically, the utility meters are for billing and will only count energy either delivered (consumed) or received (produced).

When a house is installed with some kind of local producing capacity (typ. solar panels) and if only the utility meter data is available, then energy consumed by the house while the PV is producing is not counted.

“Grid delivers” = “house consumes” - “PV produces”

If the house consumes more than the PV produces then the utility meter only counts the difference.

To measure the total energy consumption by the house, it is necessary to meter the production separately. Some PV installations may have a separate meter like the utility meter that can be measured with an external probe. In this case, the actual house consumption can be calculated in the cloud with uncertainty due to the lack of synchronization of the data and time between the meters.

Another option is to install a special meter between the grid (in series with the billing meter), the house, and the PV. The Prosumer meter from Develco Products is designed for that scenario. The meter will then measure delivered and received for the grid, the PV, and the house, and presents that as 3 separate logical meters either over Zigbee or a wired interface. Ref [2]

3.2.1.3 Measuring energy consumptions for individual appliances

High consumption appliances can be beneficial to measure independently for various reasons. Firstly, this is where the most obvious energy reductions can be achieved. Besides discovering that appliances could be turned off when not used, measuring them may also reveal that appliances are not functioning as well as they should. A refrigerator, which is defective, may still function but uses an excessive amount of energy, having to run the compressor much more than normal.

For measuring appliances that are powered through a normal power outlet socket, a smart plug can be applied, a smart plug is a type of socket extender that includes a control relay and a power meter as well as communication capabilities within the system. The smart plug can be installed by the home owners themselves. Smart plugs are available from many vendors with different communication protocols. It is recommended for this type of installation to use devices supporting global standards like Zigbee or Z-Wave.

Different smart plugs are available on the market. Many of these have proprietary communications protocols or simple IR remote on/off capability. These should be avoided, as they will be virtually impossible to integrate to the system.

Some plugs can only switch on and off and not measure energy, and some may be able to measure energy but with unknown accuracy. Due to the large variation in what is called a “smart” plug in the market, selecting the right one needs a specialized analysis to ensure that the expected capabilities are met.

The Smart Plug Mini from Develco Products to be used in inBETWEEN is capable of measuring energy usage and production with high accuracy. The smart plug can supply appliances up to 10 Amp continuous loads, and it is easy to install. It is available in both Schuko (type F) and French (Type E) version. Ref [3]

The Smart Cable from Develco Products is a functional equivalent of the Smart plug Mini. It can supply up to 16Amp continuous load, and it will be used for higher load appliances, like hot water boilers. The Smart Cable requires slightly more installation skill, like installing a lamp switch on a cable. Ref [4]

3.2.2 Indoor comfort

The foundation for smart home/building systems is sensor inputs. With regard to indoor comfort, this means measuring mainly temperature, relative humidity, and air quality indicators (VOC, CO_2). These can be complemented with the measurement of other parameters such as light level, occupancy/motion, and door/windows opening and closing. As it will be discussed in the next section, some of the latter parameters can also provide insight into the usage patterns of the building.

Some of these measured parameters have a direct impact on the comfort level we experience as humans. We feel temperature and humidity; however, CO_2 and VOC are not something we directly feel.

CO_2 levels in indoor environments are typically produced by the humans occupying the space themselves, while VOC are produced by both the occupants and everything around us, e.g. paint, plastic, furniture, cleaning chemicals etc. High levels of VOCs are suspected to cause not only discomfort but also decease, allergies, and even cancer.

For selecting sensors, battery operated devices are preferred due to the ease of installation. Also, sensors that combine either more sensor measurements or other functions may be preferred in the project for simplifying the installation and reducing the number of devices to be installed in the home.

Depending on the room, different types of primary/secondary functions make the most sense. For instance, in one room, it may be temperature and humidity that makes the most sense while in another room it may be temperature and smoke (thus providing as well a safety functionality). In a third room, it might be occupancy and temperature that will make sense to measure.

The Humidity Sensor from Develco Products is useful in this project as it supports temperature measurement, it is battery operated, and does not require any special installation skills. Ref [5] A combined Humidity and VOC sensor is currently in development and will be available in the project.

The Smoke Alarm from Develco Products is useful in this project as it supports temperature measurement. It is battery operated and does not require any special installation skills. Ref [6]

The Motion Sensor from Develco Products to be used in this project also supports temperature measurement, and light level. It is battery operated and does not require any special installation skills. Ref [7]

The Door/Window Sensor from Develco Products is useful in this project as it supports temperature measurement. It is battery operated and do not require any special installation skills. Ref [8].

3.2.3 Usage patterns

Usage patterns of a building can be derived from the measurement and combined analysis of different parameters. For instance, energy consumption metering provides insight into the use of building/dwelling energy consuming equipment. This is the case especially if smart plugs are used attached to appliances, TV's, entertainment systems, etc. Attaching sensors on appliances that have more intensive usage will be most valuable when monitoring the energy consumption. Examples of these are the refrigerator and coffee machine as these will likely be used daily. Besides, if actuators are deployed (e.g. smart plugs integrating control relays), their utilization can also provide additional information about usage patterns of appliances and in general about the efficient use of energy by building users.

Occupancy/motion detectors as well as door/windows sensors provide usage patterns that combined with information coming from the energy metering can help to detect situations of inefficient behaviour/energy use, e.g. heating system switched on while windows are open, or lighting bulbs switched on for a long period while nobody is within a room.

Lastly, even comfort parameters can provide some information about the building usage, e.g. monitoring the evolution of CO2 concentration within a meeting room will help to detect the periods during the day when the room has been occupied.

Therefore, analysis of usage patterns within inBETWEEN will be done to a large extent based on the analysis of data sent by the sensors and actuators selected for the energy and comfort monitoring and smart control of the dwelling/building.

3.2.4 Smart controls

Actuators allow implementing smart control actions on energy consuming equipment in order to operate it more efficiently and thus reduce energy consumption. Besides, smart controls can also contribute to better indoor comfort, e.g. through improved control of the temperature in each room. Smart controls are normally applied to 3 types of systems: lighting, other electric loads, and HVAC. The case of other electric loads has already been introduced in previous sections, as they can be controlled through smart plugs or smart cables.

For the case of lighting, the dominant smart light bulb wireless technology is Zigbee. Today Zigbee based smart bulbs, from leading manufacturers, are commercially available across Europe. Although they are all marketed by themselves as complete systems where you need a gateway and app from them, they are actually Zigbee devices and will also work with other gateways.

Selecting devices for HVAC control for retrofit installation requires in-depth knowledge about the existing installation in site down to a room level including the controls options for each heating or ventilation appliance. Some electrical HVAC systems have a 24V control signal interface, turning output on and off, while others have thermostats with a 230V interface. Some have no thermostats at all and are controlled directly on the heater.

For the apartments in the immediate project with electrical heating, it would be most practical to attach a Smart Cable or smart plug to each electrical radiator and control it from the InBetween platform.

Buildings with local district heating may have radiator thermostat valves that could be replaced with "smarter" thermostat valves with a suitable wireless interface. These would be possible to control with the InBetween platform. One example could be this Zigbee valve thermostat: Tom from Plugwise in the Netherlands or Living connect Z from Danfoss. Where thermostat valves are installed, the InBetween platform will be able to control the set point.

3.2.5 Placement of devices

Once decided the type of sensors/meters and actuators that will be deployed, it is important to give some thought to what the best location may be for each of the selected types. The following paragraphs provides some insight on how this exercise shall be done, using the inBETWEEN pilots as case studies. The layout of sensors described must be considered just as a first tentative proposal, as the precise installation to be done in these buildings will be defined later in deliverable D4.2.

The Vilogia pilot site in France has 3 apartment typologies: T3B (12 apartments with 2 bedrooms and living room), T3C (6 apartments with 2 bedrooms and living room, which can be considered quite similar to T3C), and T2B (24 apartments with 1 bedroom and living room). Looking at the layout and the room usage, sensors and actuators could be placed as illustrated in Figure 2 and Figure 3.

For energy monitoring, sensors are placed on the main electricity meter, and smart cables are placed on major consuming devices (heaters). 3 smart plugs are added; one is intended for the fridge, while two others could be used for other main energy consuming appliances.

For comfort, air quality sensors are placed in rooms where the residents are expected to stay for longer periods (bedrooms and living room).

Window/door sensors are placed on each window/door for the InBetween system to monitor when they are opened. Two Motion Sensors are placed in the corners. This way, they are capable of detecting movement in most of the apartment and when the residents are moving from room to room. Finally, two Smoke Alarms that also include temperature sensors are placed in a way that enables coverage of the bedrooms and the living room.

GW : Gateway - **EMI** : External Meter Interface - **MT** : Motion sensor + Temperature - **ST** : Smoke Alarm + Temperature - **HT** : Humidity sensor + Temperature - **VHT** : VOC + Humidity sensor + Temperature - **WT** : Window sensor + Temperature - **SP** : Smart Plug Mini - **SC** : Smart Cable

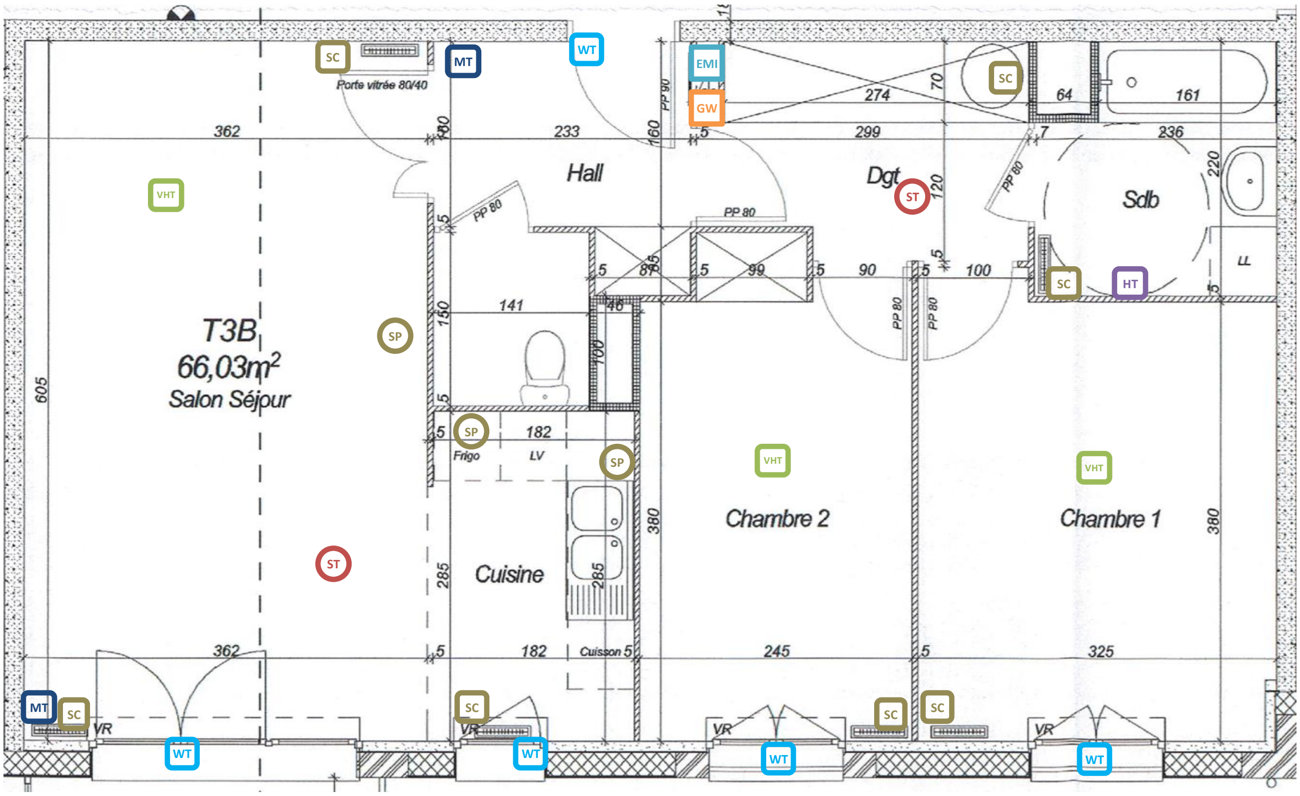


Figure 2. Example 1: Vilogia Pilot T3B

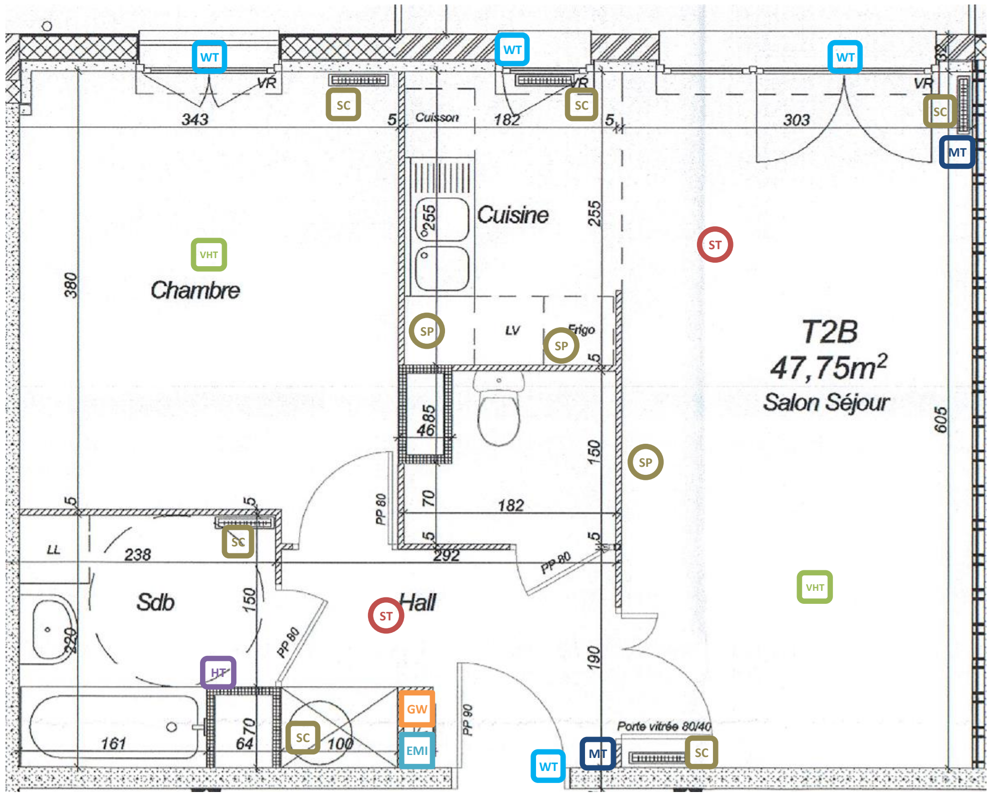


Figure 3. Example 2: Vilogia Pilot T2B

The Sonnenplatz pilot site consists of 8 single family houses and 6 public buildings, including 2 guest houses, a school, a kindergarten, and 2 community buildings. Selecting and placing the sensors and actuators for the 8 single family house will largely be a similar analysis as the smaller Vilogia apartments. The main difference is the heat source, as the houses with radiators would need smart radiator thermostats rather than the smart cables.

Due to the size of the guest houses and the public buildings, a consideration on how to build a reliable sensor network is required. Generally, the battery powered sensors rely on mains powered devices to extend the range of the network. In the case of the guest houses, which include many rooms, attaching smart radiator thermostats on each radiator in each room would allow the owner to monitor the set points in each room. This could potentially lead to a large energy reduction if managed in correlation with the occupancy of the rooms. The building manager could also monitor and control this without having to go physically into each room.

To make sure the smart thermostats are connected to the gateway, range extenders or other mains powered devices of the same network technology is needed to assist in forwarding the messages to and from the gateway. The range extenders could be smart plugs or similar devices, which can perform measurements or control functions at the same time. In the example below, a possible placement of the mains powered devices and battery operated sensors are illustrated in one of the larger buildings. It illustrates that the optimal location of the gateway in a large network is approximately the centre of the building and that the mains powered repeaters/routers should be spread across each floor of the building to form the base of a stable network and support the battery powered sensors throughout the building.

GW : Gateway - **R** : a router or range extender device - **O** : any battery operated sensor

Figure 4. Sonnenplatz Pilot (Guest house Hipp-Bruckner)

3.3 GATEWAY LAYER

The gateway layer acts as a bridge between the sensing and actuation devices deployed on the field and the inBETWEEN cloud platform. In order to accomplish its mission, the gateway shall be able to:

- Communicate with the sensors/meters and actuators, in order to collect measurements from the former and convey control set points to the latter. These communications can be done through wired and/or wireless protocols depending on the type of devices deployed.
- Manage the sensor and actuator network, process the data read from the network and translate data from different protocols into a common format.
- Provide an interface for data exchange with the inBETWEEN. This communication requires that the gateway integrate some type of Internet connectivity option.

The sections below describe a number of important criteria for evaluating each one of the gateway functionalities and thus select the most optimal one for each project.

3.3.1 Internet connectivity

WiFi/WLAN or wired Ethernet LAN provides the cheapest option for internet connectivity; this of cause requires the use of an existing internet connection.

Relying on existing internet connections does have its benefits, in cost and installation, but can also be challenging if not reliable or not available. In such cases, gateways that have their own internet connection can be the optimal solution. Therefore, choosing a gateway platform with multiple connectivity options is recommended so that it is possible to use the best configuration for each case.

As an example, the Squid.link gateway from Develco Products (see architecture in Figure 5) to be used in inBETWEEN pilots is available in various configurations where it supports Ethernet (wired), WLAN, and 3G mobile (requires a mobile data plan and sim card) internet connections.

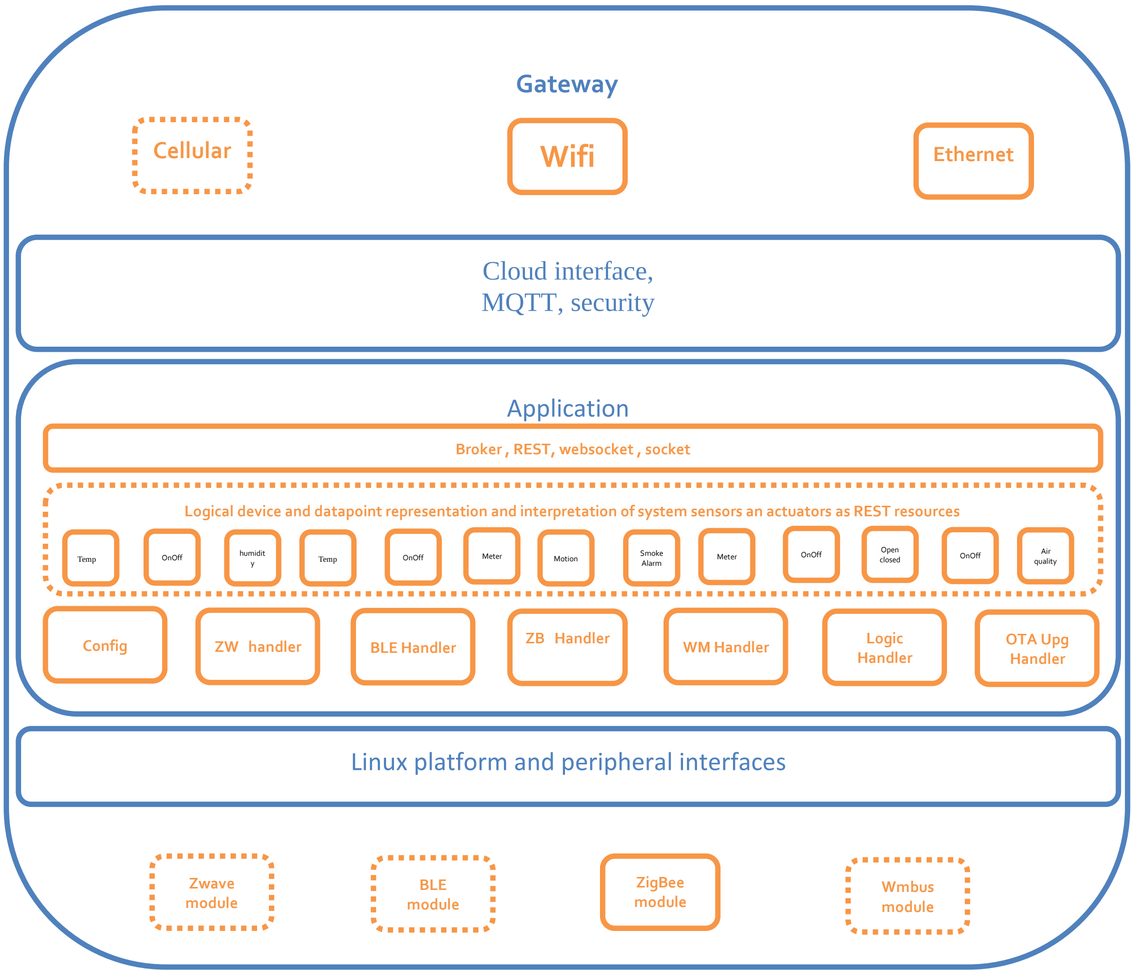


Figure 5. Gateway principal architecture diagram; key components, communication protocols and software modules.

The exact configuration chosen for deployment will depend on the pilots and the availability of internet connection.

3.3.2 Sensor/Actuator communication protocols

There are several competing wired and wireless standards that provide in premise/home communication to sensors and actuators. Some are domain agnostic and some are not. Widely adopted standards for meter reading in regions of Europe are MBUS and wireless MBUS, other regions such as France (Linky) and UK (SMETS2) have chosen Zigbee to be the wireless interface to allow access for home owner meter readings in the future. At present, these technologies have not yet been widely deployed and as a result there is still a need to attach external interfaces to the meters that adapt an optical or simple wired interface on the meters, so that in that way they can be integrated with the inBetween gateway/platform.

For home automation, security and comfort there are also a number of standards that have gained different momentum in various regions. Among the most widely known worldwide is Zigbee and Z-Wave. Many homeowners may already have systems/ devices that utilize these protocols without knowing it, e.g. the well-known Philips HUE lights and IKEA's wireless lightbulbs are using Zigbee.

Bluetooth Low Energy variant and WLAN are also widely adopted standards in commercial smart systems, however at the moment these are often locked to a proprietary single vendor solution, as these standards do not standardize the application layer.

As an example of how a single gateway model can integrate different communication protocols, the Squid.link gateway from Develco Products to be used within inBETWEEN are available in various configurations where it supports Zigbee, WMBus, BLE, Z-Wave, WLAN in premise communication protocols.

The exact configuration chosen for deployment will depend on the devices that will be finally implemented for the inBETWEEN project.

3.3.3 Gateway application

The application within the gateway is responsible for interaction with the various device communication interfaces, management of the different networks' needs, and the commissioning of the devices. Also it is responsible for translation of the various device communication protocols data layer to a common format that can be used by the cloud platform on the upper layer.

Sensor data acquisition is carried out through commercial devices that are very different and typically require different configurations to get optimal sensor data. The gateway application also need to either schedule reading of the sensors or configure the sensors to publish their sensor data, in a device-to-device appropriate way.

As an example, the Squid.link gateway from Develco Products to be used in this project is an ARM processor-based system running Linux, and is capable of supporting multiple applications running, including custom applications if needed. The gateway comes with an application called Squid Smart App, which can be configured to handle different devices using different communication protocols and using translation templates representing sensor data an actuation points from/on these devices as resources in a restful API. Ref [10]

The application has a concept were device types from vendors or individual devices can be configured through templates. These templates define any configuration needed for the devices, and the mapping of data from the device/communication standard and to REST resources. The templates are in JSON format, and can be updated on the gateways though the API.

3.3.4 Cloud interface

The cloud interface shall provide a secure and reliable communication (over internet) between the gateway and the upper cloud layer (inBetween cloud platform).

The cloud service needs not to know all the potential field communication technologies used at each pilot site.

The InBetween cloud platform will operate on a logical abstraction layer where each sensor input or actuator is represented by logical entities and data points presented by the gateway. In this representation the local communication protocol, being Zigbee, BLE or Z-Wave is abstracted away, and replaced by a restful API representing the actual sensor data and actuation states as data points/resources.

For instance, the Squid.link gateway from Develco Products to be used in this project has a representation called squid smart app API **ref [10]**, it is believed that this API is adequate for representing the devices that will be used in the system, if not, it is possible to extend it or even insert an overlay translation layer.

The communication interface between the gateway and the InBetween cloud platform is a representation of the logical entities and data points over MQTT topics.

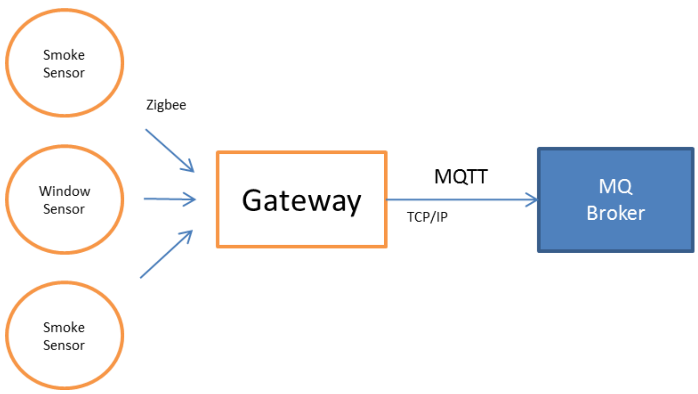


Figure 6. Interface between the gateway and cloud platform

Ref [11]

MQTT (**Message Queue Telemetry Transport**) is an ISO standard (ISO/IEC PRF 20922) publish/subscribe based "lightweight" messaging protocol for use on top of the TCP/IP protocol. It is designed for connections with remote locations where a "small code footprint" is required or the network bandwidth is limited. The publish/subscribe messaging pattern requires a message broker. The broker is responsible for distributing messages to interested clients based on the topic of a message.

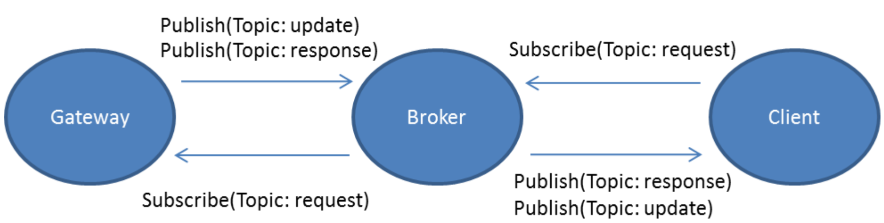


Figure 7. MQTT publish/subscribe messaging protocol

A topic is a UTF-8 string, which is used by the broker to filter messages for each connected client. A topic consists of one or more topic levels. Each topic level is separated by a forward slash (topic level separator).

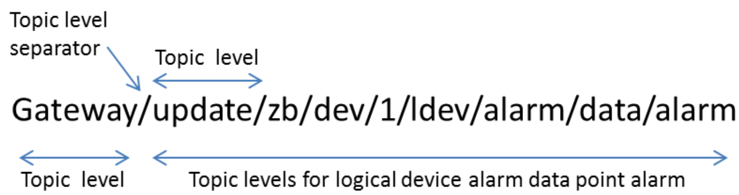


Figure 8. Topic structure

Topic mapping: update and request/response

Spontaneous data from the gateway is publishing with the topic ‘gateway/update/path’ where the path is similar to the REST API resource path. Any client can then subscribe for the topic ‘gateway/update/#’ and thus gets all update published by the gateway. Examples below illustrate data from gateway:

// Window sensor

020000010000xxxx /update/zb/dev/1/ldev/alarm/data/alarm

```
{
 "key":"alarm",
 "name":"Alarm",
 "type":"boolean",
 "value":false
}
```

Each device has a number of data points. The data points that belong logical together are grouped in a logical device. To illustrate the concept there is an example below showing the topic of the onoff data point of a ZigBee smart plug. In this case it is device 4 (dev/4) and the name of the logical device is “smart plug” (ldev/smartplug).

020000010000xxxx /update/zb/dev/4/ldev/smartplug/data/onoff

```
{
 "key":"onoff",
 "name":"State",
 "type":"boolean",
 "value":true
}
```

Device action (e.g. smart plug on off) and configuration of the gateway (e.g. adding new devices) is handled as request/response interactions. The general pattern for using topics and publish/subscribe works like this:

The requester (client) first subscribes to a topic to which the response will be sent. The response topic will be '*020000010000xxxx/***response/ID'**, where ID is a unique identifier for the client request. The gateway subscribes to the topic '*020000010000xxxx/***request/+'**, where **+** is a wildcard for a topic level. The requester publishes its message to the request topic, which is composed from '*020000010000xxxx* **/request/'** followed the same unique ID already used for the response topic. The gateway will receive this message, since the unique ID matches the wildcard. When the gateway receives the published request, it will extract the unique ID and publish a response to the proper response topic. This is an example for switching off a smart plug:

020000010000xxxx /request/1234

{

"type": "update",

"path": "zb/dev/4/ldev/smartplug/data/onoff",

"data": {"key": "onoff", "value": false}

}

020000010000xxxx/response/1234

{

"type":"update",

"path":"zb/dev/4/ldev/smartplug/data/onoff",

"status":"ok"

}

The MQTT messages can be sent with the retained flag true for update topics. Request response messages will always be sent with the retained flag set to false. The retained flag is configured with the 'retained' configuration parameter.

3.4 INBETWEEN CLOUD PLATFORM

This section provides an overview of the inBETWEEN IoT Cloud Platform and general guidelines on how an instance of the platform will be configured for the demo sites deployments. The Internet of Things (IoT) is a scenario in which objects and people are provided with the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The aim of the IoT is to create an integrated ecosystem for devices to communicate over the Internet. The reference architecture consists of a set of components. Layers can be realized by means of specific technologies. Although there are many different existing and emerging IoT architecture patterns, they all share one set of components in common: the concepts of physical device, edge and cloud plus a further layer the services delivery.

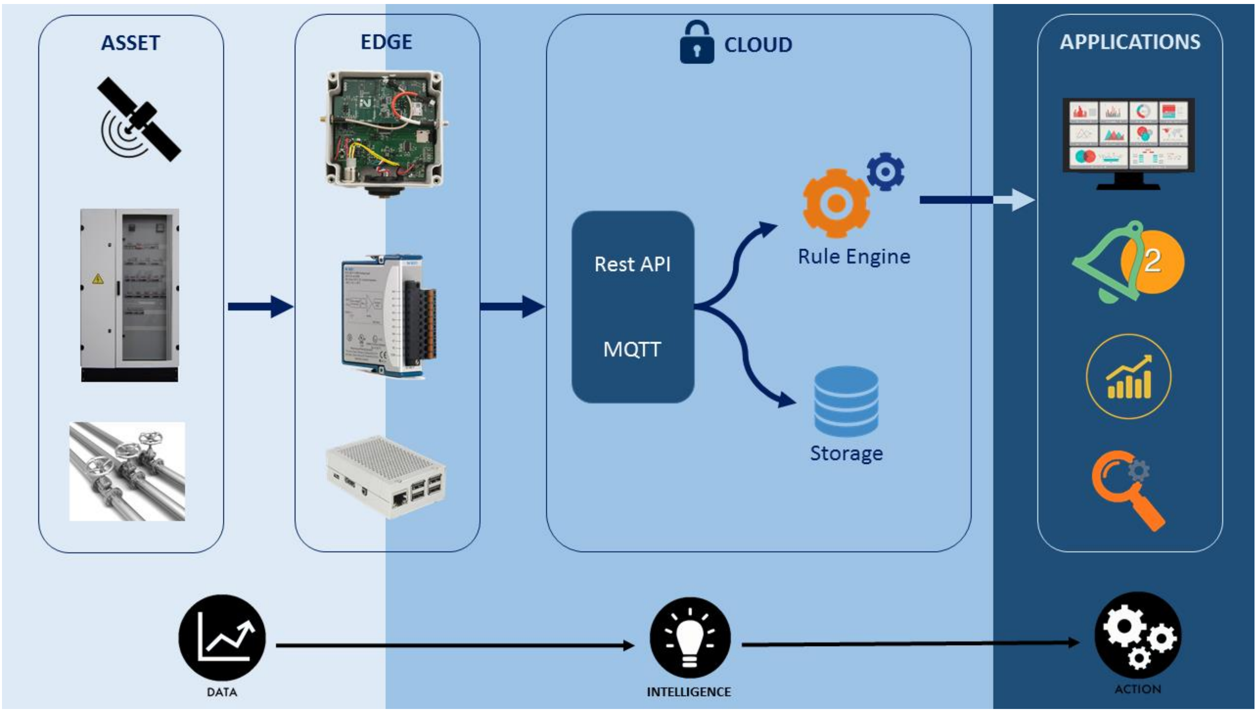


Figure 9- IoT solution architecture

The device layer refers to the hardware level of the IoT solution, the physical "thing". The concept of the "edge" refers to the aspect that comprises the operational domain of the overall IoT system. The edge is where operational components connect, communicate and interact with each other, with the platform and in some cases directly with components in other edges. To reduce the volumes of data to be transferred to the platform, an edge processing is often required that enables dynamic filtering or sampling or aggregating device data. Therefore, the edge layer of the IoT is where the action is and where some pre-processing of data is performed before moving raw data on to the cloud. Edge IT processing systems may be located in remote offices or other edge locations, but generally these sit in the facility or location where the sensors reside closer to the sensors. Therefore, the edge layer of the IoT is where the action is. Edge computing represents a shift in architecture in which intelligence is shared from the cloud to the edge, localizing certain kinds of analysis and decision-making. Edge computing enables quicker response times, unencumbered by network latency, as well as reduced traffic, selectively relaying the appropriate data to the cloud.

Data that needs more in-depth processing, and where feedback does not have to be immediate, gets forwarded to physical data center or cloud-based systems, where more powerful IT systems can analyse, manage, and securely store the data. This represents the Cloud layer. After data has been analysed, it will begin to accumulate. Over time, this data provides a rich source of information for looking at trends, and can be combined with other data, including data from sources outside of your IoT devices. Certain types of data need to be quickly sliceable along known indexes and dimensions for updating core visualizations and user interfaces. Cloud layer provides a low-latency and high-throughput database for NoSQL data.

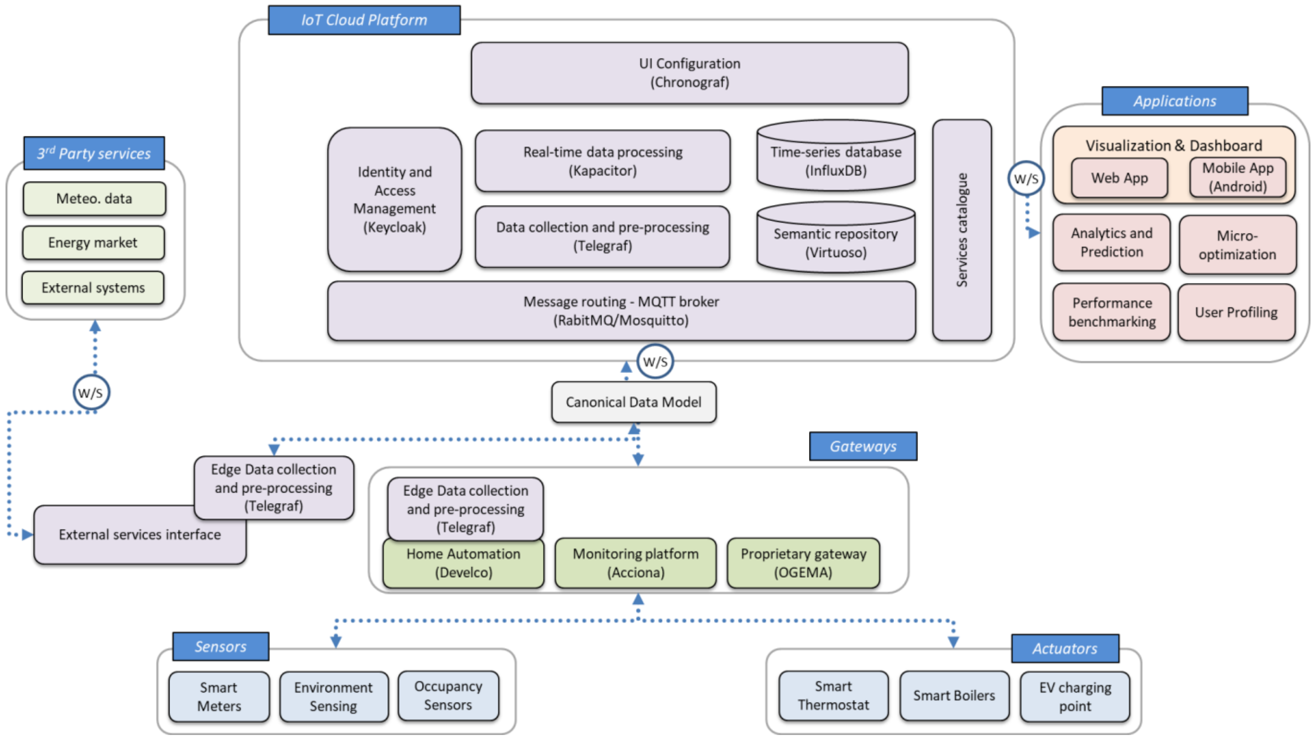


Figure 10 – inBETWEEN Cloud Plaftorm Architecture

The image above describes the evolution of InBetween Cloud Platform Architecture, highlighting software components used in development and their interactions. In particular, the InfluxData TICK Stack is composed by Telegraf, InfluxDB, Kapacitor and Chronograf GUI. Besides there is Keycloak framework to implement the security mechanisms providing the User/Application/Device Identity and Access Management services. At the highest level, service will provide security models that address two basic criteria: authentication (i.e. who has access) and authorization (i.e. what they can do). The platform will provide a role-based security model and a set of administrative tools, which can be used to configure and control this model.

The messaging exchange system describes the ingestion of inbound data from field, devices and 3rd Party Services (e.g. weather data) into the cloud-based system. This data not only includes observational data from devices (metrics), but also includes alerting and control data. This leads to having the ability to process messages in (near) real-time or batches if the rest of the system is enabled to do that. Finally, a triple store framework provides a mechanism for that, which stores semantic facts in an RDF graph.

The deployment of the different elements will be managed by the Docker container, a tool designed to make it easier to create, deploy, and run applications by using containers. Containers allow packaging up an application with all of the parts it needs, such as libraries and other dependencies, and ship it all out as one package.

3.5 APPLICATIONS

In general case, basic configuration process for InBetween advanced energy services will entail setting of **IP address of the InBetween platform endpoint**, which is necessary to enable access to the collected time series, coming from the monitoring platform, as well as metadata stored in the platform knowledge repository.

Assuming that time series and metadata services reside on the same logical address, configuration of the services further contains **the access ports** of respective time series and semantic database service.
Therefore, InBetween advanced energy services will use this endpoint to:

1. Authenticate and authorize access to the platform
2. Obtain "static" metadata from the knowledge repository about user and abuilding/dwelling (semantic database access)
3. Obtain monitoring time series (InfluxDB access)
4. Writing back either time series or metadata, or both if available

3.5.1 Consumption analytics service

The overarching objective of Consumption analytics service (CAS) is to deduce correlation between end user behaviour and yielded energy consumption and thus enabling reduction in energy consumption and associated costs, increase of end user energy efficiency, flattening peaks in consumption profile, balance appliance utilization with green energy availability etc.
The main process to be used in this regard will be the Non-Intrusive Load Monitoring (NILM), which is leveraged upon machine learning techniques, which constantly monitors and analyses changes in the voltage and current of power going into a house (or another aggregated level) and tries to deduce what appliances are used in the house in a specific moment in time as well as to estimate their individual energy consumption.
The CAS, based on NILM, will be implemented using a flexible approach which will enable its application for different types of appliances, associate with different building typologies (specially differentiating between residential and non-residential buildings), available energy monitoring infrastructure (spatial resolution, sampling frequency etc.), availability of baselining period for supervised learning, evaluation metrics, etc.
Therefore, when a specific instance of CAS is set-up, a set of customization/configuration steps are required to reflect requirements of each specific use case. The critical aspects that are greatly affected by the findings of a technical characterization for specific building and corresponding stakeholders' analysis are as follows:

- Appliance signatures

As part of the technical characterization related to the audit of existing appliances in-situ, one must determine different types, and number, of appliances operating in the monitored environment. This information will be critical to determine what kind of appliance "power signature" is expected and select the most suitable technique for each case. Typically, employed techniques will focus on steady-state and transient-state signatures. More specifically, steady state signature detection will focus on the three key aspects, which are Power Change, Harmonics and V-I Trajectory.

- Consumption monitoring sampling frequency

Once the technical characterization related to the energy monitoring infrastructure is completed, one must determine the highest available sampling frequency of retrieved measurements. This information will be especially important for selecting the technological approach of the specific instance of the CAS, that is:

- If sampling frequency is high enough (order of seconds) it is recommended that Convolution Neural Network (CNN) technique is used where major inputs would be power harmonics and observations of power consumption.
- If sampling frequency is sufficiently high it is recommended that a hybrid approach combining Factorial Hidden Markov Model (FHMM) with features extracted by deep neural network is used.

- Learning approaches

One of the critical aspects in application of machine learning techniques in general is the availability of the learning data set. Therefore, one must determine whether a specific use case allows for:

- Supervised learning, which entails availability of the user feedback during the learning process. In particular, this would require a timely action in the InBetween platform from the end user (e.g. via InBetween App) whenever an appliance is switched on or off.
- Alternatively, one could also opt for the unsupervised learning, which would result in a less accurate learning process, which would leverage upon existing open databases of appliance signatures.
  - Evaluation metrics

Finally, it is necessary to define what kind of evaluation metrics will be used as output from the CAS but also to measure its performance and accuracy. Namely, the two options are typically available:
- Event-based metrics, which entails information about appliance status, e.g. turned on or off.
- Non-event-based metrics, which entails information about actual load disaggregation, i.e. actual power level of each appliance.

3.5.2 User profiling service

User profiling service (UPS) will use a designated InBetween platform endpoint to obtain user/location metadata (semantic database access) and monitoring time series (InfluxDB access). Through the same endpoint, it will write back discovered profile information (both time series and metadata).
UPS is utilizing data driven models, trained using the supplied monitoring data, and building/apartment/user metadata, to create user profiles. These profiles further help in the process of consumption forecasting and anomaly detection.
Data collected in the initial building and tenant analysis is stored in the ontology, and UPS can reconfigure the data analysis and model generation process based on the available information. For example, if apartment orientation is available, it will be used as one of the classifiers in the profiling process. If it is not available, the model generation process will still work, using the other available classifiers. The profiling process can be configured to automatically use all, some, or different combinations of classifiers for model generation depending on their availability. The classifier selection criteria and profiling configuration is part of the application and not externally configurable at the commission time.
Collected data, that includes all potential classifiers, is stored in the semantic database according to the schema defined in D2.3 (Dictionary for metadata and building information representation).

3.5.3 Consumption forecast service

Through a designated InBetween platform endpoint Consumption forecast service (CFS) will obtain "static" metadata, such as building data, profile data, profile time series (semantic database access, InfluxDB access), different situational metadata such as weather forecast, calendar,… (InfluxDB access) as well as monitoring time series (InfluxDB access). Through the same endpoint, it will write back forecasted time series (time series).
Similar to already described operation of UPS, CFS is able to configure itself to use the data available in the semantic database. The only assumption is that the data is stored in the semantic database according to the schema defined in D2.3.

3.5.4 Energy dispatch optimization service

The main objective for the Energy dispatch optimization service (EDOS) is to devise an optimal energy dispatch in the complex environment comprising diverse conventional and renewable energy carriers, electrical and thermal storages, dynamic energy tariffing and user defined evaluation criteria. Moreover, the Optimizer will serve two different use cases:
- Planning optimization - An off-line, system design focused scenario aiming to suggest an optimal system configuration based on typical (historical) energy demand, with respect to given criteria: investment costs minimization, emission minimization, profit maximization, import minimization, etc.

- Operation optimization - An on-line/closed-loop scenario aiming to provide set-points/schedules for existing system configuration to ensure the system is operating at minimum cost.

The EDOS will be implemented as a generic and flexible optimisation environment, able to be used for an arbitrary energy infrastructure, regardless of the building typology (residential or non-residential) and able to run under different time frames. Configuration and customization of its specific instance will strongly depend on the performed technical characterization of existing energy infrastructure and the ability to map acquired information into an effective mathematical representation/model. In other words, one will need to acquire information about:

- Number and type of energy supply carriers – including electricity (e.g. conventional power grid or renewables such as solar photovoltaics, wind turbines), thermal energy (e.g. district heating, geothermal and solar thermal) or various fuels (natural gas, diesel, fossil fuels/biomass)
- Available energy conversion units and their corresponding efficiencies – which includes a list of all existing energy conversion units present in-situ, which allow for utilization of supplied energy for satisfaction of particular demand. Typically, this will entail conversion such as electricity to electricity (transformer), electricity to heating (electrical boiler), electricity to cooling (air conditioning, chiller), gas to electricity (CHP) etc. For each conversion unit, it is necessary to provide for a corresponding conversion efficiency (e.g. electrical boiler has 90% efficiency in conversion from electricity to heat)
- Applicable energy pricing policy – which entails information about specific aspects influencing cost of energy for the end user, such as costs of contracted power and delivered kilowatt-hours. For the latter, it is especially important to check whether there discrimination according the amount and time-of-use (ToU) if applicable.
- User-defined optimization criteria – which represent user preferences in the optimization process accounting for different aspects such as operation costs minimization, environmental footprint minimization, maximization of share of renewable energy in the final consumption etc. Given that the Optimizer will have the ability to simultaneously asses multiple criteria, end user will have to make a relative prioritization of the selected criteria by assigning specific “weight” to each of them.

All the aforementioned information should be made available following to a detailed characterization of each specific demonstration/deployment site and stored within the semantic database of InBetween platform following. This information will then be used for automatic configuration and instantiation of EDOS requiring only that the information is stored in the semantic database according to the ontology based schema defined in D2.3.

3.5.5 Energy performance evaluation and benchmarking service

The main objective of the Energy performance evaluation and benchmarking service (EPEBS) will be to allow fair comparison and benchmarking of end users against themselves (from previous period) and other end users. Therefore, EPEBS functionality is actually split in two phases, i.e. the first in which energy performance is evaluated (calculated) for a specific time frame and second, in which this performance is benchmarked against a designated group of “similar” end users with aim of ranking them and providing them with useful feedback. This performance-focused approach, compared to consumption focused one, will allow for setting realistic and achievable goals for the end user rather than unrealistic ones that discourage further engagement and reduce the effectiveness of the technology over time.

EPEBS will follow a data driven approach, which will leverage on acquired energy consumption monitoring data and normalize this data against a range of contextual metadata to calculate end user energy performance. The metadata will typically include:

- Building/apartment metadata (total area, heated/cooled area, construction material and its thermal properties, sun exposure/orientation etc.)
- Climate conditions (meteorological parameters comprising outside ambient temperature, solar irradiation, wind velocity etc.)
- End user information (number of inhabitants, age, type of their activity, real-time occupancy, etc.)

In other words, the EPEBS will leverage the data collected in the initial building and tenant analysis, stored in corresponding instance of the InBetween ontology. Moreover, EPEBS will be able to automatically reconfigure the performance calculation methodology based on the information available in the ontology. Similarly as for the UPS, EPEBS will dynamically adjust the performance calculation algorithm depending on the available information.

3.5.6 End user App

End user mobile app primarily targets the residential building users that will use it as the main interface towards the InBetween platform. Based on the energy consumption, environmental conditions, occupancy, and other relevant data, the InBetween platform will generate a set of reports and recommendations. These results will be delivered in a non-disturbing manner to the users via the mobile app with the aim of steering their habits towards a more energy efficient lifestyle. In addition to providing reports on energy consumption and energy saving recommendations, the mobile app will also present the benchmarking results where the user will be compared to other similar users in the neighborhood. In such a way, the effect of positive social pressure and competition will further motivate users to adhere to recommendations provided by the app, and improve its final acceptance and retention rate.

The set of features provided by the mobile app strongly depends on the scale of the monitoring and control devices deployment. The mobile app will be developed with self-configuration capabilities, adapting itself to different data availability, so that the user does not need to deal with the technical details.

The data collected by the InBetween cloud platform that will be employed by mobile app in its reports and recommendations are as follows:

- Energy consumption of individual households and different appliances in the household (where applicable)
- Building physical parameters
- The type of appliances used and their properties (e.g. power consumption, whether the load can be scheduled, etc.)
- Environmental conditions (temperature, humidity, etc.)

All the aforementioned information should be made available following to a detailed characterization of each specific demonstration/deployment site and stored within the semantic database of InBetween platform following. This information will then be used for automatic configuration and instantiation of Mobile app requiring only that the information is stored in the semantic database according to the ontology based schema defined in D2.3.

3.5.7 Visualization dashboard

The visualization dashboard aims to provide building/facility managers with a tool for global visualization and analysis of data from the buildings, which will serve as well as global management tool to be used within the timeframe of InBetween project for supervising the operation of all the pilots. It shall be noted that in principle this dashboard is not intended to be used by dwelling owners/tenants, because the app described in the previous section is better suited for this purpose, although they can be provided as well with access to their own data through this tool if they wish so.

It must be considered as well that this tool is generally better suited for non-residential than for residential buildings. The reason is that in non-residential buildings facility managers will generally not have any privacy-related issue for accessing any of the monitored parameters within the building. However, in residential buildings facility managers will normally have access only to devices deployed in common areas, unless there is a special permission from the dwelling owners/tenants to access their data. This will be the case for the inBETWEEN project time frame, but in general the visualization dashboard applied to residential buildings would often be restricted to the common areas. Even so, the application can be useful as well in this context, e.g. if a facility management company is in charge of the operation/maintenance of several buildings, this dashboard provides support for remote analysis of important building parameters such as electricity consumption of lighting in common areas, electricity consumption of lifts, global gas consumption (in case there is a central heating system), etc.

In order to provide maximum flexibility to the dashboard user, a tool in the form of a web application integrating Responsive Web Design (RWD) approaches will guarantee ubiquitous access to the dashboard through virtually any device (PC, tablet, smartphone) with internet connection and a standard web browser. Of course, this could be complemented with native apps for Android and iOS devices. However, it is considered that the web application can be suitable enough for most use cases involving building/facility managers.

General features that the visualization dashboard shall include are:

- **Access control functionalities:** the dashboard shall implement a user account management and access control levels to determine which user can access to each installation. It is also desirable that the access control can be customized at the device level, i.e. determine which devices within an installation each user can access. This last feature will facilitate for instance to manage installations in apartment buildings: a building administrator may be granted access to all the devices deployed, but a dwelling owner/tenant will be given access only to the devices within her/his dwelling.
- **Device management functionalities:** the dashboard shall provide management options for easily configuration of the different installations registered in the system, e.g. for adding/removing devices when any update is carried out.
- **Installation supervision functionalities:** the dashboard shall provide automated functionalities that assist building managers in the supervision of all active installations. These can be based on alerts that can be triggered by either any malfunction detected in an installation (e.g. data missing from a device, devices sending incorrect values that may be signaling an internal error, etc.), or by certain conditions that have been previously configured by the dashboard user (e.g. setting threshold values for sensor readings, so that values out of these limits trigger an alert).
- **Dashboard design functionalities:** the dashboard shall provide some kind of flexibility to the user for adapting the layout of the interface. One option of doing this is the dynamic creation of "widgets" that allow adding to the screen different charts or other visual controls with the most critical values that need to be constantly monitored.
- **Data analysis functionalities:** the dashboard shall provide flexible functionalities for analysing any monitored value or group of values during any period. These include in first place the download of data in a standard format (e.g. CSV), the generation of different types of charts, and the export of these charts to standard formats (e.g. PDF, JPG). The generation of charts shall allow the parallel comparison of variables having different physical parameters (e.g. heating consumption vs. indoor temperature), and the comparison of a same variable throughout different periods (e.g. heating consumption during one year compared with the previous year).

4 GUIDELINES FOR DEPLOYMENT PLANNING AND PREPARATION

4.1 MONITORING PHASES PLANNING

The overall objective of InBetween platform is to provide end users with means to identify energy wastes, provide effective energy conservation measures and motivate them to act through a unique social engagement approach. Moreover, it aims to induce behavioural changes with end users leading to more energy efficient lifestyles. To be able to measure the effectiveness of the delivered solution one must find a way to measure unambiguous effects of the solution application compared to the period prior to its deployment. Hence, it is very important to exclude any negative or positive effects from external factors. Therefore, it is important to adopt a carefully devised plan for different phases of solution implementation, which allow assessment of energy savings and behaviour change.

Following the same principles as ISO 50001 Standard for Energy Management Systems, based on the continuous optimization with Plan-Do-Check-Act, the InBetween solution implementation plan should cover the following important aspects:

- Planning phase – This phase entails that a detailed technical and end user characterisation is made to collect all contextual information and necessary solution requirements together with potential limitations for its deployment. At this stage the initial energy baselining should be performed (through existing energy bills, historical measurements etc.), energy performance indicators should be defined and operative energy objectives and the action plans should be defined.
- Monitoring phase – This phase is an optional one and should be used in case when no baseline was assembled during the planning phase. In this phase, monitoring platform is established and necessary energy consumption points are monitored. Ideally, planning and monitoring phase should deliver a representative baseline sample covering one year period to account for seasonal changes in climate, user habits etc.
- Action phase – Initiation of this phase entails that fully-fledged InBetween platform is operational, meaning that the energy monitoring features are complemented with advanced energy services and that the end user is engaged through the platform interfaces (namely the InBetween App in case of a home user or Dashboard in case of an energy manager).

Recurrent validation phase – Finally, the validation phase is a non-stopping recurrent phase in which energy-related performance is monitored and measured against the baseline. The retrieved results are then compared to the previously-established objectives and corrective measures are taken (e.g. some constraints are loosen up, like the extension of the time window for applying demand side management actions).

4.2 PRODUCTION OF DEPLOYMENT BLUEPRINT AND CALCULATION OF EQUIPMENT COSTS

Once the inBETWEEN platform customization for each specific site has been defined, the next step will be to produce all technical documentation that will describe with the maximum possible detail the installation to be done. Based on this documentation it will be possible to prepare the detailed planning of the installation tasks and launch the purchasing and permits processing processes, which are described in the following sections.

The documentation will include a detailed breakdown (identifier/model, description, number of units, etc.) of all the devices to be deployed on site: sensors, actuators, gateway devices and potential communication devices, cabling, electrical protections, mounting accessories, auxiliary software tools, etc. Indicative unit prices shall be collected for all the listed components so that it is possible to estimate the cost of acquisition of all devices, consumables, and any other installation components. These costs will be later complemented with the calculation of the costs associated to the installation process (deployment and configuration of hardware and software components). The estimation of the cost of acquisition at this stage is not final, it can then vary during the purchasing process depending on the prices offered by the different suppliers and the final choice done by the building owner/manager.

The exact location of all devices shall be represented on top of building plans. If it is a building with multiple floors, one plan per floor shall be provided. This plans shall also show the network topology of the devices to be deployed, e.g. it shall be made clear which sensors/actuators are associated to each gateway. Examples of how this type of plans looks like have already been provided in Section 3.2.5.

4.3 PLANNING OF INSTALLATION TASKS AND CALCULATION OF INSTALLATION COSTS

When it comes to the planning and estimation of required efforts and duration of activities related to the installation and configuration of software parts of InBetween platform it should be noted that the platform itself is developed as a cloud platform, having its advanced energy services developed in a flexible manner able to self-configure themselves according to the information stored in the designated knowledge repository. This means that majority of configuration is done centrally and automatically leaving only minor effort to set-up connection between the gateway of the physical monitoring platform and the InBetween platform end-point in the cloud. However, there is a considerable amount of effort related to the:

- Acquisition of data/information from an end user using the InBetween demo site questionnaire, which can be done by a technician.
- Collection of contextual metadata from third party services.
- Translation of acquired information from the field into an instance of InBetween ontology, which requires a knowledge engineering expertise.

It will be then necessary to estimate the resources and time needed for each of the aforementioned tasks.

Installation and commissioning of equipment in the pilot sites

Once the residents participating in inBETWEEN have been selected, and the documentation of which sensors and actuators are to be installed in each location, as defined in section 4.2, have been prepared, the planning of the installation can begin in more detail. The type of sensors and actuators selected is essential for both the installation commissioning procedure and the requirements to the skills of the installer. At this time not knowing the actual device requirements and the skillset of the installer, any estimate done at this stage is subject to a high uncertainty.

Assuming the devices selected in the apartment examples given in section 3.2.5, the estimation is that it would require a skilled technician (electrician) and the time required would be:

French pilot:

- Initial training installing and commissioning the different device types approximately: 1 day
- Installing the devices per apartment, not including transport, approximately: 1-2 hours

Austrian pilot:

- Initial training installing and commissioning the different device types approximately: 1 day
- Installing the devices per single family home, not including transport, approximately: 1-2 hours
- Installing the devices per larger building, not including transport, approximately: 0.5-1 day

4.4 OTHER PREPARATION ACTIVITIES: PERMITS AND PURCHASES

Once the needs of the project have been defined, the stakeholders identified and the technical solution has been set up it is necessary to get permits and availability of the components of the ICT solution in order to proceed.
The permits phases is mainly composed by two sub-phases involving two of the categories above mentioned: Building owners and dwellings tenants.

Within the **first sub-phase,** permits to deploy the project need to be provided by building owners:

- For single property owners it is foreseen the approval of the building owner itself to allow intervention on its own building.
- For multi property, it is necessary to apply the national law to proceed defining the mechanism and the rules to be or not be able to implement technical solution in the building if the 100% of will is not reached.

Following this first step of permits, it is necessary to proceed testing the will of each tenants. **Second sub- phase**:

- For single property owner it is needed to check the will of tenants to be part of a project in which data are collected and analysed even if in a private way – in that sense in the project a consensuses template has been prepared and shared with tenants for signatures.
- For multi property owner normally if they will to participate they automatically give permits on data collection and treatment under protection rules. Also in this case a consensus form need to be signed in accordance to the legislation on data protection.

In terms of availability of the ICT-hardware and software different scenarios may occur. In our project, there are partners belonging to different companies providing ICT hardware such as sensors and ICT software as edge and cloud services and platform so there is no need to externally buy any devices.
The project partners will be future candidates to sell their solution across Europe where the solution can be replicated however they will be no the only one in the market.
In a general view, it is clear that once a building owner will identify an ICT based solution as the key to provide services and reduce energy consumption within its buildings it has to purchase the solution or identify suppliers with specific Business models.
Private owner may decide to refer directly to market suppliers based on their selection criteria

For public owners the situation is more complex. Based on the quantities of hardware and software needed it can be necessary to have a tender procedure to select the most convenient offer. Each EU country has its own rules to select the winner of the tender.

A general procedure to be followed by the Public authority to identify the company/ies executing the activities planned can be defined as follow:

- Visits to the demo site with expert and technicians in order to evaluate and consider the specificity of the area of interest. In particular, a photographic survey should be made in order to support the design phase and to complete the project documentation. All the physical interferences with other systems should be detected as well as accessibility constraints
- A technical report has to be provided completed with graphics, tables, photographic documentation in order to give a clear picture of the status of the site to the winner of the grant procedure. The report should also clarify the objectives of the activity and the technical and economical boundary conditions and constraints to be respected.

- A tender procedure (public call) has to be called out defining all the technical, economical, legal and contractual aspects needed to participate. A clear assignment procedure should be included specifying the score assigned to each of the requested criteria.
- If a tender procedure is not requested, a market survey has to be carried out in order to evaluate and select the winning companies. Technical economic condition are taken into account and an evaluation by means of a score is anyway used for the assignment. A typical type of evaluation is “offer to the lowest bidder with fault threshold” method: this method allows for the selection of the winning firm as the one offering the highest discount but, employing mathematical corrections (weighted average, average of averages and others), could exclude the cheapest offers.

The firms winning the public procedure obtain consequently all the public permissions as defined in the grant agreement signed.
Usually the winning firms are in charge of the production of all the technical documentation required by law to execute the installation activities.

5 GUIDELINES FOR INSTALLATION, COMMISSIONING, VERIFICATION AND USER TRAINING

5.1 PRACTICAL GUIDANCE FOR INSTALLATION

Each selected pilot home/building needs to have a gateway and at least one device installed. The gateway needs to be powered at all times through the included power adaptor. The gateway also needs to be placed within the home. If internet through Ethernet is available, this is preferred, and the gateway should be placed near an Ethernet plug. If this is not the case and Wi-Fi is available, the gateway can be placed anywhere within Wi-Fi range. If no internet is available, a gateway including a cellular module is required, and a sim card with a mobile data needs to be installed.
The gateway needs no user interaction after installation, but needs to be in range of the sensors and actuators included in the system. When placing the gateway, considerations have to be taken to avoid disturbing the residents. If possible, the gateway can be placed in a closet, cabinet, or near other technical installations. The gateway should not be placed in metal cabinets.

After properly installing the gateway, the installer needs to verify the connection to the InBetween cloud service. Now, the installation of the sensors and actuators can begin. To ensure a good coverage, it is recommended to begin with installing the devices that can act as range extenders first. Before adding the battery powered sensor devices. The devices that can extend the range are the smart cables and smart plugs.

The devices does not require any configuration after the installation to the system, except the External Meter Interfaces, which interface needs to be configured with the right number of impulses per kWh, as well as the current total counter value of the meter. This has to be done on site through a tool or the mobile app.

Installation manuals
Ref [?] Squid.link Gateway
Ref [?] Smoke Alarm
Ref [?] Heat Alarm
Ref [?] Motion Sensor
Ref [?] Humidity Sensor
Ref [?] Smart Plug Mini

Ref [?] Smart Cable
Ref [?] External Meter Interface

5.2 COMMISSIONING

In general a commissioning process is defined by a commissioning plan. The commissioning plan provides an overview of the commissioning and define the methodology to successful carry out the activities.
The commissioning process has the objective to provide a fully functional facility:

- Tested in all its parts and components to meet all functional requirements and operate properly at nominal and limit conditions,
- Provided with all the information and documentation to be installed and put into operation.

The commissioning plan is addressed to different key actors such as:

- Project Manager that have the clear view of the context in which the facility will operate and the unique point of contact between the client and the supplier
- Commissioning Manager assuring that all commissioning activities are carried out in compliancy with the plan
- Construction Team responsible for construction/installation also in accordance with Commissioning plan indications
- Property Manager responsible for the facility and for day-to-day operation and maintenance of the facility representing the lead role in the operation phase.

The commissioning plan is usually revised, refined and updated during the different phases of the design process and, if needed, during the construction/deployment phase.
The commissioning process is composed by the main following phases:

- Pre-commissioning activities such as performance verification tests, inspection, verifications of compliancy for each of the components composing a system,
- Commissioning of integrated system in order to deliver the facility in compliance to end user need and responding to all safety prescription foreseen by law,
- Installation and start-up

The commission process provide the following deliverables:

- Description of the pre-commissioning activities as previously described,
- Schedule of commissioning of the integrated system,
- Installation and start-up check list,
- Product information report,
- Performance verification report,
- Commissioning report,
- Activities to be performed during warranty report,
- Training plan for O&M personnel and users.

In the framework of InBetween project for example to have the ICT solution fully deployed and working the process will be group different phases. Each phase will be detailed with a type of action and description in the pre commissioning activities. The table below is reported as example.

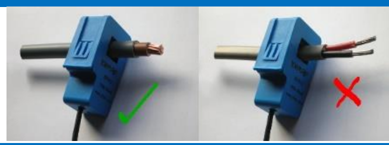
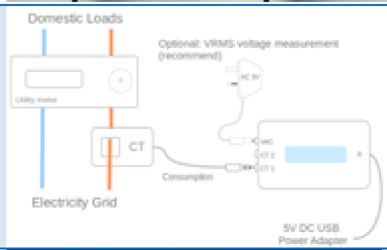
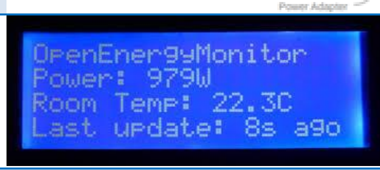
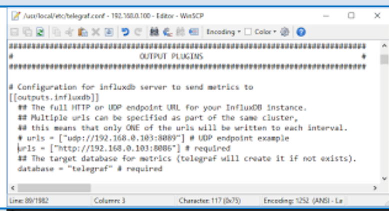
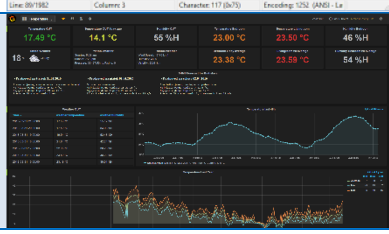
Phase	Picture	Type of Action	Description
1		Sensor installation	Install the sensors according to the monitoring planning. Read the sensors' installation guide before installing.
2		Sensor connection	Connect the sensors with the control unit. The connection can be via a wireless or cable according to the device characteristics. The wireless connection requires a pairing phase.
3		Log Data Locally	Data can now be logged to the local control unit.
4		Internet connection	Connect the control unit to Internet through a cable or wifi connection. If no internet connection is available, use a 3G/4G module.
5		Control unit connection	Configure the control unit to connect with the cloud system. Specifications are reported in the installation guide.
6		Log Data Remotely	Open the platform web interface and check if the data are coming into the cloud database

Table 3 Example of steps for the commissioning process

5.3 VERIFICATION

Verification activities shall be carried out just immediately after or in parallel with the commissioning activities, and they shall ensure that all components of the platform are operating correctly and according to the initial specifications. The verification shall be performed at all levels of the deployed platform:

- **Sensor and actuator layer:** the verification shall ensure in first place that all field devices (sensors, meters and actuators) are correctly calibrated. This can be done for instance through the comparison of values measured by the deployed sensors with those provided by a calibrated multi-function portable measurement instrument. It shall also be checked that the sensors provide data at the configured sampling rate.

- **Gateway layer:** the verification process shall ensure that all data collection processes are being done correctly, i.e. no significant data losses are found. This is particularly critical in the case of wireless devices, as there can be coverage problems that may cause important communications flaws, and therefore must be detected immediately. For the case of actuators, it shall be checked that control signals reach actuators in a timely fashion. Communication of the gateway layer with the cloud layer shall also be checked, i.e. ensuring that all data locally connected is transmitted correctly to the cloud layer. One important aspect to validate is the robustness of the gateway in case of power outages or coverage/internet connection failures. It shall be checked that the system can recover correctly and automatically from these situations.
- **Cloud layer:** the verification process shall ensure that all data are finally stored correctly in the cloud-hosted database. It is important to check that all mechanisms for ensuring data integrity (e.g. backup procedures) are operating correctly.
- **Applications:** finally, it shall be checked that bi-directional communication among the inBETWEEN applications and the cloud platform is working properly.

5.4 STAKEHOLDER TRAINING

InBetween consortium aims to build a platform that will eventually enable different user groups to learn more about their energy consumption and identify ways to conserve energy by changing their habits without compromising their comfort. Nevertheless, for the end users to understand and appreciate these new kinds of tools, a high degree of usability of InBetween system and applications is necessary. The more intuitive the platform is, easier a user can learn how to use it, the higher the acceptance and retention rate are achieved. Building the system around the target user groups and having in mind their requirements and expectations from the beginning, undoubtedly helps to achieve the aforementioned goals. Through early prototyping and user engagement during whole development process, it is possible to tailor the technical capabilities of the InBetween platform to preferences and expectations of the target user groups.

Understanding how future users of the InBetween platform currently use and interact with similar systems for energy management is fundamental for tailoring the design and features that will be offered at the project's end. Differentiating between the preferences of the target user groups is necessary since each user group has different needs and previous knowledge regarding energy efficiency area. Building/energy manager user may require one-to-one or workshop training session as she is likely to have a comprehensive range of features to master. On the other hand, a home user might be less concerned with the potential savings and impact that the InBetween platform may have on their monthly bill and the environment. Besides, they are likely to be interacting with different interface (mobile app) with different range of features, requiring more personalized online or even in-app training and guidance material.

The possibility to provide one-to-one training may be unrealistic due to higher costs. To overcome this potential issue, inBETWEEN will mainly rely on online training methodologies which are particularly suitable for software related products and services. Online training for the building/energy managers can be performed by using open-source learning management systems (e.g. Moodle) where comprehensive and visually attractive material can be put and easily updated when new versions of software are available. Such online platform would allow an easy collection of user feedback, particularly valuable at initial phases, when user opinion could help to steer the platform development into right direction. Besides, on-screen help and guidance features can be integrated directly into the web application interface by using some of the popular JavaScript libraries (e.g. JoyRide, Crumble), as shown in Figure 11.

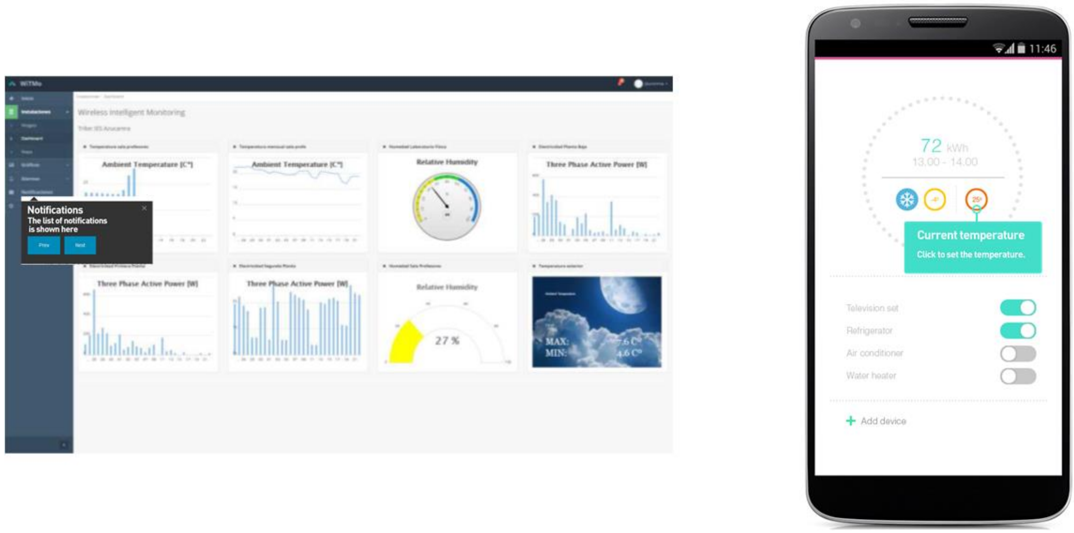


Figure 11 On-screen help for web and mobile application

On the other hand, home users will be using the corresponding mobile application. By adhering to design policies issued by mobile OS manufacturer (e.g. Android, iOS) during the app development phase, the users are likely to quicker get acquainted with unknown user interface and experience less steep learning curve. In addition, in-app help could also be provided (AppIntro, ShowCase libraries), further ensuring the adoption by users that may not be that technology savvy.

6 CONCLUSIONS

D4.1 has laid the foundations for the implementation of the inBETWEEN platform in the project demo sites. It provides methodological guidelines structured into the different phases needed for completing a successful deployment, starting from a deep analysis of the demo site –including building(s) and stakeholders– that will provide the requirements for specifying a customized implementation of inBETWEEN encompassing all the layers of the foreseen architecture (sensors and actuators, gateway cloud platform, and inBETWEEN applications and services).

Based on this customization, a detailed planning of the deployment will be carried out, including the elaboration of detailed blueprints of the installation, list of hardware and software components, planning of installation tasks, estimation of costs of component and of deployment, and preparatory activities such as purchases an permissions processing.

The last phase will be the actual installation in the demo sites, that must include the planning of the commissioning and verification activities in order to ensure that all hardware and software components of the inBETWEEN platform work as expected, and shall be followed by adequate training activities/materials to support end users of the demo sites.

The guidelines produced in this document can be reused beyond the time frame of the project in order to replicate the deployment of INBETWEEN platform in other residential and non-residential buildings beyond the project demo sites.

7 REFERENCES

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