D1.4 –INBETWEEN PLATFORM REQUIREMENT SPECIFICATIONS

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ICT enabled BEhavioral change
ToWards Energy EfficieNt lifestyles

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DISSEMINATION LEVEL

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Recent advances in wireless networking and microelectronic fabrication have enabled a mass production of low-cost computationally capable miniature devices that can be used in different innovative solutions. Expected growth of human population and steady acceleration of technological advancements will require either an increase of energy production or shifting the general community behaviour towards more energy efficient and less wasteful practices. Since residential sector has been identified as one the most energy demanding, there exists a strong interest in exploitation of connected smart devices with the aim of improving energy efficiency, user comfort and the overall quality of life. The platform that will be developed within the InBetween project aims to reach the aforementioned goals with the combination of smart monitoring and control devices with the advanced energy services capable of analysing the collected data and providing control actions and suggestions towards the end users via intuitive mobile and web applications.

The aim of this document is to provide technical and functional specifications for the InBetween platform that will serve as a basis for the development and deployment tasks in other related work packages. In order to arrive to the set of specifications, a structured approach is taken, having in mind the project objectives, work packages structure and characterization of pilot sites and their residents.

First, the analysis of two pilot sites comprising residential and non-residential building types in France and Austria have been performed. The analysis focused on the building properties, apartment occupants, available appliances, installed metering equipment, and other relevant aspects that have to be taken into account before any further platform specification and development can be performed. Next, the identification of three possible use cases for the platform has been provided. In particular, the aim of the identified use cases is to enable users to reduce energy wastes, operate energy infrastructure in an optimal manner, and provide an evaluation of their energy performance against similar/neighbouring end users. Based on the given use cases, the technology deployment scenarios necessary to support the envisioned functionalities are presented, having in mind the constraints such as type of building, occupants needs, and total investment cost. Besides, the choice of possible deployment models for the InBetween platform was influenced by a general requirement to integrate different hardware and software components devoted to energy monitoring and automated control at the building/household level. Then, a preliminary platform architecture consisting of monitoring and control layer, IoT cloud platform and advanced energy services and visualisation is described. In addition, some of the already available technologies suitable for implementation of different platform modules have been identified. Finally, the results of previous analysis is formalized in a list of functional and non-functional requirements provided in a tabular form along with the conclusions and further recommendations.

2 INBETWEEN PLATFORM DEMONSTRATION CASE STUDIES

For the purpose of InBetween project demonstration, its main outcome, the InBetween platform, will be deployed at the two pilot sites offering a valuable diversity in building typology, construction material, and geographical location. The demonstration pilot sites will be used to validate platform's deployment flexibility and replicability thus ensuring its full roll-out potential.

In general, the platform will be deployed in the demonstration pilot sites under two separate phases, as follows:

- Baselining phase – this first phase will entail deployment of platform monitoring functionalities aiming to provide necessary information related to the baseline operation of considered energy infrastructures at the pilot sites. It will consider monitoring of all relevant energy carriers through their consumption points, ambient sensing as well as corresponding end user behaviour. However, at this stage the platform will operate with its limited monitoring functionalities providing no feedback or advanced energy services to the end user. Once such limited platform is deployed, it is intended that the baselining process takes one whole year period so as to account for different seasonal changes and different end user operational scenarios. This is foreseen for the period M12-M23.
- Validation phase – once the baselining process is completed, the fully fledged platform will be commissioned and up and running. Apart from the existing monitoring functionalities platform will be equipped with operational advanced energy services, which were developed and calibrated prior and during the baselining process. Is intended that the overall validation process takes one whole year period so as to enable capturing platform effectiveness under different seasonal and end user behavioural scenarios. During this process, end users will be actively involved in platform operation through systematic energy saving related notifications and recommendations they receive as well as control actions available through the platform. This is foreseen for the period M14-M35.

The actual timing for the two phases is defined in the corresponding Gantt chart of InBetween DoW.

Following is a brief description of the two project's pilot sites in Leers (France) and Großschönau (Lower Austria), which briefly summarizes location, number and typology of buildings to be employed for demonstration. Moreover, a comprehensive technical characterization describing building construction features, existing energy infrastructure, available ICT and monitoring/automation systems and corresponding operation scenarios of each building considered within the two pilot sites is available within deliverable D1.1 "Report on operation scenarios and technical characterization of demo sites".

2.1 SOCIAL HOUSING IN LEERS, FRANCE

Owing to the participation of project partner Vilogia, InBetween project has been provided with an opportunity to demonstrate and validate its solution within their social housing buildings stock. Although Vilogia currently owns and operates a large number of buildings throughout France, for the purpose of the project pilot site the two typical buildings were selected in the city of Leers, situated in the north-east part of France. More precisely, the two buildings, referred to as Buildings A and B, are located in the street Chemin des Chasses with the exact geographical coordinates as follows, Latitude 50°41'18.2" North and Longitude 3°13'48.6" East. Moreover, since Vilogia is also operating another building in their vicinity, referred to as Building C, this third building will be used as a back-up in case the current pilot size is not enough or a number of finally confirmed participants in the research is not sufficient. Aerial view of the aforementioned buildings is provided in Figure 1.

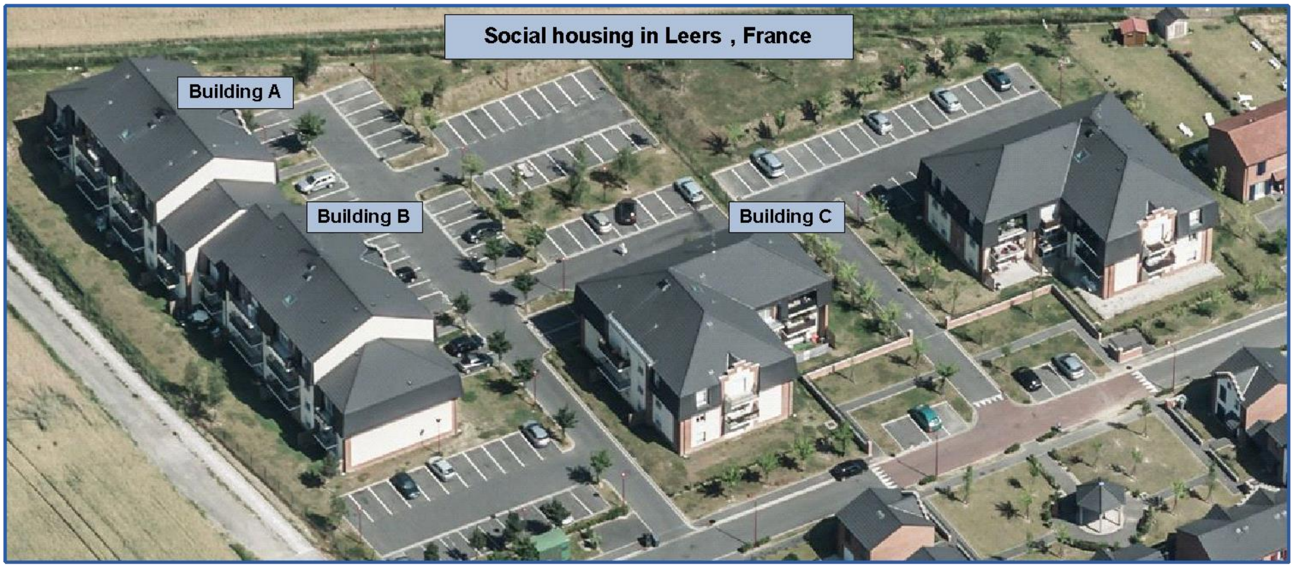

Figure 1: **Aerial view of pilot site in Leers, FR**

Both buildings A and B were constructed in the 2010, having identical layout composed of a ground level and 3 storeys, and being built with identical construction material. Each building has 21 apartments and consider two typical apartment structures/typologies, as depicted in Table 1.

Table 1: Apartment typology at pilot site in Leers, FR

Apartment type	Description	Building A	Building B
T2	1 bedroom apartment	12 apartments	12 apartments
T3	2 bedrooms apartment	9 apartments	9 apartments

Currently, there is no comprehensive energy monitoring platform deployed at the pilot site, however all apartments are equipped with individual electricity and water consumption meters. Heating and domestic hot water demand is satisfied individually for each apartment through an electric heating system. However, since there is only bulk electricity monitoring available, a breakdown of electricity consumption between heating, domestic hot water and appliances is not accessible.

2.2 PUBLIC BUILDINGS AND PRIVATE HOMES IN GROßSCHÖNAU COMMUNITY, AUSTRIA

Owing to the participation of project partner Sonnenplatz Großschönau, InBetween project has been provided with an opportunity to demonstrate and validate its solution within several public and commercial buildings together with a number of private dwellings. More precisely, the project pilot consists of 8 residential houses and 6 non-residential houses of different ages and sizes, representing therefore a broad spectrum of used building materials as well as different building usages. All 14 buildings are located in the municipality Großschönau in Lower Austria with the following exact geographical coordinates: Latitude 48°39'06.9" North and Longitude 14°56'33.8" East, on a sea level of around 700 m. The aforementioned buildings have been constructed in the different time periods starting from 1900s over 1950s, 1970s, 1990s and 2000s up to 2010s. Aerial view of the municipality of Großschönau where aforementioned buildings are located is provided in Figure.

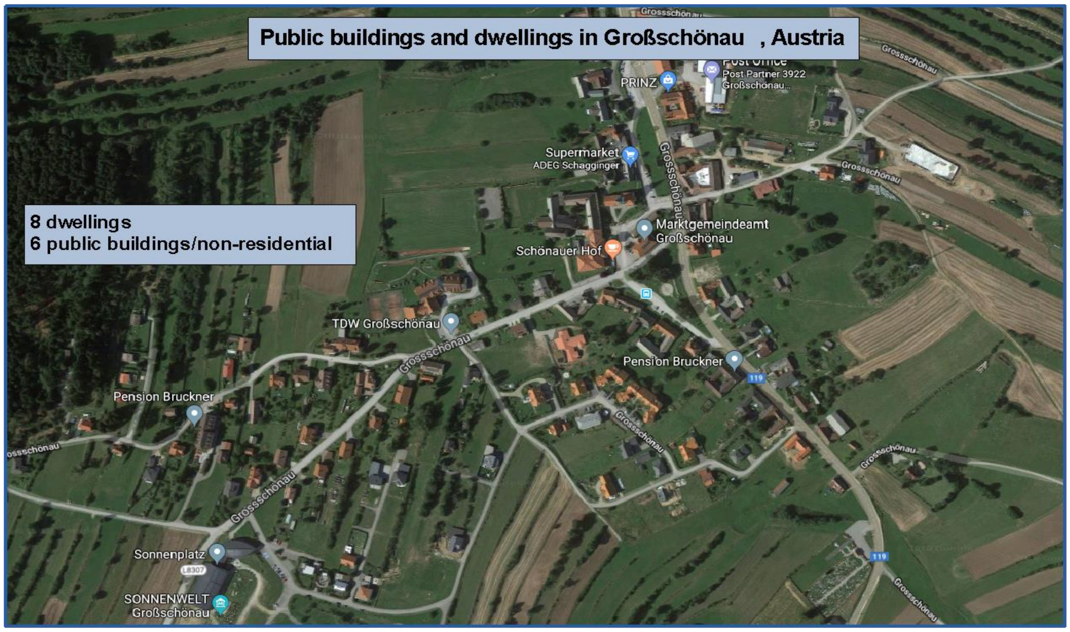

Figure 2: Aerial view of pilot site in Großschönau, AT

The overall building typology available at the pilot site is depicted in Table 2. Both non-residential and residential buildings vary in different aspects such as:

- Building properties – they are different in size, age and construction material;
- Energy requirements – there is difference in available insulation, heating systems and, where applicable, difference in local energy generation;
- Socioeconomic characteristics – building inhabitants differ in their age, number, education, etc.

Table 2: Building typology at pilot site in Großschönau, AT

Non-residential buildings	Residential buildings
1 Nursery building	8 private dwellings
1 School	
1 Municipality Office	
1 Multi-functional community building	
2 Guest-houses	

Currently, there is no comprehensive energy monitoring platform deployed at the pilot site, however all buildings are equipped with individual electricity and water consumption meters and, in some cases, even with the heat meters (calorimeters).

3 IDENTIFICATION OF PLATFORM USE-CASES

InBetween platform represents a highly flexible, cloud-based, IoT platform which will integrate energy monitoring and automation devices with environment sensing and innovative InBetween advanced energy services. Although aiming to build a comprehensive platform the InBetween's approach does not entail development of 'one size solution that fits all'. On the contrary, the proposed platform will try to induce energy related behaviour changes through tailored recommendations, decision support and guided action. In other words, the platform will provide relevant energy and cost saving measures that are relevant to a specific end user, who is then able to act upon them without compromising personal comfort and convenience. Moreover, the platform will engage end users through specific incentives according to their preferences and limitations.

The aim of this section is to determine different use cases for InBetween platform, i.e. different aspects in which the platform may contribute to reaching improved energy and cost efficiency. Seeking for different ways to raise end-user awareness in energy and environmental related aspects and aiming to induce a behavioural change in this regard, the platform will follow a comprehensive approach which shall allow end-users to:

1. **Reduction of energy wastes** – by detecting wasteful practices through cross-correlation of information about operating heating/cooling systems and lighting devices with ambient and occupancy sensing.
2. **Optimal energy infrastructure operation** – by optimally satisfying requested energy demand based on information about available energy assets and dynamic energy pricing context, forecast of local generation etc.
3. **Evaluate performance and benchmark** – by periodically assessing energy performance and raising awareness through benchmarking with similar/neighbouring end users.

The three core features of InBetween platform will be leveraged upon availability of devices dedicated to energy monitoring and home automation (such as electricity/gas meters, calorimeters, smart plugs and relays etc.), ambient and environment sensing (temperature, luminance, humidity, CO/CO2, occupancy etc.) and InBetween's advanced energy services.

The later will comprise of the following services:

- Consumption analytics service (CAS), dedicated to consumption disaggregation, i.e. estimation of appliance-level electricity consumption from a single metering point;
- User profiling service (UPS), focusing on profiling and categorization of end-user and their consumption;
- Consumption forecast service (CFS), offering prediction of near future energy related behaviour;
- Energy dispatch optimization service (EDOS), delivering optimal energy dispatch strategy for existing energy assets while satisfying various economic, environmental, societal and technological criteria;
- Energy performance evaluation and benchmarking service (EPEBS), enabling end user's energy performance and its benchmarking against 'similar' end users.

Although each of these services represent part of same value chain, they will be developed and deployed independently operating as a black box from the platform's perspective requiring specific inputs and offering corresponding outputs, which are detailed in one of the following chapters. Their integration into a unified workflow will depend on the requirements of each use-case which will also define which services are required and what will be their corresponding sequence of operation. When it comes to communicating devised energy conservation measures or corresponding performance deviation notifications both Mobile and Web clients will be made available with their intuitive and user-friendly GUIs.

The following subsections will detail on specific platform use-cases whereas the following section will elaborate on the flexibility of the undertaken technological approach and its ability to integrate legacy systems and pre-existing equipment which will have a direct impact on the cost-effectiveness of InBetween approach and, even more, it will allow for adoption of a flexible business approach accounting for different levels of equipment and service deployment.

3.1 REDUCTION OF ENERGY WASTES

InBetween will primarily look for the so called 'quick wins' related to overall energy efficiency and thus seek for the wasteful energy practices which can avoided without compromising end user comfort and operational capacity. The platform will combine energy consumption information from major consumers, such as heating and cooling system and lighting, with ambient and occupancy sensing to deliver custom, end-user tailored, energy conservation measures (ECMs). The typical energy wastes, such as open windows in HVAC conditioned area or working lights during the daylight, have enormous, untapped, potential for avoiding energy wastes and thus increasing the end user efficiency.

Necessary information and data flow behind this use case is depicted in Figure 3. In particular, the figure summarizes employed InBetween's advanced energy services and necessary steps to fulfil the workflow. All three use-cases share the same part of workflow dealing with the energy/ambient monitoring, corresponding data analytics/processing and visualisation. In particular, this part of the workflow is responsible for 1) acquiring and storing raw monitoring data in the Data repository and 2) data enrichment based on load disaggregation performed by the Consumption analytics service (which implements Non-intrusive load monitoring techniques, *NILM*) and User profiling service. It should be noted that load disaggregation techniques are employed in cases when existing energy monitoring does not provide for sufficiently detailed consumption information. Also, a common part of the workflow is also Visualisation which serves for presentation of monitored energy and ambient data but also provides interface for presentation of intermediate outputs from each service and, the most importantly, is used to communicate derived recommendations/actions/awareness information. For this use case, in particular, Visualisation component will provide derived ECM recommendations delivered by the ECM inference engine. The latter represents proprietary component employed for this use case which takes energy and ambient monitoring data, enriched with corresponding analytics/profiling services, to detect wasteful practices using a heuristic based methods.

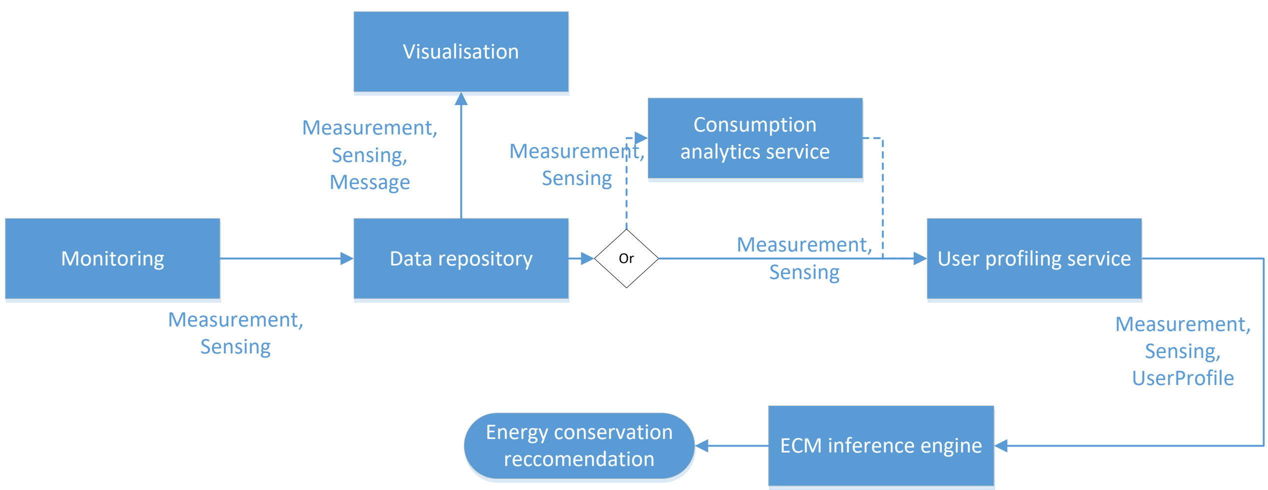

Figure 3: Data flow diagram for use case Reduction of energy wastes

Outputs from the ECM inference engine are finally presented to end user. However, InBetween's approach revolves around a principle of limited and targeted communication with the end user, exchanging only critical actionable information. In other words, the platform will not push large amount of information towards an end user such as current energy consumption, local production, change of device status etc. Instead, the focus will be on alerting an end user only in case an action from his/her side is required and keep all the data available for presentation, on demand. Therefore, following are a few examples of ECMs which are to be communicated to the end user:

- "Luminance sensor shows presence of daylight and lighting is ON"
- "Occupancy sensor shows absence of occupants and lighting is ON"
- "HVAC is running and window is open – prompt for change in HVAC set point"
- "Reduce or turn OFF heating/cooling when leaving the house."
- "Current consumption exceeds contracted power peak."
- "Electricity tariff will change in x minutes." etc.

3.2 OPTIMAL ENERGY INFRASTRUCTURE OPERATION

Once energy wastes are minimized, InBetween platform will assist end users in reaching optimal energy infrastructure operation strategy for satisfaction of the remaining energy demand. Proposed operation strategy will leverage user-centric energy consumption modelling and consumption prediction combined with pricing/load/stability information received from ESCOs. In particular, it will consider available energy carriers and sources such as power grid, district heating, renewables etc., energy conversion assets such as electric boilers, heat pumps, furnace etc. and dynamic energy pricing context for each energy carrier. Moreover, this use case will also capitalize on increasing Demand Response and Demand Side Management programmes through integrated optimisation of energy supply and demand which takes additional inputs related to load characterisation (e.g. classification into critical, reschedulable and curtailable loads), required comfort levels, etc. In other words, the platform will extend information supplied through energy conservation measures by performing comprehensive energy infrastructure operation optimization to detect optimal energy management strategy of available energy assets. Although optimal energy management strategy is often associated with minimization of operation costs, InBetween's optimisation service will bring the flexibility of multi-criteria decision making process so as to simultaneously evaluate range of economic, environmental, technical and societal criteria.

Required information and data flow leveraging this use case is depicted in Figure 4. In particular, the figure summarizes employed InBetween's advanced energy services and necessary steps to fulfil the workflow. As previously elaborated, part of workflow dealing with the energy/ambient monitoring, corresponding data analytics/processing and visualisation is common for all three use cases and thus the same description holds. However, there are proprietary components/services for this use case. In particular, this use case employs the Consumption forecast service which takes archived data from consumption monitoring and various contextual information to deliver short-term predictions regarding energy consumption. Output from this service is then fed into Energy dispatch optimisation service which is another proprietary component of this use case. The optimization service will deliver optimal energy supply and consumption profiles, for each energy carrier and load types respectively, to the component referred to as Optimised control which main responsibility is to translate outputs from the optimisation service into actual control actions applicable by end user through existing energy assets. In other words, this component will ensure that an optimal operation strategy is communicated to the end user in the form of manual, semi-automatic or automatic controls such as actuator switch, set-point, time table etc.

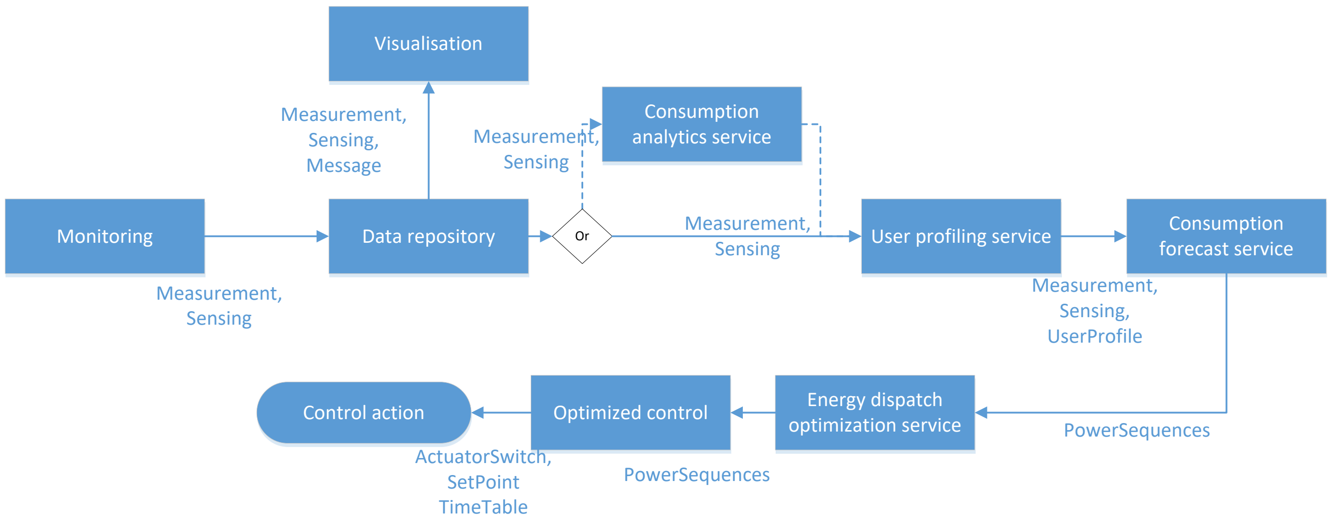

Figure 4: Data flow diagram for use case Optimal energy infrastructure operation

Following the same principle of limited and targeted communication with the end user, exchanging only critical actionable information, an example of optimal energy management measures to be communicated to the end user is as follows:

- "Power consumption is approaching contracted power peak"
- "Electricity tariff will change in next x minutes"
- "Your local energy generation will be available in x minutes" etc.

3.3 EVALUATION OF PERFORMANCE AND BENCHMARKING

Following the general project's approach that there is no 'one size solution that fits all', InBetween platform aims to engage end users and induce behaviour change by delivering tailored advices and personalized incentives based on monitored data and contextual information. However, InBetween platform will also offer a use case that offers more general feedback aiming to create positive social pressure and raise awareness in energy related issues. Namely, by aiming to understand barriers for action, and target those specifically, InBetween adopts approach of 'fair' comparison (fair, as perceived and defined by end user) which will enable unique social nudges (i.e. positive reinforcement) towards the desired behaviour change.

The platform will bring the ability to benchmark and compete through evaluation of end user energy social practice and performance rather than just consumption. The performance evaluation considers normalization of consumption against a range of 'objective parameters' such as building size, construction material properties, number of occupants, climate conditions etc. Moreover, current adoption barriers, faced by the similar ICT platforms, will be tackled by using energy services approach (rather than energy consumption) and by incorporating insights and methodologies for user engagement from the 'Practice theory' and the 'middle out framework'.

Required information and data flow leveraging the use case related to performance evaluation and benchmarking is depicted in Figure 5. In particular, the figure summarizes employed InBetween's advanced energy services and necessary steps to fulfil the workflow. As previously elaborated, part of workflow dealing with the energy/ambient monitoring, corresponding data analytics/processing and visualisation is common for all three use cases and thus the same description holds. However, this use cases features a proprietary Energy performance evaluation and benchmarking service. This service takes energy and ambient monitoring data, enriched with corresponding analytics/profiling services to evaluate end user energy performance through normalization of energy consumption against a range of contextual parameters, such as climate conditions, building construction material, number of inhabitants etc. Such normalization is employed to ensure that an objective performance indicator is calculated which sets the ground for comparison and benchmarking with other end users.

Following the same principle of limited and targeted communication with the end user, exchanging only critical actionable information, end user is finally presented (through the Visualisation service) only with information about his/her achieved energy performance, over a defined time-horizon, in the form of performance score and corresponding ranking against similar end users.

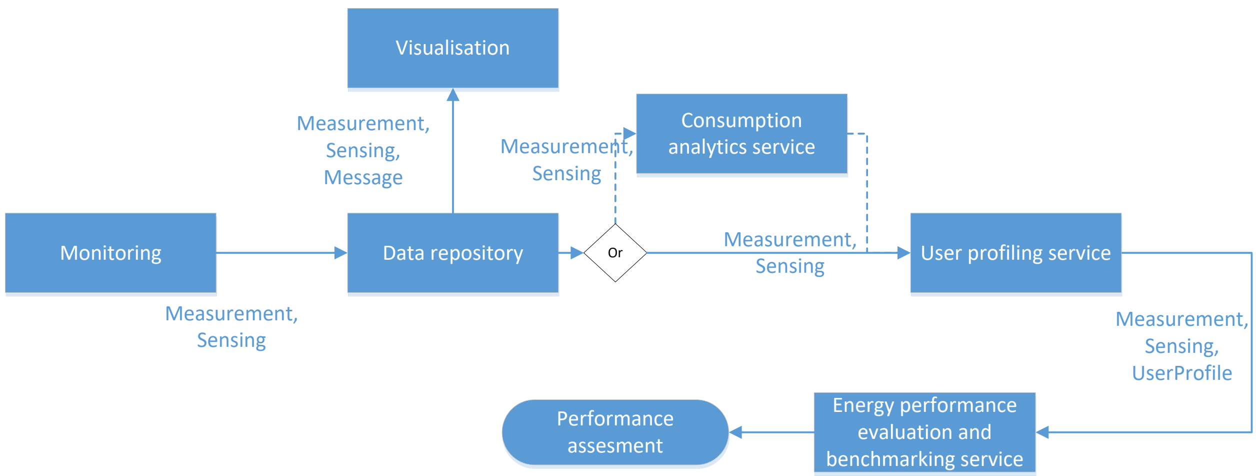

Figure 5: Data flow diagram for use case Evaluation of performance and benchmarking

4 TECHNOLOGY DEPLOYMENT SCENARIOS

The focus of this section is to elaborate on the possible deployment models for the InBetween platform given a general requirement to integrate different hardware and software components devoted to energy monitoring and automated control at the building/household level. The integration problem has been known and investigated for several years and the existing literature has emphasized that the complexity of this integration is severely dependent on the number of different devices employed, existing on-site energy generation and storage etc. In principle, the most widely acknowledged solutions propose architectures that use a data-unifying layer for tackling both syntax and semantic interoperability problem. More precisely, this layer focuses on the abstraction of complexity of lower level, facility related, components and aims to solve existing interoperability challenges through unification and conversion of data coming from these lower software levels. In this way, any format-related issues for pluggable application layers is overcome.

On the other hand, when it comes to finding a viable deployment model for such a system, a strong influence is made by the underlying hardware requirements, location of data sources, how data is generated, transported and consumed across the value chain. Moreover, the deployment model also strongly affects the type of business models which can be supported. In other words, it also affects further design of actual software components of the system.

The presented research examines the deployment models from the perspective of the two key stakeholders: the energy utility (both electricity and gas) and the energy end-user, i.e. the customer. For this stakeholder constellation, the three types of deployment models are considered:

- **A cloud-based deployment model**: which assumes that system components are deployed in a private cloud of an energy provider or energy service company (ESCO). Furthermore, it builds on a fact that both energy monitoring and ICT equipment is under full control of energy and/or service provider and that information about end-users is centrally available. The monitoring equipment located at the end-user is relatively lightweight, e.g. a single smart meter for entire household and does not penetrate into premises of the end-user.
- **An extended edge deployment model**: system components are distributed between a private cloud governed by the energy/service provider and edge systems deployed at the end-user premises (e.g. energy gateways) and/or distribution network. This deployment model assumes that some of the end-user oriented services can be provided by the edge systems (e.g. energy gateways), thus forwarding only the necessary information to the central system while leaving some simple calculations and decision making (with corresponding alarms and notifications) for the edge systems and components. Energy monitoring, such as smart meters/occupancy/ambience sensing, as well as actuation equipment such as smart plugs/boilers/EVs, can penetrate the end-user premises and offer a richer information and control environment to be locally exploited.
- **A hybrid deployment model**: this model assumes that not all end-user will have edge system, and corresponding components, deployed at their premises. As a result, some end-users, with limited hardware deployment will only use the cloud-based part of the solution while the others, offering more advanced monitoring and control capabilities, are able to use the system functionalities to the full extent. Such deployment model allows for development of flexible business model and larger market outreach.

Inspired by the previous analysis, the InBetween platform has been designed having in mind different business models that ensure widest possible market coverage and at the same time adapting itself to different user budgets and expectations. In the following sections we will describe three envisioned technology deployment scenarios.

4.1 SINGLE METER DEPLOYMENT

The minimum amount of data necessary to get an insight into user's energy consumption behaviour can be provided by a single electrical energy metering device. Nowadays, the ESCOs usually deploy smart meters that support remote reading of the energy consumption. The main reason behind the usage of smart meters is to lower the operational costs of ESCOs, since previously, authorized personnel needed to visit the user's premises and collect the consumption data manually. Although ESCOs often provide some basic analysis of the collected data on the monthly bill (e.g. energy consumption per month, average consumption, etc.), the full potential of the available data is often left unexploited. If the energy consumption data is collected relatively frequently (on the order of couple of seconds), the machine learning algorithms can be used e.g. to disaggregate the energy consumption per different appliances. In such a way, additional value could be brought to the end user, which could then be able to identify potentially wasteful and costly practices (e.g. using washing machine during peak hours when the energy price is high). This is the exact opportunity that InBetween project aims to exploit by offering its advanced energy services.

In this regard, we envision two deployment scenarios:

1. Smart meters are property of the ESCO which provides external service API that could be used by InBetween platform to acquire energy consumption readings (upper part of Figure 6).
2. Smart meters are deployed by the InBetween consortium that has full ownership of the data that it collects directly via Develco's gateway (lower part of Figure 6).

In the first scenario, which belongs to the group of cloud based deployment models described above in the previous section, the InBetween consortium would offer its services to the end users via monthly subscription for the mobile application, in partnership with the ESCO that provides the consumption data via external API. In the second scenario, which belongs to the group of extended edge deployment models, the InBetween could offer its service subscription directly to the end user without intermediaries, and even for case where non-smart meters are previously available. Nevertheless, in the second scenario there exists an initial cost of equipment installation, that could drawback the potential users, especially if ROI period turns out to be very long.

Since the single meter deployment approach requires no or very little equipment deployment effort on the end-user's side, it allows an easy market entrance. Nevertheless, its main shortcoming when compared to the more comprehensive deployments, which will be described later, is the accuracy of consumption disaggregation that in some cases may lead to erroneous reports and recommendations which would not provide very much value to the end user.

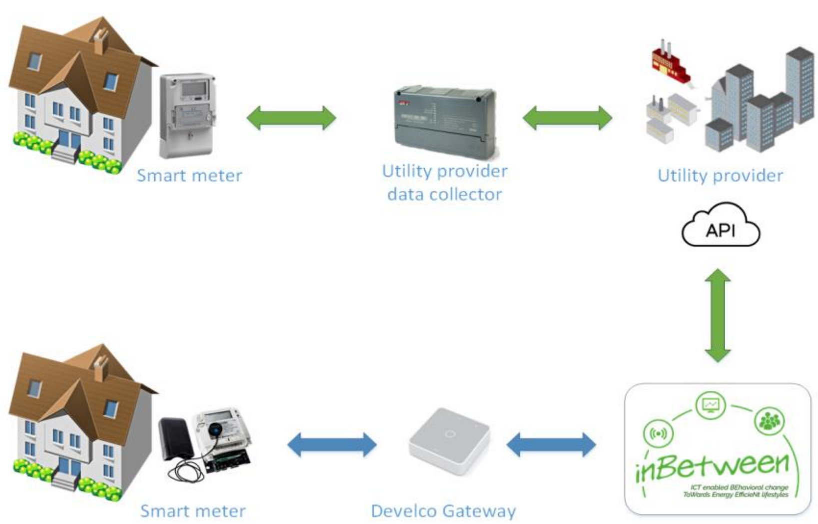

Figure 6: Single meter deployment

4.2 COMPREHENSIVE ENERGY MONITORING AND SMART SENSING DEPLOYMENT

In this Section, we propose a more comprehensive deployment approach aimed for the end-users that are willing to invest more into smarter monitoring and sensing platform, as shown in Figure 7. As can be seen, this deployment approach mainly relies on the Develco's product portfolio, although similar interoperable devices provided by other manufacturers can be also employed for this purpose.

In Figure 7, we see that there exist different types of sensors that, in addition to power consumption, can also monitor other parameters such as temperature, occupancy, widow/door detector, humidity, etc. The data provided by these additional sensors through a dedicated gateway aim to help InBetween platform to learn more about general user's behaviour and its environment and therefore provide more personalized and accurate reports and recommendations for energy saving. For instance, the window/door sensor can detect potentially wasteful practice (e.g. cooling/heating device is turned on while the window is open). Also, the energy consumption can be directly measured at the appliance level leading to the more accurate disaggregation of the total consumption.

It is important to note that in the comprehensive monitoring deployment scenario, the InBetween platform itself is not capable of performing any energy conservation actions automatically. Instead, based on the advanced energy services, the platform is able to predict the energy consumption, schedule the optimal usage of different appliances and detect bad energy efficiency habits. As a result of this analysis, InBetween platform will provide users with a number of recommendations (e.g. close the windows while the HVAC is working, schedule dishwashing machine to work during low pricing period, etc.) aimed to steer their behaviour to be more energy efficient and economic.

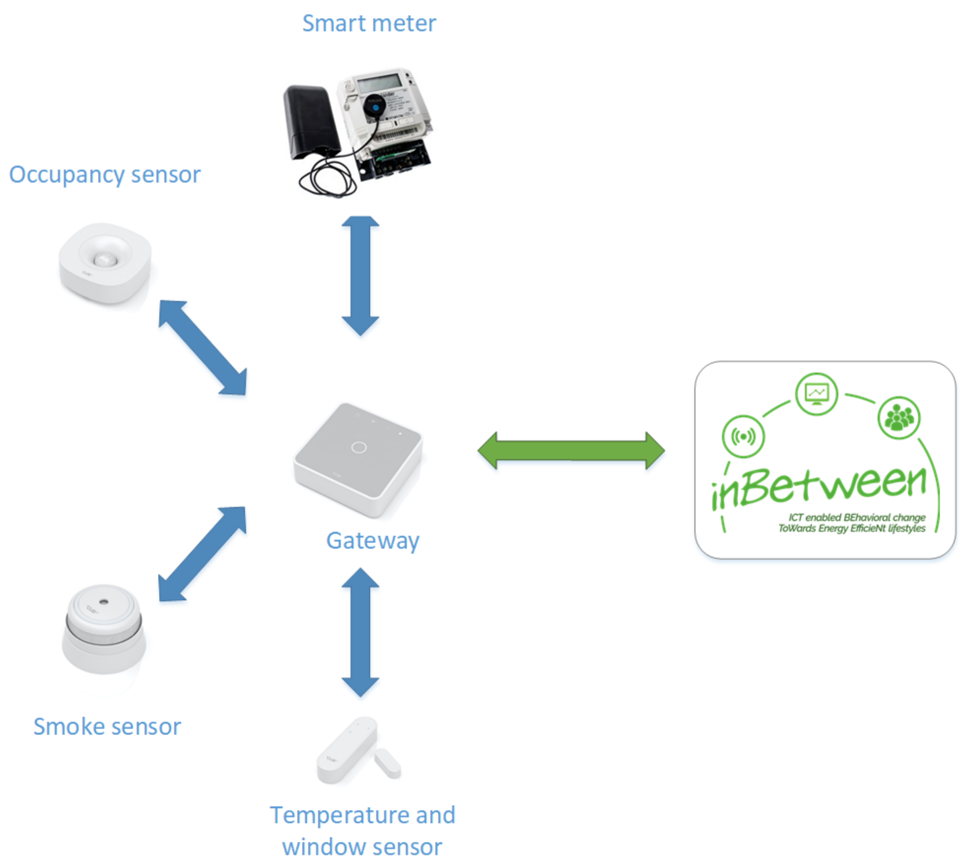

Figure 7: Comprehensive energy monitoring and sensing

4.3 COMPREHENSIVE MONITORING, SENSING AND CONTROL DEPLOYMENT

Building on the capabilities of the previous approach, in this section we propose an extended deployment scenario. In Figure 8, we present a comprehensive energy monitoring and deployment approach that is enriched with the capability to perform some energy conservation actions on the user's behalf with previous acknowledgement or even completely automatically. As can be seen, the additional devices, in the form of smart plugs and smart relays, have been added for this purpose. It is important to note that these devices provide only binary control (i.e. on/off) that may not be suitable for all types of appliances found in a household. For instance, a washing machine usually have different types of programs while HVAC system needs more fine grained control regarding temperature set point. To counteract these issues, the InBetween platform will support the following control scenarios:

- Manual control, where a user follows recommendations in the case where there is no automatic control capability or the recommendation requires a sequence of actions (e.g. set a program on a dishwasher that shouldn't be empty at the program start).
- Semi-automatic control where platform proposes a control action but waits for user action/approval (e.g. although it is daytime, a user might need lights turned on).
- Automatic control where the platform does not require user approval but simply performs an action (e.g. manages heating/cooling system within predefined temperature/humidity constraints).

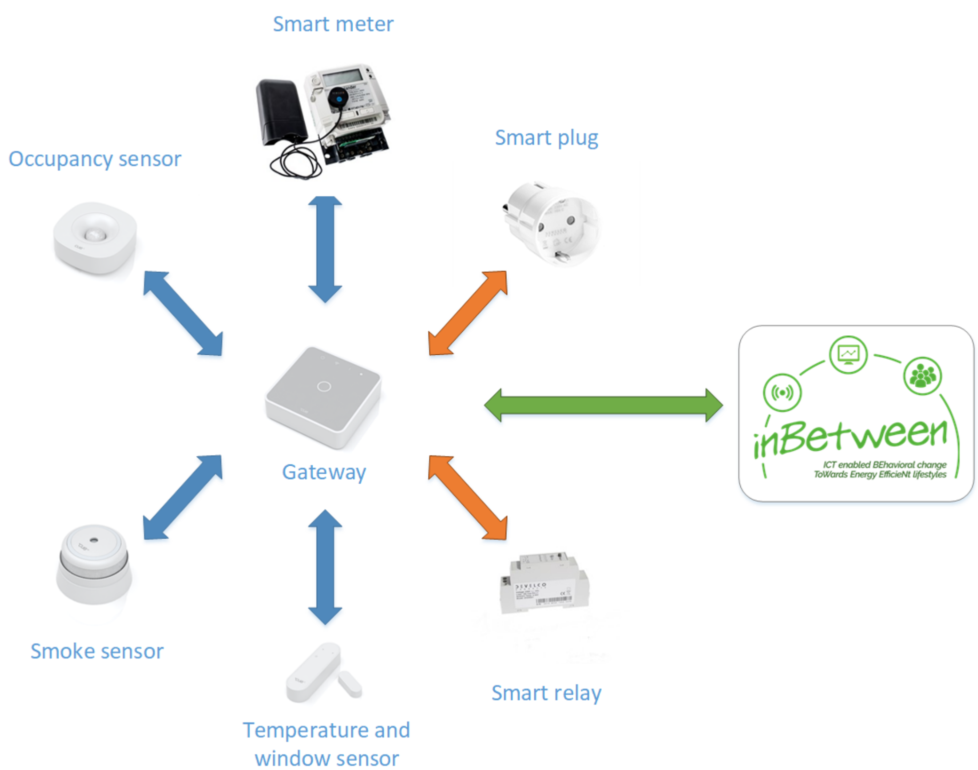

Figure 8: Full-blown monitoring and control

5 PRELIMINARY INTEGRATION APPROACH AND ARCHITECTURE

In this section we provide a preliminary InBetween platform architecture proposal designed in line with the technical requirements provided later in this document. Before going into further details, following is a brief overview of different middleware architecture proposals in the context of energy management.

The AIM project[1] present a framework architecture for modelling, visualizing and managing energy consumption of home appliances. The project proposed development of a gateway which consist of the three separate modules: i) a module providing machine-to-machine interfaces through a common API for implementation of gateway-related services, ii) an identity management module for user authentication and authorization, and iii) a module for service integration and orchestration offering also creation of new, composite, services upon such integration. The HYDRA project[2] brought a generic middleware platform for heterogeneous devices which facilitated communications between the devices and provided an architectural infrastructure for network abstraction, event management and services communications. It was not built primarily for energy efficiency purposes, however it provided infrastructure for construction energy-aware solutions. The EPIC-Hub project[3] developed a new methodology, an extended architecture and services able to provide improved energy performances both on building and neighbourhood level. It leverages upon energy gateways to integrate various data sources in the middleware architecture and offer implementation of advance energy demand and supply optimization services.

Inspired by aforementioned and other relevant projects and having in mind particular requirements of the InBetween project, we propose the InBetween platform architecture (see Figure 9) that consist of three main layers:

Gateway layer comprises different sensors, actuators and metering equipment that are deployed at the buildings and inside the households and connected via gateways to the rest of the InBetween platform. The aim of this layer is to ensure the collection of different measurements (power consumption, temperature, etc.) that will be stored in InBetween cloud platform, further processed by advanced energy services and presented to the end users via web and mobile applications. Besides, the InBetween platform will be able to perform control actions (turn on/off the boiler, set the temperature on HVAC, etc.) following decisions made by advanced energy services. Finally, this layer also includes a number of interfaces towards external services that will be used to get data related to energy pricing, weather, etc.

IoT Cloud platform layer is the main data collecting and processing point of the InBetween platform. Its main functionalities include lightweight message exchange (MQTT or AMQP message broker), data storage optimized for time series data (InfluxDB) and identity and access component (Keycloak) that will provide centralized authentication and authorization management. In addition the semantic data related to the deployed devices will be stored inside a semantic repository (Virtuoso), whereas real-time data processing will be performed by Kapacitor component.

Advanced energy services and visualisation layer comprises a number of services used for energy consumption analytics and forecast, energy optimization, user profiling and benchmarking, as well as a web and a mobile application that provide visual user interface for energy managers and building occupants. This layer employs information collected by the monitoring and control layer that have been stored in the IoT Cloud platform. The collected data are processed by means of advanced energy services that result in a number of control actions performed by the deployed actuators (smart plugs, relays, etc.) and recommendations for users aimed to change their behaviour towards more energy efficient lifestyle.

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[1] Fp7 AIM project, A novel architecture for modelling, virtualizing and managing the energy consumption of household appliances, link.

[2] Fp6 HYDRA project, Middleware for networked devices, http://hydramiddleware.eu/news.php.

[3] Fp7 EPIC-Hub project, Energy Positive Neighbourhoods Infrastructure Middleware based on Energy-Hub Concept, link

In the sequel, we will provide more details for each of the aforementioned layers and propose a preliminary integration approach.

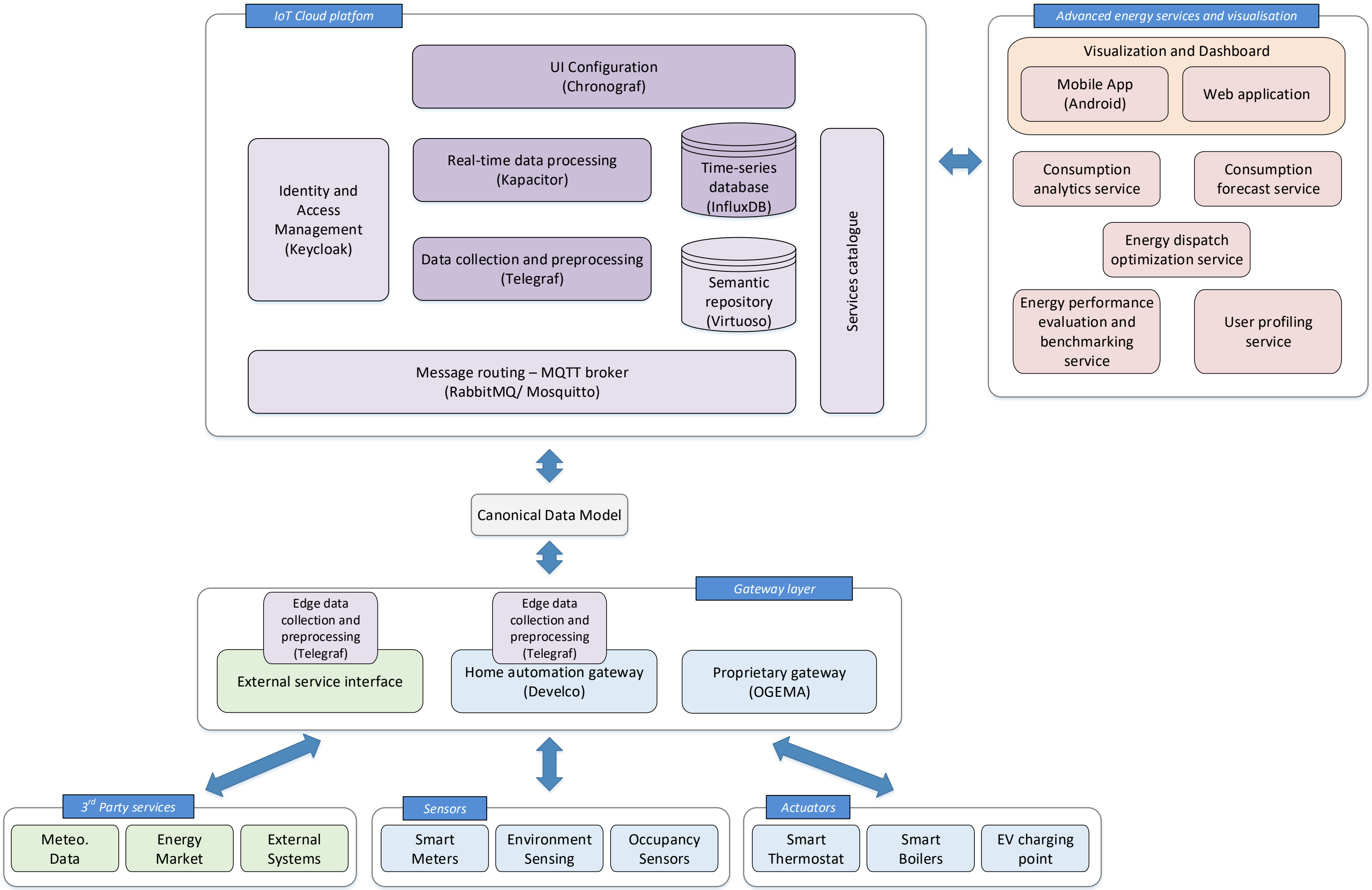


Figure 9: InBetween platform preliminary architecture

5.1 GATEWAY LAYER

As has been explained previously, the monitoring and control layer aims to provide a connection between the physical devices and appliances in the buildings and individual households by measuring different physical phenomena (temperature, power consumption, etc.) and enabling InBetween platform to act (turn devices on/off, set temperature on HVAC, etc.). The InBetween will make this possible by integration with available and mature monitoring platforms brought by the consortium partner Develco.

Develco is a B2B company providing white-label products within the fields of smart home, energy management, home security, and assisted living. Its products portfolio encompasses a variety of smart metering equipment and corresponding wireless communication interfaces and is fully compliant with InBetween cloud based approach. The Develco's platform is able to measure the consumption of electricity, water, heat and gas thus enabling InBetween platform to infer the User's consumption habits. In addition, it enables monitoring of indoor key environment parameters (temperature, light) and other phenomena (occupancy, individual device consumption meter, window sensor, etc.) that will be used as an input for the advanced energy services (see Figure 10).

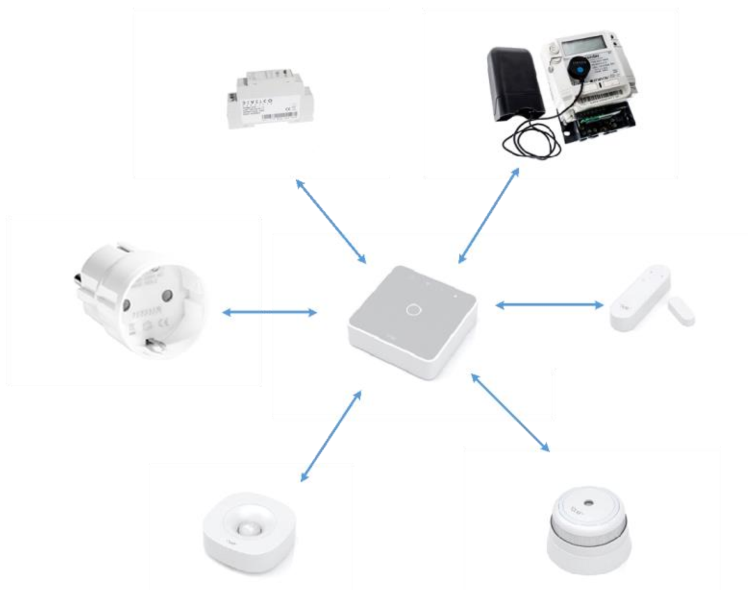


Figure 10: Develco platform

Based on such smart monitoring equipment, the InBetween platform will be able to set lights according to the occupancy, to detect if window or door has been left open for a longer period which could significantly increase thermal power consumption, etc. In addition, the smart metering interfaces offered by Develco will empower third party and legacy meters with wireless communication, allowing them to be effectively integrated into the InBetween platform. Finally, all monitored data will be made available to InBetween through Develco's proprietary Gateway solution (Squid.link) that will be responsible for connecting home devices and sending the information to the InBetween platform. The gateway is based on programmable Linux platform and supports ZigBee, Z-Wave, Wireless M-Bus, WLAN HAN networks, and cellular 2G/3G communication technologies. Besides monitoring, Develco offers different devices able to control energy assets as shown in Figure 11.

Figure 11: Develco control devices

Such devices perform seamless control according to recommendations provided by advanced energy services without disrupting User's normal daily routine. Nevertheless, control actions to be performed will be constantly evaluated against the possible influence on comfort levels of building occupants so that the desired comfort level is maintained. Develco will integrate its Smart Home solution, which consist of smart plugs and smart relays, in the InBetween platform. By deploying smart plugs (Smart Plug Mini - ZigBee based smart plug), the InBetween platform will be capable of switching the connected equipment on or off remotely according either to the User command or an automated action from the platform itself. Besides, smart relays (Smart Relay 30A for remote control of heavy-load equipment and Smart Relay 16A DIN designed for DIN mounting) will grant the InBetween platform wireless control of groups of appliances, or of individual elements.
Finally, in order to ensure interoperability with legacy hardware and software systems OGEMA (Open Gateway Energy Management) will also be deployed. OGEMA is an open source software platform that supports standardized energy management and building automation applications and links them to the customer's loads and generators. The software is designed to be installed on a gateway computer between the customer and the smart grid. Since the platform is manufacturer and hardware independent, OGEMA allows energy flows within customer premises to be optimized with high degree of modularity. It is designed to be easily extendable by means of plugins (i.e. communication drivers) which support different communication protocols and enable translation from and to proprietary data formats (ZigBee, ZWave, Modbus, BACnet, KNX).

5.2 CLOUD-BASED INTEGRATION LAYER

As can be seen in Figure 12, the cloud based integration layer aims to integrate the advanced energy services with the corresponding monitoring and control devices. It ensures the provisioning and connection of sensors, smart meters and actuators to the network and enable collection, processing and exchange of data among the related components. In particular, In Figure 12 we highlight the InfluxData TICK Stack, composed of Telegraf, InfluxDB and Kapacitor. These components can be configured and some tests can be performed in order to check sensor data acquisition, storage and visualisation through a testing GUI (Chronograf). InfluxData TICK stack is an open source platform for managing IoT time-series data at scale, that makes it particularly suitable for InBetween platform development. It allows users to manage metrics, events, and other time-based data.
Time-series databases such as **InfluxDB** are known to deal with specific workloads and requirements. In particular, they need to ingest a large amount of data points per second, to perform real-time queries across these large data sets in a non-blocking manner, and to down-sample and evict high-precision low-value data. Besides they have to optimize data storage to reduce storage costs and to perform complex time-bound queries to extract meaningful insight from the data. The InfluxData platform is a complete solution able to handle all

time series data, from humans, sensors, and machines, seamlessly collecting, storing, visualizing, and turning insight into action.

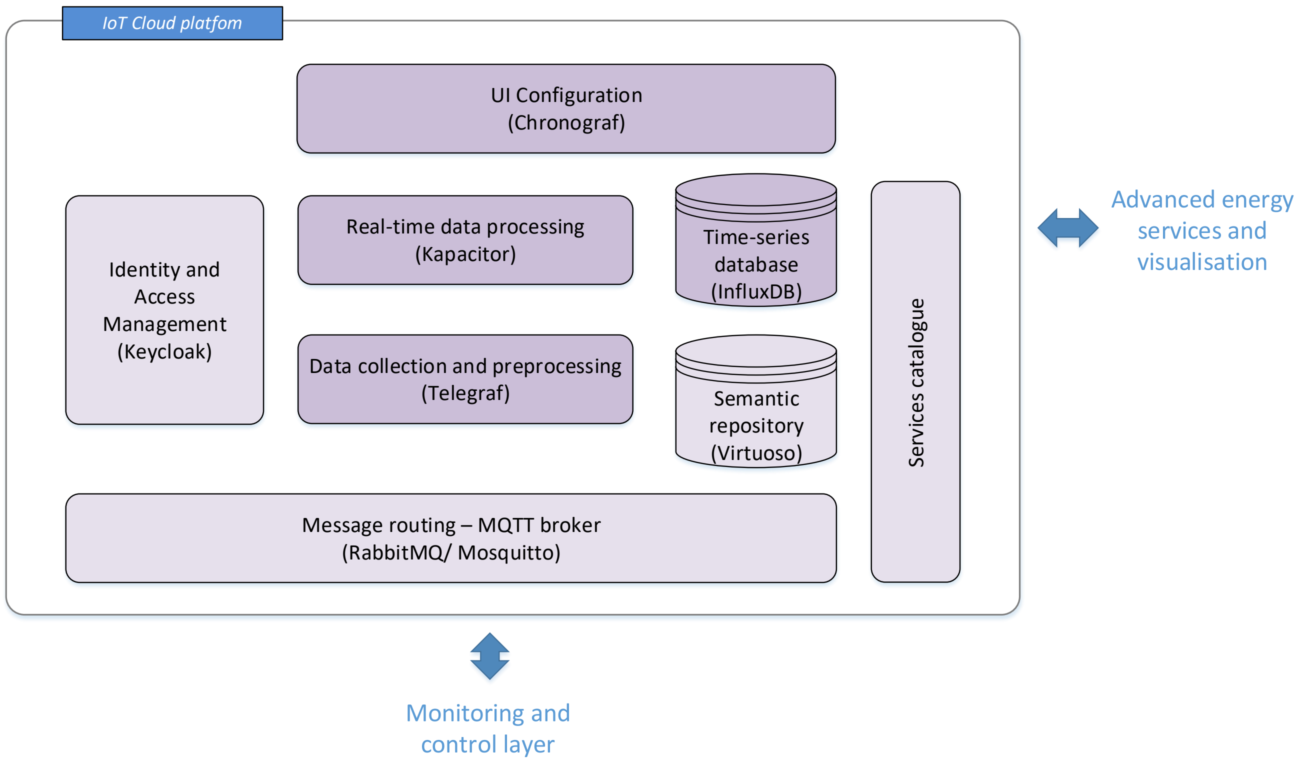


Figure 12: Cloud-based integration layer

The deployment of the different elements of TICK stack 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.

The IoT Cloud Platform is designed as a three-container environment: the **services catalogue**, which describe each service and how to access them, the **resource data model**, which describe how the resources are modelled (see Figure 13 below) and the **data service** which provide a unified way to retrieve data from the IoT Cloud Platform.

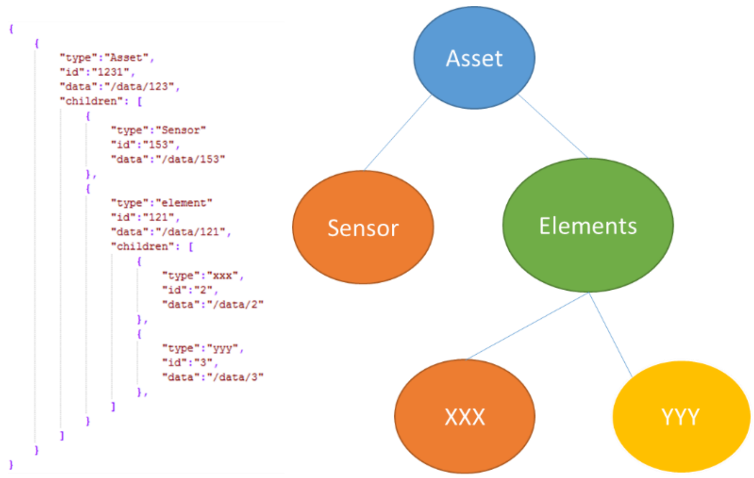


Figure 13: Resource description model

Some of the components of the InBetween Cloud Platform, which have already been defined in a preliminary architecture proposal, are presented in the sequel:

Telegraf is a metric collection service that can collect metrics from a wide array of inputs and write them into a wide array of outputs. It is a plugin-driven server agent for collecting, reporting metrics and events data from sensors, devices, systems, machines, containers, databases, and applications. Telegraf is written in Go which is popular choice these days. Besides, it also has a small enough footprint to run on embedded devices as well as in a cloud system.

Regarding the **Identity and Access Management services**, the security mechanisms are implemented using Keycloak framework (an open source identity and access management solution). At the highest level, this service will provide security models that address two basic criteria: authentication (i.e. who has access) and authorization (i.e. what they can do). Furthermore, the platform will provide a role-based security model and a set of administrative tools, which can be used for its configuration and control.

Figure 14 below (left side) describes the key concepts of the InBetween Platform security model. As can be seen, within this model, the end users (people and external/internal tools) represent the physical actors that use the platform, where the people-type user is a member of an organization (i.e. Tenants, Owner, Manager, etc.). Different actors have different roles that define the functionality that users can perform using a series of access rights.

The implemented Governance flow is shown in Figure 14 below (right side). Secure Socket Layer (SSL) is utilized in order to establish a trusted connection between applications and the security service. The trusted certificates to enable secure connections are provided by *Let's Encrypt* SSL service, which it is a free, automated, and open certificate authority (CA).

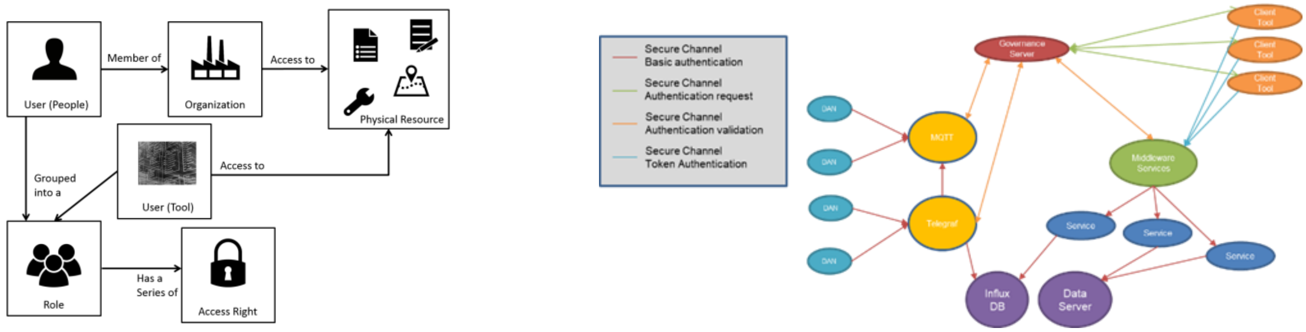


Figure 14: InBetween cloud platform security model

The *"Basic Authentication"* is used by:

- Devices at the monitoring and control layer in order to communicate with message broker, able to validate requests through governance server's services;
- Telegraf to communicate with message broker and Influx database.

On the user side, a tool/client use a TOKEN-based authentication (Authentication request) that sends the token with each request to Cloud service (Token Authentication). Services validate the token (Authentication validation) on governance server, and process only the request that are validated successfully.

The **message exchange** system provides a decoupling of different system functions in the InBetween system and allows efficient communication between these components following a service oriented paradigm. The messaging exchange system describes the ingestion of inbound data from the field (devices at monitoring and control layer and 3rd Party Services) into the cloud-based system. These data not only include observational data from devices (metrics), but also includes alerting and control data. Having a cloud-based messaging system allows for scalable ingestion and egress (from producers and towards consumers), routing depending on the message type or topic, and differentiation of the producer from the consumer. This enables message processing to be performed in (near) real-time or batches if the rest of the system is enabled to do that. Usually, the systems that are chosen as a starting for the message exchange purpose are Apache Kafka[4] and RabbitMq[5].

Apache Kafka is used for building the real-time data pipelines and streaming apps. It is horizontally scalable, fault-tolerant, and can be distributed over a cluster by using multiple broker machines that manage their own partitions of the topic data.

On the other hand, RabbitMQ is a messaging broker that implements AMQP (Advanced Message Queueing Protocol). AMQP defines an application level communication protocol, taking the OSI model as reference. This protocol allows compatible applications to communicate by means of messaging brokers. AMQP is based on TCP (Transmission Control Protocol). As in every other communication protocol, there are sending side and the

[4] http://kafka.apache.org

[5] http://rabbitmq.com

receiving side. AMQP implements the Producer – Consumer pattern, so from the point of view of RabbitMQ, senders are producers and receivers are consumers:

- Producers – Applications, components or other AMQP-compatible pieces that send AMQP messages.
- Consumers – Applications, components or other AMQP-compatible pieces that receive AMQP messages.

RabbitMQ is more flexible than Apache Kafka in terms of routing and in terms of not mandating how it is used on the client side. On the other hand, RabbitMQ was not really designed for large amounts of persistent data in the same way as Kafka, for example.

Beside the aforementioned AMQP protocol, RabbitMQ also supports the MQTT protocol. MQTT provides a low-overhead, simple to implement way to send data, especially from embedded devices. Similarly to AMQP, it stands above TCP/IP, and is intended to be used to allow programs to send and receive messages asynchronously irrespective of their choice of hardware, operating system or programming language. Besides, MQTT is designed to be of use for many small, devices with constrained resources sending small messages on low-bandwidth networks In addition, MQTT's messaging is optimised for the use case of active routing of simultaneously connected publishers and subscribers. Consequently, it is very difficult to use it for classic long-lived message queuing. MQTT supports publish-subscribe messaging to topics with two types of clients being defined:

- Publishers - Send message to the specific topic on the MQTT broker
- Subscribers - Receive messages from the MQTT broker for the topics they are subscribed to

It is important to note that a particular client can be registered at the MQTT broker as a publisher and a subscriber at the same time, depending on the topics where it sends or receives data.

A **triple store** is a framework that provides a mechanism for persistent storage and access of an RDF graph. Triple stores can be divided into 3 broad categories based on the architecture of their implementation:

1) in-memory,
2) native,
3) non-memory non-native.

In-memory triple stores store the RDF graph in the main memory. The approach of storing everything in-memory can be used to perform certain operations like caching data and performing inference. Most of the in-memory stores have efficient reasoners available and can help solve the problem of performing inference in persistent RDF stores, which otherwise can be very difficult to perform. On the contrary, the in-memory triple stores do not generally provide high performance for storing and managing extremely large volumes of data. This type of functionality is instead provided by native triple stores which provide persistent storage with their own implementation of the databases. The third category of triple stores, the non-memory and non-native stores are configured to run on third party relational databases like MySQL, PostgreSQL, and Oracle databases.

The Virtuoso Universal Server is a multi-model data server chosen for this project. It is a native triple store and it provides command line loaders and a connection API. Moreover, it supports SPARQL, web server to perform SPARQL queries and supports uploading of data over HTTP. It is developed by OpenLink Software and it is available in both open source and commercial licenses.

Finally, the InBetween IoT Cloud Platform will also enable the access to data offered by 3rd party services. The integration of these data will be delegated to the **External Services Interface.** For each external service a custom application will be developed with the aim to query the services (e.g. Weather services, Energy market), retrieve, translate and push the data into the InBetween platform. The behaviour and the workflow of this module is similar to a gateway deployed in the field. This approach makes the platform extremely flexible. In particular, once the data is stored inside the InBetween cloud platform, it can be processed in the same way as the data coming from the devices deployed at the monitoring and control layer.

5.3 ADVANCED ENERGY SERVICES AND VISUALISATION LAYER

In this section, we present the core value provided by the InBetween platform that comprise advanced energy services and the corresponding visualisation layer (see Figure 15).

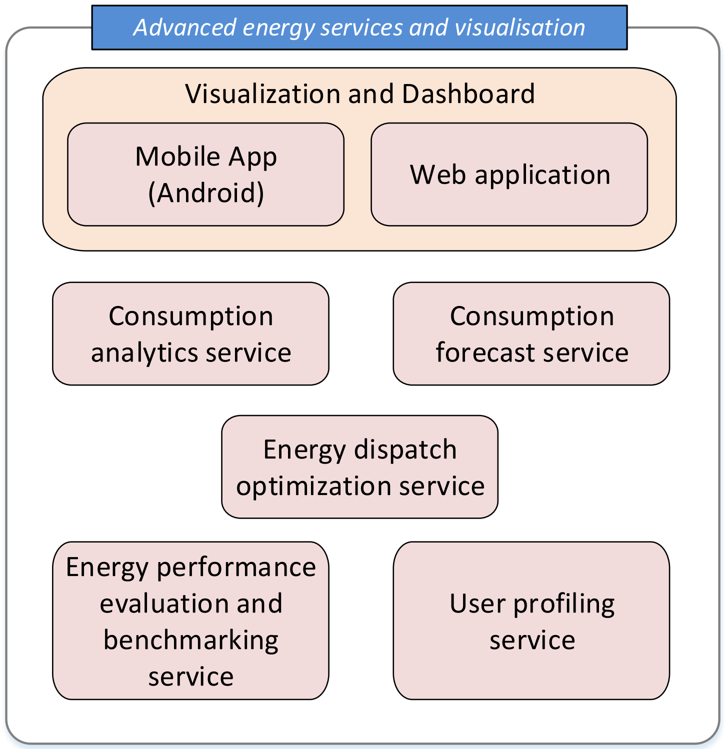


Figure 15: Advanced energy services and visualisation

The advanced energy services consist of number of interrelated software modules that work on top of data that are stored in cloud based layer, extracting valuable information and providing user recommendations and control actions aiming to enable 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.

5.3.1 Consumption analytics service

One of the purposes of Consumption analytics service (CAS) is to enable disaggregation of loads monitored through a single metering point and help finding the correlation between cumulative energy consumption and individual consumption yielded by a particular device/appliance. In case of a household, this single metering point may refer to a location of a smart meter (or conventional one) measuring the entire household consumption or, in case of a non-residential building, it may refer to only a part of a building (e.g. building floor) for which aggregated monitoring of consumption is available. In other words, the overall ambition is to use existing analytics methods and tools to reach information about individual device/appliance consumption without deployment of additional monitoring.

The CAS will therefore be leveraged on the well-known process of Non-Intrusive Load Monitoring (NILM) which is based on constant monitoring and analysis of changes in the voltage and current levels of power consumed at a designated, aggregated, level (e.g. point where smart meter is located) and aims to deduce what devices/appliances are used in a specific moment in time as well as to estimate their individual energy consumption. For this purpose, a set of automated/machine learning algorithms and techniques (e.g. support vector machine, ANN) will be employed. Moreover, CAS will follow a flexible development approach enabling its application in both residential and non-residential use cases which entails its flexibility in terms of devices/appliance to be supported, technical properties of existing energy monitoring infrastructure (sampling frequency, spatial resolution etc.), availability of so called labelled data which enable supervised learning, different metrics used for evaluation of performance etc.

In addition, CAS will provide the detection of potentially wasteful user behaviours based on heuristic algorithms that will deal with raw collected data as well as the processed ones (e.g. NILM). These algorithms will be able to detect situations where e.g. a window is open while the heater or air-conditioner are working, and to send a suggestion to the user, so that the energy and cost wastes are prevented in a timely manner.

In the following table, we provide the list of inputs that are commonly used in NILM for the training and validation phase, as well as the data used for the identification of potentially wasteful practices.

The inputs to disaggregation service are provided in Table 3 below:

Table 3: Inputs to Consumption analytics service

INPUTS - Consumption analytics service	
Data	**Description**
Aggregate power consumption	The aggregated power consumption (active and/or reactive power) is disaggregated by employing the already trained machine learning models. Besides, when aggregate power consumption is part of the training set (along with the individual power consumption) it is also used for training of the machine learning models.
Individual power consumption	Individual power consumption for each appliance is used in the phase where machine learning models are trained.
Labelled data on appliance activity	The activity of individual appliances over time is labelled so that machine learning algorithms can train their models for CAS.
Apartment profile model	The physical model of the apartment will be correlated with the energy consumption.
Environment monitoring	Environmental data (e.g. temperature, humidity, presence) will be used in heuristic algorithms that aim to detect potential energy wastes (e.g. the window is open while the air-conditioning is working)
Gas/water/hot water metering	It is important to consider other available energy carriers in the overall energy consumption.
Weather data/weather forecast	Current weather data and the weather forecast (e.g. temperature, humidity, solar radiation, and wind direction/speed) are correlated with the energy consumption data in order to identify potentially wasteful behaviours.

Calendar information	It is important to take into account the information on holidays and bridge days when the user may be out of home for longer periods of time when analysing the energy consumption.

Once the models have been trained, the disaggregation service takes the current aggregate power consumption as an input in order to produce the result. The resulting outputs of NILM process are given in Table 4 below:

Table 4: Outputs from Consumption analytics service

OUTPUTS - Consumption analytics service	
Data	**Description**
Appliance activity labels	CAS process provides the information that describes which appliances are being used during given time intervals.
Individual power consumption	Disaggregated individual power consumptions for each appliance are provided as one of the outputs of CAS. These data will be further used by consumption forecast and energy dispatch optimization services.
Detected events and anomalies	The consumption analytics service aims to detect potentially wasteful energy consumption practices and anomalies in order to inform the end users so that they can steer their behaviour towards more energy efficient lifestyle.

5.3.2 Consumption forecast service

Consumption forecast service (CFS) aims to provide the detailed analysis of consumption data and the prediction of the energy demand. The availability of a Consumption Forecast, at operation time, represents a key input to the Energy Dispatch Optimization service. Besides, it also helps operators to determine which configuration of machinery and associated set points are necessary to meet the desired comfort levels, at the lowest operational cost. By using CFS, Consumption data gathered either from CAS or measured directly on the particular appliance will be further processed by algorithms based on knowledge discovery in databases (KDD) and on predictive analytics (PA). Besides, additional semantic information such as building type and constructional data, as well as previous consumption patterns, weather, user behaviour will be exploited with the aim of improving the accuracy of the prediction. Finally, as a result, the Consumption forecast service will provide the energy demand curve for specific load (household, building, etc.) during the given time frame.

In Table 5 and Table 6 , we provide a list of inputs and output from the consumption forecast service:

Table 5: Inputs to Consumption forecast service

INPUTS - Consumption forecast service	
Data	**Description**
Disaggregated consumption data	Power consumption of individual appliances (measured directly or provided by CAS) will be taken into account for the computation of the predicted power

	consumption.
Apartment profile model	The physical model of the apartment will be considered for the prediction of overall power consumption.
Environment monitoring	Historical information of environmental data (e.g. temperature, humidity, presence) will be used as one of the inputs to predict the power consumption for other days with similar conditions.
Gas/water/hot water metering	Historical data on the consumption of all available energy carriers will be taken into consideration for the prediction of the overall and individual energy consumption.
Weather data/weather forecast	Weather forecast (e.g. temperature, humidity, solar radiation, wind direction/speed) will be taken as an input for the prediction of energy consumption by correlating the consumption with previous days with similar weather conditions.
Calendar information	The information of holidays and bridge days will be used for the prediction of energy consumption by correlating the consumption with other similar days.

Table 6: Outputs from Consumption forecast service

OUTPUTS - Consumption forecast service	
Data	**Description**
Long and short term energy consumption prediction	The consumption forecast service will provide the prediction of the energy consumption in the short and long term based on the all above mentioned data inputs.

5.3.3 User profiling service

User profiling service (UPS) aims to identify user profiles based on the monitored energy consumption, building physical properties, occupancy, environmental data, weather conditions, etc. It employs data driven models, trained using the supplied monitoring data, and building/apartment/user metadata, to create user profiles, that can further help in the process of consumption forecasting and anomaly detection. The profiling service can be configured to automatically use all, some, or different combinations of classifiers for model generation depending on their availability. The identified profiles will be further used as an input to performance benchmarking and micro-optimization services.

In two tables below, we provide a list of possible inputs and outputs from the user profiling service:

Table 7: Inputs to User profiling service

INPUTS - User profiling service	
Data	**Description**
Location metadata	Different metadata related to the geographical location of the building will be taken into account for the apartment/user profiling.
Building metadata	Metadata related to the building construction details, insulation, environment, building orientation.
Apartment and appliance metadata	Metadata related to apartment size, composition, exposure, glazing, heating/cooling/ventilation details, lights, and other available appliances.
Occupants metadata	Metadata regarding the number of people, their age, education, presence pattern, and the corresponding energy-related behaviour.
Environment monitoring	Environmental parameters such as temperature, humidity, presence, as well as energy/water/hot water metering data.
Disaggregated consumption data	Disaggregated consumption data, either directly measured or obtained from the consumption analytic services.
Weather data/weather forecast	Current weather and weather forecast parameters: temperature, humidity, solar radiation, wind direction/speed, etc.
Calendar information	The information regarding day types (e.g. holidays/bridge days).

Table 8: Outputs from User profiling service

OUTPUTS - User profiling service	
Data	**Description**
Apartment profile model	User profiling service provides categorizing of each user/apartment into groups based on selected criteria (energy consumption, water consumption, hot water consumption, etc.).

5.3.4 Energy dispatch optimization service

Energy dispatch optimization service (EDOS) aims to provide optimal energy dispatch strategy in a complex energy environment involving different conventional and renewable energy sources, various electrical and thermal energy storages and dynamic energy pricing schemes under user-defined objectives. In particular, EDOS will serve under two different use cases:

- Energy infrastructure planning - this first use case represents an offline scenario focused on selection and sizing of different energy assets in a future, planned, energy infrastructure. It aims to recommend optimal power/capacity of each asset and their corresponding interconnection based on typical (historical) energy demand, renewable resource potential and applicable pricing framework with respect to user defined selection criteria ranging from investment costs minimization, emission minimization, energy losses minimization etc.
- Optimal operation of existing energy infrastructure - 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.

EDOS is configured for the specific deployment instance taking into account different types of energies that are available, energy conversion options, and other relevant parameters. It employs energy demand predictions data provided by Consumption forecast service in order to calculate the optimal energy consumption patterns that can be further translated into control actions and recommendations for users on how to optimally use both energy resources and corresponding assets. Besides, the actual energy consumption provided by the InBetween monitoring platform along with information on on-site energy production and applicable pricing scheme are employed by Energy dispatch optimization service in order to provide optimal energy supply mix and scheduling of available energy conversion assets. The output of this service will be directly communicated to the end user via dedicated user interfaces such as in-home display, smartphone, and desktop computer.

Following is a list of required inputs and delivered outputs from EDOS distinguished by the two aforementioned use cases.

<u>Energy infrastructure planning</u>

This subsection aims to list the necessary EDOS inputs for the use case of energy infrastructure planning. As described, the objective of this use case is to deliver an optimal energy infrastructure topology and sizing/dimensions of each energy assets. The following table suggests the categories of required inputs which are evaluated at each time step of the preformed optimization. In other words, each variable from the table will be represented as time series for the time interval of interest.

Table 9: Inputs to Energy dispatch optimization service (planning)

INPUTS - EDOS for Energy infrastructure planning	
Data	**Description**
Typical Loads	In order to design optimal system configuration, the typical energy consumption is required. Therefore, any historical data gathered through existing monitoring platforms, BMSs, energy bills or other means are required.

Dynamic energy pricing	Unit price of energy is required for all available energy carriers. In case of a variable energy pricing, further information on applicable energy zones (quantity discrimination) and time periods (timing discrimination) for each energy carrier should be supplied.
Renewable energy generation potential	Information on renewable energy generation potential from different sources should be supplied. In order to evaluate and consider renewable energy harvesting potential for particular location, a set of historical meteorological data is required.
Energy storage	Set of various types of storage systems that can be taken into account according to existing technical/environmental/safety conditions.
Available energy conversion elements	In order to design an optimal system configuration, a pool of considered conversion elements has to be defined.
Existing energy carriers	Set of available energy carriers offered by existing nearby energy infrastructures.
Optimization objectives	Set of various technical, economic, environmental and societal objectives which will steer the decision making process.

This section elaborates the model outputs in the case of optimal system selection. The selection of optimal system encompasses not only the system configuration, i.e. system topology which indicates the set of modules included, but also the sizing of each of module. More precisely, that includes the capacity and/or throughput of all the modules taking part in the energy dispatch. Therefore, the model outputs are distinguished in the two main categories and described as following:

Table 10: Outputs from Energy dispatch optimization service (planning)

OUTPUTS - EDOS for Energy infrastructure planning	
Data	**Description**
Set of conversion elements and their capacities	Taking into consideration existing energy supply infrastructures, meteorological potential of the desired location and range of various technical limitations, an optimal system topology is suggested, thus a complete list and layout of converters between various energy carriers is provided. Moreover,

	a required capacity/energy throughput of each converter module is calculated in order to provide the means for optimal energy dispatch.
Set of storages and their capacities	In most cases, where variable pricing is present together with renewable energy production, the use of storage modules can be highly beneficial for decreasing the overall operation costs. Moreover, in case of island operation the use of storage modules is inevitable when trying to avoiding the loss of power supply. Therefore, a set of storage modules, corresponding different energy carriers, is provided as output of optimization.

The following table reveals the mentioned outputs in more details. It should be taken into consideration though that in this case, i.e. optimal system selection, the output set is derived as a result of simulation for the total project lifetime, unlike in the case of optimal system operation where the output set is derived at each time step.

Optimal operation of existing energy infrastructure

This section reveals the necessary model inputs in the case of delivering optimal system operation. Model inputs are divided in the following categories together with additional implicitly required information:

Table 11: Inputs to Energy dispatch optimization service (operation)

INPUTS - EDOS for Optimal operation of existing energy infrastructure	
Data	**Description**
Loads forecast	In order to achieve optimal system operation, a forecast of energy consumption is required. This requires additional static (e.g. type of building, number of floors, total floor area, conditioned area etc.) and dynamic (number of people, ambient temperature, comfort levels, luminosity etc.) parameters.
Energy prices forecast	Considering existing variable trifling in most cases, a forecast of energy prices per carrier and per both quantity and timing of each carrier contribution is required.
Renewable energy generation forecast	In order to evaluate and consider renewable energy potential of particular location, a forecast of the set of meteorological data is required.
Energy storage status	Encompasses a set status parameters of existing energy storage systems that are taken into account to evaluate the potential of system to store or supply desired amount of energy.

Existing energy conversion elements	Defines a pool of conversion elements that can be actively involved in the system operation optimization.
Existing energy carriers	Set of available energy carriers existing at the entity level.
Optimization objectives	Set of various objectives which will steer the decision making process.

The following table suggests the required inputs which are evaluated at each control decision interval. This means that each variable from the table will actually be represented as an array of values for the given forecast time interval.

This section elaborates the model outputs in the case of optimal system operation. Following a given objective function, assembled from different optimization criteria, an output set is derived at each time step and contains the information about contribution of each energy carrier, and the corresponding storage systems, for fulfilment of the energy demand. More precisely, the model outputs in this scenario can be divided into three main categories and described as following:

Table 12: Outputs from Energy dispatch optimization service (operation)

OUTPUTS - EDOS for Optimal operation of existing energy infrastructure	
Data	**Description**
Optimization of each energy carrier contribution	Taking into consideration existing energy supply infrastructures, dynamical energy pricing, renewable energy potential of the desired location and range of various technical limitations, an optimal operation strategy is accomplished with the delivery of exact contribution from each energy carrier. More precisely, the output represents both overall energy import of the infrastructure as well as its breakdown for each energy carrier.
Optimization of dispatch factors	Since the general model of the energy infrastructure allows for the conversion from each supply energy carrier to each demand energy carrier, it is necessary to establish an energy dispatch matrix which will hold the information about the particular energy carrier dispatch.
Optimization of storage levels	In most cases, where variable pricing is present together with renewable energy production, the use of storage modules can be highly beneficial for decreasing the overall operation costs. Moreover, in case of island operation the use of storage modules is inevitable when trying to avoiding the loss of power supply. Therefore, taking into consideration different forecast

	"windows" (namely the time intervals), both for renewable supply and demand, an optimization of the storage system operation is performed. This is done through the delivery of the list of set points for the state of charge of each storage module at particular time step.

The following table reveals the outputs which are offered at each control decision interval. This means that each variable from the table should actually be represented as an array of values for the given forecast time interval.

5.3.5 Energy performance evaluation and benchmarking service

Energy performance evaluation and benchmarking service (EPEBS) represents one of the very core services provided by the InBetween platform which aims to contribute to a greater end user engagement related to energy saving actions and focuses on raising the awareness of people about how much energy they consume compared to similar consumers. To do so, EPEBS will first deliver an estimation of overall end user energy performance calculated for each individual household or commercial/public building and, secondly, will use this performance to provide self-comparison and benchmarking against different similar users, thus generating a positive social pressure capable of inducing behavioural changes in this regard.

Having selected an approach which compares end user's 'energy performance' instead of actual 'energy consumption' allows for having a fair benchmarking which sets realistic and achievable goals for end user rather than unrealistic ones that discourage further engagement and reduce the effectiveness of the technology over time.

EPEBS will employ data driven algorithms that take energy consumption, provided by the InBetween monitoring components, as main input together with a range of contextual metadata, such as climate conditions, number of occupants, building materials etc. Based on this data, the service will perform normalization of actual energy consumption with corresponding user specific data in order to calculate end user energy performance.

The following is a list of variables that could serve as potential inputs to the EPEBS to deliver its main output, the energy performance indicator. However, although the provided list indeed summarizes various aspects that do influence one's energy consumption, the definitive list of inputs will only be available following to a careful examination of available datasets. In other words, during the development process a regression analysis will be employed to evaluate influence of each of the aforementioned variables. Being a statistical method for predicting the behaviour of a dependent variable based on the independent variables, it will point out to the most relevant variables and discard those that only dilute the search space.

Table 13: Inputs to Energy performance and benchmarking service

INPUTS - Energy performance evaluation and benchmarking service		
Data		**Description**
Time/Date	- Time/date - Working days - Weekends - Holidays	Actual timing and date of the energy consumption will be taken into account especially considering whether it is a working, non-working day or holiday.

Energy consumption	- Electricity - Gas	Energy consumption is the key input and will consider all available energy carriers (e.g. electricity, gas). Since it will represent dependent variable in the regression analysis, the provided baseline data set should cover at least one whole year period so as to account for the entire climate cycle.
Building data	- Total area - Conditioned area - Construction material (thermal properties) - Sun exposure - Orientation	Building data entail necessary parameters to cover specific thermal aspects of different part of the building. Apart from basic parameters such as conditioned area, it will also capture building physics parameters such as thermal conductivity and resistivity as well as level of thermal gains from ambient conditions to evaluate their influence in the overall consumption.
Climate data	- HDD/CDD - Ambient temperature - Solar insolation - Wind velocity	Climate data arguably represents the most influential parameter in consumption estimation. Ideally, time-series measurements of various ambient parameters, such as temperature, solar insolation and wind velocity, will be employed or their cumulative indicators (heating degree days and cooling degree days) will be used.
End user data	- Number of inhabitants - Age - Occupancy	End user data entail information about both static parameters, such as number of inhabitants and their age structure, and dynamic one like real-time occupancy.

Table 14: Outputs from Energy performance and benchmarking service

OUTPUTS - Energy performance evaluation and benchmarking service	
Data	**Description**
Energy performance indicator	The indicator represents a single dimensionless number which measures end user energy performance based on normalization of energy consumption against a range of contextual parameters, such as climate conditions, building construction material, number of inhabitants etc.
Energy performance ranking	The ranking provides a relative order of 'similar' end users which may form a virtual or physical community.

5.3.6 Web and Mobile application

The aforementioned advanced energy services operate in the background performing real time and history data analysis. In order to communicate the results of these services to the User in a comprehensive, meaningful and engaging manner, a visualisation layer will be deployed. Depending on the User type, InBetween platform envisions two different visualisation interfaces:

Web application will be mainly used by building/energy managers (see Figure 16). It will be built upon the web interface that is part of WiTMo platform provided by consortium partner Acciona. WiTMo (Wireless inTelligent Monitoring) provides remote data visualisation and analysis as well as administration functionalities for any kind of monitoring installation composed of heterogeneous IoT devices (sensors, actuators, local data acquisition systems, etc.). Since InBetween does not in principle plan to integrate this hardware layer within the project platform, as this will be mainly implemented with Develco products (sensors and actuators), in the sequel we will focus exclusively on the visualisation layer of WiTMo. Its main functionalities comprise the following:

- Authorization management module allows system administrator to manage user accounts and define and assign different resource access permissions depending on the user role.
- Dashboard: consists of visualisation widgets configured to show the current value of a parameter or its evolution over time allowing a user to get a quick overview of system status, important KPIs, etc.
- Maps: provides GIS based overview of different monitoring points and their status
- Charts: provide visualisation and analysis of the data collected by InBetween platform. Charts could be exported to CSV, JPG, or PDF file format for further analysis.

WiTMo dashboard | Google maps visualisation | Charts comparing different variables

Figure 16: WiTMo platform visualisation interface

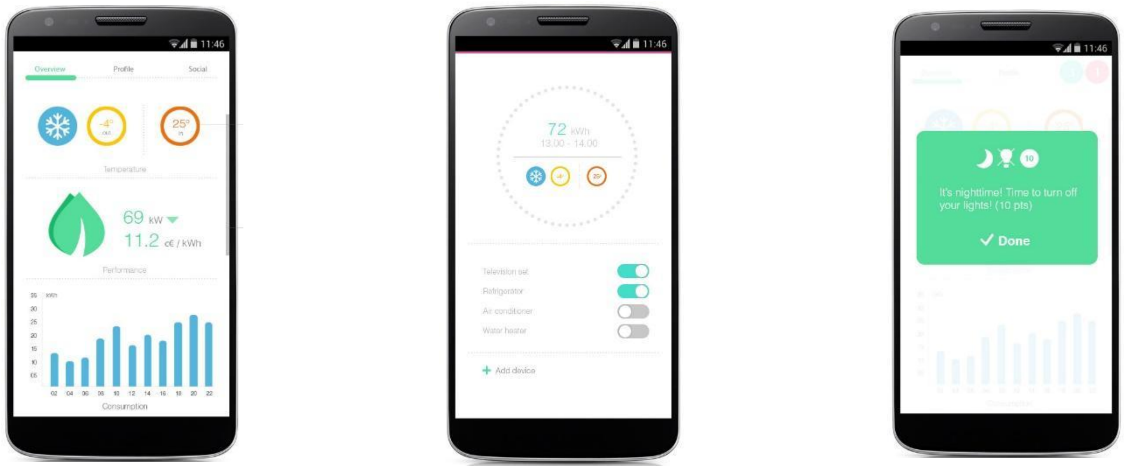
The web application will present different kinds of collected and processed data, as shown in Table 15.

Table 15: Outputs from Web application for Building/Energy managers

OUTPUTS - Web application for Building/Energy managers	
Data	**Description**
Energy consumption	Aggregate and individual energy consumption (directly measured or computed by the Consumption analytic service). The user will be able to select the time period for which the data will be presented, the type of energy carrier (electrical, thermal, gas), overlay energy consumptions of different monitoring areas (households, rooms, etc.) on the same figure or even correlate the energy consumption with other relevant parameters (temperature, weather conditions,

	energy pricing, etc.).
Environmental data	Indoor and outdoor environmental parameters (measured or obtained by an external weather service) such as temperature, humidity, and solar irradiance will be presented in a graphically appealing manner, with the possibility to select the time period, the subset of data to be shown, select the unit of measurement, etc.
Key Performance Indicators (KPIs)	In addition to raw data collected by the monitoring layer and stored in the InBetween cloud platform, the web application will also present a number of KPIs that will be computed such as: energy consumption by person (total, heating, lighting), CO_2 emissions, energy savings, peak load indicators, temperature discomfort indicator, and many others that could provide even more insights into user behaviour regarding energy efficiency.
Optimal scheduling of energy assets	The web application will also present the optimal scheduling of energy asset consumption computed by the Energy dispatch optimization service. Graphical as well as textual information will be presented in order to help building/energy manager to perform different control actions on the energy assets in an automatic or semi-automatic manner.

Mobile application is primarily aimed at residential building users, as shown in Figure 17. Based on the collected data, consumption analytic and behavioural pattern recognition, the InBetween platform will be able to learn user energy consumption habits and provide recommendations to steer their behaviour towards a more energy efficient lifestyle. The mobile app will act as the main interface from the InBetween platform towards the User by delivering personalized experience with energy saving recommendations that are adjusted to that particular User needs. Besides providing information on energy consumption and personalized recommendations, the mobile application will provide user benchmarking against herself and other similar user in its neighbourhood by effectively employing positive social pressure.



Mobile app dashboard with different widgets showing current monitored parameters such as: temperature, power consumption, user performance, etc.	Overall and per-device energy consumption	Pop-up recommendation with an aim to increase user awareness and engagement.

Figure 17: Mobile application

The mobile application will provide different types of data aimed to raise user's awareness about energy conservation measures as shown in Table 16.

Table 16: Outputs from Mobile application for Building occupant end users

OUTPUTS - Mobile application for Building occupant end users	
Data	**Description**
Monitoring data	The mobile application will present the current and historical data collected by the InBetween platform, such as: aggregated and individual power consumption of different home appliances, energy pricing, environmental parameters (temperature, humidity, air pressure, etc.) made available by external services or by the InBetween monitoring layer. In such a way, the users will be able to find more details about their energy consumption, and therefore to make better decisions regarding the usage of their energy appliances.
Energy and cost saving recommendations	Energy and cost saving recommendations are envisioned to be presented in a user friendly and non-disruptive manner in order to motivate a user to change her bad habits and reduce energy wastes.
Benchmarking and user engagement	The users will be benchmarked with other similar user in their neighbourhood, having in mind not only energy consumption, by including other parameters like weather conditions, building materials, and number of occupants, in order to provide more fair comparison. The result of this benchmark will be shown inside the mobile app, with the aim of producing positive social pressure and steering user's behaviour to be more energy efficient.

5.4 INTEGRATION OF WITMO WITHIN INBETWEEN ARCHITECTURE

As it has been described above, the purpose of the use of WiTMo within the InBetween platform is to provide building/facility/energy managers with a tool for visualisation and analysis of monitored data in public buildings. It is not foreseen to use the tool for presenting data directly to end users (e.g. tenants in social dwellings), as these will be able to receive more immediate and meaningful information through a mobile app.

Besides, it is not foreseen to use the complete WiTMo "software stack". The bottom layers (monitoring hardware, gateway) will be implemented with hardware/software components provided by other project partners. Therefore, from all the modules that WiTMo provides (monitoring hardware layer, data collection and transmission layer, web interface layer), only the ones depicted below (and maybe not all of them) will be integrated within InBetween platform:

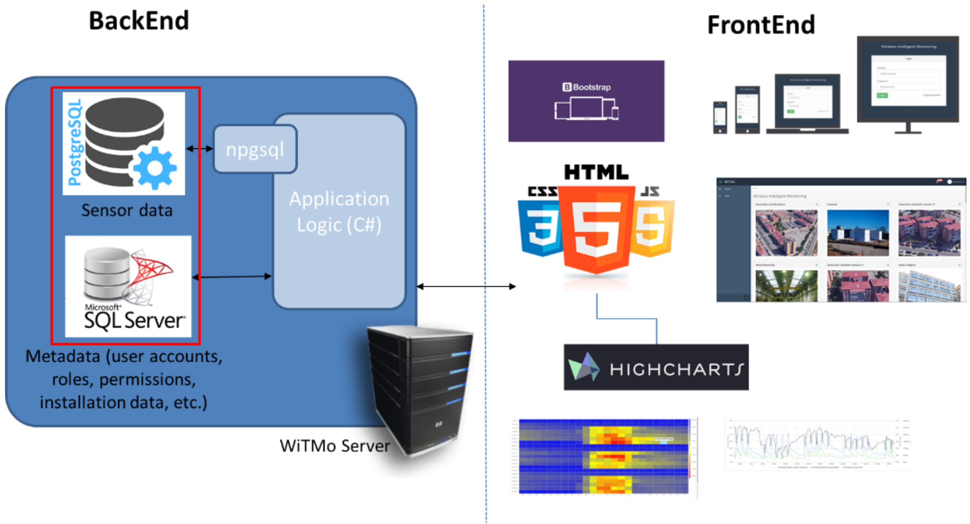


Figure 18: Potential WiTMo modules to be integrated with InBetween platform

As it can be seen in Figure 18 above, WiTMo databases are marked with a red rectangle because it could be the case that they are not integrated with InBetween platform. This will be the first main choice that will need to be done within WP2, and depending on it, the following options can be considered:

- Option keeping the usage of the WiTMo databases: if WiTMo databases are included in the InBetween architecture, the rest of WiTMo modules will hardly need any other adaptation (unless some additional interface functionality is needed and finally implemented). Data from the pilots would need to be retrieved from the InfluxDB database of the InBetween cloud platform. This would have to be done periodically in order to maintain WiTMo databases synchronized with InfluxDB. Possible methods to be considered are:
    - Direct queries to InfluxDB.
    - Using Kapacitor as an intermediate module that would enable data extraction from InfluxDB.
    - Using specific web services that could be implemented in InBetween platform for communicating with the InBetween applications.
- Option doing without WiTMo databases: if it is decided to do without WiTMo databases, then it would be needed to perform adaptations in the application containing the business and access to data logic (implemented in C#), so that it retrieves data directly from InBetween cloud platform instead of from its own databases. In this case, instead of periodical synchronization with InfluxDB, data could be extracted on demand following the requests done by interface users from the front-end. The possible methods to extract the data would be similar to the ones described above (direct queries, use of Kapacitor, specific web services).

Final decision about the methods to be used will be done based on multiple criteria, e.g.:

- Comparison of the potential workload on the InBetween platform for data extraction using the different methods.
- Complexity of changes that would be needed in WiTMo business and data access logic if WiTMo databases were not used.
- High level decisions in the architecture of the InBetween cloud platform that could propose homogenous methods for accessing the data from all external applications (e.g. mobile apps, optimization service, etc.).

6 INBETWEEN PLATFORM REQUIREMENTS

In this Section, we report the list of InBetween's ICT platform requirements derived from the analysis of information collected from demonstration sites through InBetween questionnaire as well as from envisioned platform use cases and preliminary platform architecture. Questionnaire answers have been analysed and translated into formal verifiable inputs for project work packages according to the information processing schema depicted in Figure 19.

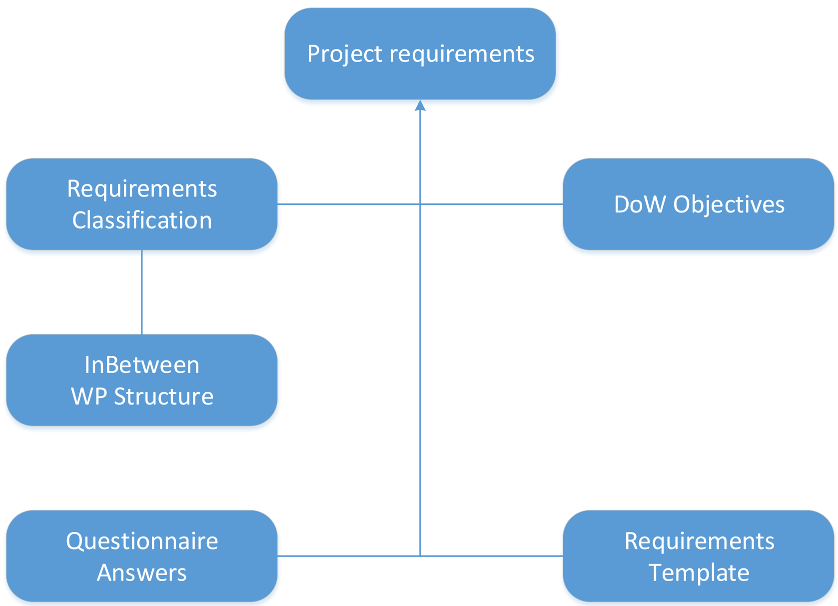


Figure 19 Inputs for Project Requirements definition

The definition of platform requirements follows a standard system-software requirement template. The main objective of such template is both to standardize the way design information is represented within the InBetween project and to enable full traceability as well as the allocation of functionalities onto model logical subsystems.

More specifically, the schematic organization of platform features will provide identifiable, unique and verifiable inputs for development and integration activities encompassed by WP2 and WP4.

The classification of information into standard categories followed the schema reported in the listing below:

- **[ID]:** Short Requirements Identifier
- **[Headline]:** Short description of requirements
- **[Req Description]:** Full description of the requirements
- **[Classification]:** WP/Task identifier accountable for the requirement
- **[Type]:** Task or other sub-activity accountable for the requirement alternatively can be category, i.e. functional/performance/other/...
- **[Rationale]:** Purpose of the requirements definition, can be a sub-activity of the Work Package, DoW (Description of Work) reference, a verbose motivation, etc.
- **[Acceptance criteria]:** Method/technique to be employed for requirement demonstration/validation
- **[Priority Level]:** Classification of relevance, to be taken into account for first and second phase of a task

6.1 FUNCTIONAL REQUIREMENTS

[ID]	[Headline]	[Req. Description]	[Classification]	[Type]	[Rationale]	[Acceptance criteria]	[Priority Level]
FUNC_REQ_01	Message Broker for interconnectivity	Interconnectivity architecture of InBetween shall be based on a integration message brokering layer	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	Message broker allows information to flow between disparate applications across multiple hardware and software platforms. In InBetween, multiple implementation of a single application layer are expected (i.e. multiple gateways) and message broker middleware provides communication with loose component coupling.	Design validation	1
FUNC_REQ_02	Home automation gateway	InBetween platform shall support standard protocols for communication with home automation gateways	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween shall support standard communication protocols for communication with home automation gateways (HTTP Rest, Message broker, etc.)	Design validation/Demonstration	1
FUNC_REQ_03	Open source IoT platform	InBetween system shall be based on an open source IoT platform for	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween cloud platform shall be based on the open source cloud platform that supports efficient time-series data store and real-time data processing	Design validation/Demonstration	1

		data processing and data storage			(e.g. InfluxData, Eclipse Kapua, Eclipse OM2M)		
FUNC_REQ_04	External Meteo. service interface	InBetween platform shall support interface to external weather services	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween cloud platform shall provide interface to open and free-of-charge external weather service APIs (e.g. openWeatherApi.org, accuWeather.com, etc.)	Design validation/Demonstration	2
FUNC_REQ_05	Authentication and authorization	InBetween platform shall support centralized authentication and resource access authorization management	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall use open source authentication management system (e.g. KeyCloak, DACS)	Design validation/Demonstration	1
FUNC_REQ_06	User roles	InBetween platform shall support different user roles	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall support definition of different user roles and the corresponding authorization rules based on those roles	Design validation/Demonstration	1
FUNC_REQ_07	User accounts management	InBetween platform shall support management of	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall support CRUD operation related to account management.	Design validation/Demonstration	1

FUNC_REQ_08	User authentication types	InBetween shall support different procedures for authentication	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall different types of user authentication (e.g. token based, username/password, etc.)	Design validation/Demonstration	2
FUNC_REQ_09	Cloud platform configuration	InBetween cloud platform shall support intuitive and user friendly configuration	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall be configured by using intuitive user interface supporting configuration of sensors, equipment, as well as advanced energy services and visualisation layer.	Design validation/Demonstration	2
FUNC_REQ_10	Real time alerts	InBetween platform shall support real-time processing of monitored data	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall support real-time processing of monitored and external data creating alerts when anomaly in data has been detected (e.g. consumption unexpectedly rises, energy price changes, etc.)	Design validation/Demonstration	1
FUNC_REQ_11	Time-series data storage	InBetween platform shall support open source time-series storage	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall support time-series data storage (e.g. Influx Database), suitable for persistent storage of monitored and external data, their optimal retrieval, and pre-processing.	Design validation/Demonstration	1
FUNC_REQ_12	Semantic repository	InBetween platform shall support open source	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall support open source semantic repository (e.g. Virtuoso) for optimum storage and retrieval of linked data associated to	Design validation/Demonstration	1

		semantic repository			different resources identified (e.g. Building parameters, sensor metadata, etc.)		
FUNC_REQ_13	Service catalogue	InBetween shall support a service catalogue	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall support service catalogue providing necessary information regarding available services (endpoint, protocol, availability, parameters, etc.)	Design validation/Demonstration	1
FUNC_REQ_14	Analytics and prediction	InBetween platform shall support prediction of energy consumption	WP2-InBetween cloud-based ICT platform	T2.4 Consumption Data Analytics and Prediction	InBetween shall support energy consumption prediction by employing historical consumption data, user behaviour, weather data and processing them by algorithms based on e.g. knowledge discovery in databases (KDD) and on predictive analytics (PA).	Design validation/Demonstration	1
FUNC_REQ_15	Single-point energy consumption monitoring	InBetween platform shall support disaggregation of energy consumption from the aggregate measurement	WP2-InBetween cloud-based ICT platform	T2.4 Consumption Data Analytics and Prediction	InBetween shall use Non-Intrusive Load Monitoring algorithm (e.g. based on Machine learning) to disaggregate total energy consumption and identify which appliances were working in a particular time instant with the corresponding power consumption	Design validation/Demonstration	2
FUNC_REQ_16	Comprehensive energy consumption monitoring	InBetween shall support monitoring of energy consumption	WP2-InBetween cloud-based ICT platform	T2.4 Consumption Data Analytics and Prediction	InBetween platform shall support the monitoring of consumption of different appliances directly in order to be	Design validation/Demonstration	1

		by employing smart meters directly connected to a particular appliance			able to optimize and schedule their consumption		
FUNC_REQ_17	Direct control of appliances	InBetween shall support the direct control of appliance (on/off state, set temperature point, etc.)	WP2- InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall support the automatic control of appliances upon user authorization.	Design validation/Demonstration	1
FUNC_REQ_18	Performance benchmarking	InBetween platform shall support the benchmarking of user energy efficient behaviour	WP2- InBetween cloud-based ICT platform	T2.3 EE Performance Evaluation (Services) and User Benchmarking	InBetween platform shall support the energy efficiency performance evaluation and a fair comparison of Users. This functionality shall employ algorithms that take into account a range of parameters such as climate conditions, number of occupants, building materials, and family conditions in addition to energy consumption provided by InBetween monitoring platform.	Design validation/Demonstration	1
FUNC_REQ_19	User profiling	InBetween platform shall perform profiling of users	WP2- InBetween cloud-based ICT platform	T2.2 User profiling and categorization	InBetween platform shall perform user profiling based on energy consumption, occupancy, building properties, and other available metadata.	Design validation/Demonstration	1

FUNC_REQ_20	Mobile application monitoring data	InBetween platform shall expose the user energy consumption and related information via mobile application	WP3-User engagement and behavioural change	T2.3 Improving the relevance and effectiveness of the technology for users	InBetween platform shall support mobile application (e.g. Android OS) that provides the personalized user experience. The mobile application shall present the current and historical data collected by the InBetween platform, such as: aggregated and individual power consumption of different home appliances, environmental parameters (temperature, humidity, air pressure, etc.), energy pricing, etc.	Design validation/Demonstration	1
FUNC_REQ_21	Mobile application recommendations	Mobile application shall present different kinds of recommendations	WP3-User engagement and behavioural change	T2.3 Improving the relevance and effectiveness of the technology for users	Mobile application shall provide energy and cost saving recommendations in a user friendly and non-disruptive manner in order to motivate a user to change her bad habits and reduce energy wastes.	Design validation/Demonstration	1
FUNC_REQ_22	Mobile application user benchmarking	Mobile application shall provide user's energy related behaviour benchmarked in comparison to other similar users in the	WP3-User engagement and behavioural change	T2.3 Improving the relevance and effectiveness of the technology for users	The mobile application shall provide the reports on the user benchmarked with other similar users in their neighbourhood, having in mind not only energy consumption, by including other parameters like weather conditions, building materials, and number of occupants, in order to provide more fair comparison.	Design validation/Demonstration	1

		neighbourhood					
FUNC_REQ_23	Mobile application automatic configuration	Mobile application shall be automatically configured	WP3-User engagement and behavioural change	T2.3 Improving the relevance and effectiveness of the technology for users	Mobile application shall be automatically configured according to the data stored in InBetween cloud platform (deployed sensors, control devices, user profile, etc.)	Design validation/Demonstration	2
FUNC_REQ_24	Web application interface	InBetween platform shall support web interface that automatically adapts to different screen sizes	WP3-User engagement and behavioural change	T2.3 Improving the relevance and effectiveness of the technology for users	InBetween platform shall support automatic adjustment of web visualization interface according to the screen size/device type.	Design validation/Demonstration	1
FUNC_REQ_25	Web application widgets	Web application interface shall present different monitoring and processed data	WP3-User engagement and behavioural change	T2.3 Improving the relevance and effectiveness of the technology for users	Web application shall present aggregate and individual energy consumption. The user will be able to select the time period for which the data will be presented, the type of energy carrier (electrical, thermal, gas), overlay energy consumptions of different monitoring areas (households, rooms, etc.) on the same figure or even correlate the energy consumption with other relevant parameters (temperature, weather conditions, energy pricing, etc.).	Design validation/Demonstration	1

FUNC_REQ_26	Web application KPIs	Web application interface shall present different Key Performance Indicators	WP3-User engagement and behavioural change	T2.3 Improving the relevance and effectiveness of the technology for users	Web application shall present a number of KPIs that will be computed such as: CO_2 emissions, energy savings, peak load indicators, energy consumption by person (total, heating, lighting), temperature discomfort indicator, etc.	Design validation/Demonstration	2

6.2 NON-FUNCTIONAL REQUIREMENTS

[ID]	[Headline]	[Req. Description]	[Classification]	[Type]	[Rationale]	[Acceptance criteria]	[Priority Level]
NONFUNC_REQ_01	Architectural model composition to support interoperability	The Architectural model shall natively support the interconnection and composition of devices and systems produced by different manufacturers	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	The InBetween system should support a variety of different devices to allow long-term interoperability and to prevent vendor lock-in	Design validation/Demonstration	1
NONFUNC_REQ_02	Information model definition to	InBetween platform should	WP2-InBetween	T2.1 InBetween Integration Approach /	A way to specify and exchange energy and building assets information should be defined,	Demonstration	1

	support semantic interoperability	consider Information Modelling standard processes	cloud-based ICT platform	Architecture / Development	preferably by using well defined standard (e.g. EEBus SPINE)		
NONFUNC_REQ_03	Integration architecture	InBetween overall architecture should be based on open and standard integration frameworks and communication protocols	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	Web services and Service Oriented Architecture are the preferable choice as integration frameworks. Also, SOAP and WSDL-based APIs or REST protocols should be considered for synchronous communication. Asynchronous communication should be based on OSGI publish/subscribe mechanisms	Demonstration	2
NONFUNC_REQ_04	Home automation interoperability	InBetween should support well known communication protocols for home automation	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	Communication with home automation system should be based on well-known communication protocols (ZigBee, Z-Wave, etc.)	Design validation/Demonstration	1
NONFUNC_REQ_05	Smart metering interoperability	InBetween should support well known communication protocols for smart metering	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	Communication with smart metering devices (Electricity, water and gas consumption) should be based on well-known communication protocols (ZigBee, Wireless M-bus, etc.)	Design validation/Demonstration	1

NONFUNC_REQ_06	BMS/EMS interoperability	InBetween should support newly deployed as well as already available legacy BMS/EMS systems	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	Communication with BMS/EMS systems should be done in a protocol agnostic manner by supporting different open protocols (BACnet, KNX)	Design validation/Demonstration	1
NONFUNC_REQ_07	Grid interoperability and services 1	InBetween should try to comply with the main coming standards and initiatives relevant to Smart Grids and advanced metering infrastructures especially concerning: data exchange, ICT security, distribution management and tariff and load control	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	The main outputs from technical working-groups of CEN/CENELEC/ETSI should be considered. For instance: - TC57 WG21 (interface/protocols for systems connected to grid) - SG-CG M490 (mandate of the smart grid coordination group to define a SG reference architecture) - IEC 61850 (comm. networks and systems for s/stations automation) - CIM / IEC61968 (energy distribution management) - CEER Publications - OASIS Energy Interoperation Committee Specification Also, the AMI security profile from SG Security Working Group (UCAIug) & The NIST Cyber	Demonstration	1

					Security Coordination Task Group may be considered for the cyber security issues.		
NONFUNC_REQ_08	Grid interoperability and services 2	InBetween should try to align with current standardization efforts in the field of energy standard information exchange	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	In order to implement energy working demand-response processes, it is important that energy consumers/producers and utilities share standardized data on energy characteristics, energy availability, energy price, flexibility offers, operational schedules, building information, etc. For instance EEBus SPINE, eMIX, oBIX, CIM, etc. are example of initiatives to consider as reference for RESPOND.	Demonstration	2
NONFUNC_REQ_09	Scalability	InBetween platform shall be scalable	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall be able to scale up and to support increased number of users and monitoring points	Demonstration	2
NONFUNC_REQ_10	Replicability	InBetween platform shall be replicable	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall be replicable to other similar use case scenarios not envisioned during the course of the project without significant changes in the platform itself	Demonstration	1
NONFUNC_REQ_11	Backup	InBetween platform shall include backup solution	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall enable seamless backup of all stored data in order to enable easy recovery in case of storage failure or data loss	Demonstration	1

NONFUNC_REQ_12	Performance – low latency	InBetween platform shall be accessed through low latency communication network	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall be connected via low latency communication link in order to ensure near-real-time data storage and retrieval	Demonstration	1
NONFUNC_REQ_13	Performance – high bandwidth	InBetween platform shall be accessed through high bandwidth communication network	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall be connected via high bandwidth communication link ensuring fast data storage and retrieval	Demonstration	1
NONFUNC_REQ_14	Performance – computational power	InBetween shall platform shall have enough computational resources	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall be installed on a computing platform with computational resources that ensure fast data processing	Demonstration	1
NONFUNC_REQ_15	Cloud server	InBetween platform shall be installed on a cloud server infrastructure	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall be installed on a cloud server that can adjust the computational capabilities (CPU, RAM, HDD storage size) on demand	Demonstration	2
NONFUNC_REQ_16	Data Privacy - communication	InBetween shall be designed to support private data communication	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall be designed to support encrypted communication in order to ensure the privacy of data transferred.	Demonstration	1

NONFUNC_REQ_17	Data privacy – data storage	InBetween shall be designed to support private data storage	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall be designed to support encrypted data storage in order to ensure the privacy of stored data.	Demonstration	1
NONFUNC_REQ_18	Reliability	InBetween platform shall be reliable	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall have low probability of failure by employing e.g. off-site backup, redundant servers, etc.	Demonstration	1
NONFUNC_REQ_19	Robustness	InBetween platform shall be robustly designed	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall be able to cope with errors during operation as well as to cope with erroneous input and commands	Demonstration	2
NONFUNC_REQ_20	Usability	InBetween platform shall be designed with usability in mind	WP2-InBetween cloud-based ICT platform	T2.1 InBetween Integration Approach / Architecture / Development	InBetween platform shall be designed to be efficient to use and easy to learn.	Demonstration	1

7 CONCLUSIONS

In this report, we have presented a basis for the development of InBetween cloud platform and related energy services and monitoring layer in the form of functional and non-functional requirements. In order to arrive to the set of specifications, a structured approach is taken, having in mind the project objectives, work packages structure, technology constraints, and characterization of pilot sites and their residents. Although the approach that led to the list of requirements is concerned primarily with the pilot sites, it is general enough to be easily replicable beyond the InBetween project for similar use cases.

Firstly, we provided the analysis of two pilot sites comprising residential and non-residential building types in France and Austria. In particular, the analysis focused on the building properties, apartment occupant structure, installed metering equipment, available appliances, and other relevant aspects that have to be taken into account before any further platform specification and development can be performed.

Then, we identified three possible use cases for the InBetween platform where the main goal is to empower users with the capability to reduce energy wastes, to operate their energy infrastructure in the optimal manner, and to evaluate and benchmark their own energy performance against similar end users in the neighbourhood.

Next, and having in mind the functionalities necessary to support aforementioned use cases, we proposed three deployment scenarios paying particular attention to the constraints such as type of building, occupants needs, and total investment cost. Then, we presented a preliminary platform architecture, where we provided more details on monitoring and control layer, IoT cloud platform and advanced energy services and visualisation layer. Besides, we also identified some of the already available technologies suitable for implementation of aforementioned platform modules. Finally, and having in mind the analysis presented previously, we provide a list of functional and non-functional requirements, that will be taken into account in other related work packages where development and deployment activities will be performed.